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Information Technology Policy

An International History



Edited by

Richard Coopey

INFORMATION TECHNOLOGY POLICY

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Abbreviations

ABB	Asea Brown Boveri
ACM	Association for Computing Machinery
ACT	Advisory Council on Technology
ACTS	Advance Communications Technologies and Services
AEA	Atomic Energy Authority
AEC	Atomic Energy Commission
ALCS	Authors' Licensing and Collecting Society
APACE	Aldermaston Project for the Application of Computers to Engineering
ARPA	Advanced Research Projects Agency
ASDD	Applied Systems Development Division
ASML	Advance Semiconductors Materials Lithography
AWRE	Atomic Weapons Research Establishment
BTG	British Technology Group
CAE	Compagnie Electronique d'Automatisme Electronique
CAP	Computer Analysts and Programmers
CAS	Computer Advisory Service
COCOM	Coordination Committee for Mulitlateral Export Control
CDC	Control Data Corporation
CDP	Computers and Data Processing
CER	Coordinated Experimental Research
CGE	Compagnie European d'Electricite
CII	Compagnie Internationale pour l'Informatique
COPEP	Commission Permenente de L'Electonique du plan
CPU	Central Processing Unit
CSF	Compagnie Generale de Telegraph sans fil
CTI	Calculus Techniques Institute
CTI	Centre Technique et Industrielle
CTL	Control Technology Limited
CTL	Computer Technology Limited
DARPA	Defense Advanced Research Projects Agency
DDR&E	Director of Defense Research and Engineering
DEC	Digital Equipment Corporation
DGRST	Delegation Generale a la Recherche Scientifique et technique
DIMES	Delft Institute for Micro-Electronics and Submicron Technology
DoD	Department of Defense
DoE	Department of Energy
DRI	Data Recording Instrument Company

ECL	Electrochemical Laboratory
ECRCs	Electronic Calculus Regional Centres
ECROs	Electronics Calculus Regional Offices
ECSC	European Coal and Steel Community
ECUS	European Currency Units
EDS	Electronic Data Services
EEC	European Economic Community
EELM	English Electric-Leo-Marconi
ELDO	European Launcher Development Organization
ESPRIT	European Strategic Program for Research in Information Technologies
ESRO	European Space Research Organization
ETL	Electrotechnical Laboratory
FONTAC	Fujitsu-Oki-NEC-Triple Allied Computer
FRICC	Federal Research Internet Coordinating Committee
FY	Fiscal Year
GE	General Electric
GATT	General Agreement on Tariff and Trade
HP	Hewlett Packard
HPC Program	High Performance Computing
HPCC Program	High Performance Computing and Communications
IAS	Institute for Advanced Studies
ICTI	Institute of Calculus Techniques and Informatics
ICT	International Computers and Tabulators
ICT	Information and Communication Technologies
IDA	Institute for Defense Analyses
IPC	Information Perfection Center
IPTO	Information Processing Techniques Office
IRC	Industrial Reorganization Corporation
IS	Information Systems
IST	Information Society Technology
IT	Information Technology
IT2	Information Technology for the Twenty-First Century
ITAA	Information Technology Association of America
JDB	Japan Development Bank
JECC	Japan Electronic Computer Corporation
MCC	Microelectronics and Computer Technology Corporation
Mintech	Ministry of Technology
MITI	Ministry of International Trade and Industry
MOF	Ministry of Finance
NBS	National Bureau of Standards
NCC	Numerical Computing Centre
NCI	National Commission for Informatics
NCR	National Cash Register

NEB	National Enterprise Board
NEDO	National Economic Development Office
NIH	National Institutes of Health
NOAA	National Oceanic and Atmospheric Administration
NPL	National Physical Laboratory
NRC	National Research Council
NRDC	National Research Development Corporation
NREN	National Research and Education Network
NSA	National Security Agency
NSF	National Science Foundation
OA	Office Automation
OCA	Office of Computing Activities
OMB	Office of Management and Budget
ONR	Office of Naval Research
OSTP	Office of Science and Technology Policy
OTL	Office Technology Limited
PC	Personal Computer
PCGD	Dutch Postal Cheque and Giro Services
PCI	Philips Computer Industry
PERA	Production Engineering Research Association
R&D	Research and Development
RACE	Research and Development in Advanced Communications and Technologies in Europe
RAE	Royal Aircraft Establishment
RANN	Research Applied for National Needs
RII	Research Institute for Informatics
ROMCD	Romanian Control Data
RRE	Royal Radar Establishment
SAGE	Semi Automatic Ground Environment
SBC	Service Bureau Corporation
SC Programming	Strategic Computing Programming
SCME	Center for Micro-Electronics
SDC	Systems Development Corporation
SEA	Societe d'Electronique et d'Automatisme
SPERAC	Societe Europeenne de Semi-conducteurs et de Microelectronique
TRE	Telecommunications Research Establishment
UMC	United Medical Company
VLSI	Very Large Scale Integration
WEU	Western European Union

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1

Information Technology Policy: Competing for the Future

Richard Coopey

In the decades following the Second World War, there was a deepening of the impact of three major trends affecting the major industrialized nations. First, the postwar period saw a realignment in the international economy. While the United States continued its rise to world prominence, consolidating the industrial and economic expansion of the wartime period, other economies struggled to readjust to peacetime. Damaged economies were rebuilt under the stewardship of the United States. In the case of the defeated nations, Japan and Germany, the lessons of the First World War had been learnt as reconstruction replaced reparation, and the new Cold War atmosphere favored alliance and bulwarks over attempted economic suppression. The old imperial European economies, France and Britain, also struggled to readjust, though in an uneasy relationship to the growth of US economic power.

The second notable trend was the seemingly exponential rise of science and technology. In the wake of accelerated innovation during the war—a war that had witnessed the mobilization of science to unprecedented levels—a wave of new technologies seemed to burst forth into the 1950s. Three of these stood out, each in its own way defining a new age—atoms, aerospace, and computing. The three combined to usher in a world where the future seemed to be arriving at breakneck speed—and importantly, extrapolations of the trends in innovation pointed toward a radically different future just around the corner. From today's perspective, in a world where "big science" has either stalled or is viewed with heightened skepticism or suspicion, such predictions may seem wildly optimistic and naive. However, a world of unlimited power, space colonization, and superintelligent machines seemed almost axiomatic to those contemplating the start of the twenty-first century from the perspective of the 1950s.

The third major paradigm shift in the postwar world took place in political economy, notably the ascendency of the idea that government had a role to play in economic activity. This, as with the two other trends noted above, was not new of course, but rather was reemphasized and expanded in a way that did mark a real shift in importance, perhaps even a new consensus in the western economies. States had a long history of intervention in the industrialized economies. From the nineteenth century onward we can point to the regulation of factory acts in Britain, American military sponsorship of industry and antitrust activities, the state-led

modernization programs in Japan and Russia, and many more examples of governments overruling the free market, in an ostensibly successful way. After 1945, however, a new intensity, indeed a new sense of urgency, characterized state intervention. This was supported by the example of successful economic and technological management which the wartime experience had provided. It was also supported by the growing acceptance of Keynesian economics, which gave intellectual, perhaps mathematical legitimacy to management of the market. Moreover, the depression of the 1930s had only been alleviated by wartime rearmament and the war economy—a new political–economic paradigm was essential to avoid the economic and political turmoil, which the depression had ushered in. For individual states there was also the question of jostling for position in the new international economic order. There was no guarantee that industries, left to themselves, would be up to the challenge. Governments entered the race if not for technological and economic supremacy, at least for survival.

After 1945, the computer industry or Information Technology (IT) as it later became known, developed against the backdrop of these three processes, and we can see a complex interaction between the effects of each of them in terms of the political economies of IT that emerge. If computing was one of the triumvirate of modern, postwar technologies then it was perhaps the most important since it was an essential component in the design and control of the other two and had a potential impact in many other areas from labor control to scientific enquiry. Little wonder then that the computer, and the computer manufacturing industry generated an intense interest for governments across the industrialized world.

The American Challenge

The defining feature of the IT industry in the period was the rise and dominance of US manufacturers, followed by a series of, mostly unsuccessful, rearguard actions by European and Japanese producers. The oft-cited Organization for Economic Cooperation and Development (OECD) report on *Gaps in Technology* and Servan-Schreiber's *American Challenge*,[1] which appeared in the mid-1960s, echoed the widespread feeling that the United States had consolidated its twentieth century rise to global supremacy in the post-1945 period, and was now moving to a new level of hegemony, based on the scale and effectiveness of its technological base. The large American corporation, with its scale research and development (R&D) was increasingly monopolizing the new world of science-based industry. Moreover, computers were increasingly seen as the vanguard technology in this process, the leitmotif of modernity. As Servan-Schreiber asserted, "The war is industrial, and its major battle is over computers."[2] IBM in particular had emerged as the dominant force in the industry, dwarfing the other, albeit successful, US manufacturers and progressively capturing a major share of the global market in mainframe computers.

Many reasons have been put forward for the success of the American manufacturers in IT, from first mover advantage, the scale and scope of the large American

enterprise, linkage affects, the role of the military in R&D and procurement, the primacy of the free market, and more recently the effect of clustering and networks. Government policy has entered the picture as part of the explanation—an important part. Following the increased expectations for science and technology stemming from the Second World War, and the continuing Cold War technology race (accelerated by the salutary episode of Sputnik), the most oft-cited example of government support for the IT sector in the United States has been that of military funding. Perhaps the most notorious examples here have been the development of ENIAC; the Whirlwind computer system for the Semi Automatic Ground Environment (SAGE) early warning air defense system, built by IBM; and the establishment by the Advanced Research Projects Agency (ARPA) (later the Defense Advanced Research Projects Agency, DARPA) of the ARPANET—the progenitor of the Internet. There were also a wide range of software developments which originated in the military sector.[3]

Chapter 2 by Norberg outlines this story—but is also careful to show the ways in which a rich community of science and technology developed under the aegis of government. Many agencies were involved in influencing and shaping the research agenda in IT from the 1950s onward, including the National Science Foundation (NSF), the National Bureau of Standards (NBS), and the Census Bureau. Norberg's account stands out as a balanced and useful corrective to accounts which stress the primacy of Pentagon funding as part of the development of an almost sinister "closed world" of computing research, presided over by the military sector. The chapter does stress, however, the importance of government, and specifically military R&D funding at the earlier stages of technological development—the formative point in the life cycle of the IT industry. (This issue of the life cycle of an industry is one to which we shall return.) An example here is the development of high-speed computing by the nuclear weapons laboratories. Government interests also had a role in shaping early programming language developments, such as COBOL. While there was then a significant, indeed crucial role played by the US government, particularly the military sector, in the development of the earlier phases of computing, as Norberg stresses, this was not a uniform and coordinated program of support. The various government agencies and military departments were amorphous in nature, often pursuing diverse and conflicting programs. The impact of funding is better viewed perhaps as a building inertia, a critical mass of programs, which provided a broad foundation for aspects to be taken up and advanced by commercial actors.

Government policies less directly linked to the development and production of computer systems themselves are also important. There has been a general trend toward enabling or environmental policies in terms of IT in many countries since the 1980s, but such policies do have a long lineage in some cases—notably that of the United States. In particular, as Chapter 3 by Aspray illustrates, the US government had a growing interest in the labor market in computing. In his exhaustive examination of the education and training sector he traces the history of education and training in computer programming and systems analysis, and emergence of

computing as a profession, under the aegis of a range of government institutions and agencies. Again the picture that emerges is one of a high level of general support, particularly in scientific and academic computing, but no overall, coordinated plan. Rather, as with influence from the defense sector, the pattern is more amorphous in nature, a building, general support that in the end creates or sustains the momentum of the US IT sector expansion and its consolidation as the world leader. Where more targeted policies are attempted, as in the case of the educational programs linked to social reform under President Johnson, these have fared less well.

As we shall see below, one response of the European and Japanese governments to the growth of the US computer industry was to attempt to construct a national champion to compete with IBM. In the case of the United States, policy came from the other direction. If anything, the government was faced with the task of controlling, rather than creating a national champion. Chapter 4 by Usselman points out the way in which an entity such as IBM can be seen as too powerful from within a domestic economy. At what stage does a national champion become a national monopolist—frustrating competition and innovation? Usselman points to the difficulty governments encounter when faced with this question and when confronted by a large, and ostensibly successful firm.

The US government had a very long history of antitrust activity from the turn of the century onward. A myriad of theories surround regulation as being either pro- or anti-American capital, regulators being seen as "captured" by the industry under control, or as an example of democratic control of the inherent excesses of the free market. IBM itself was pursued from the 1930s onward, initially over its exclusionist tactics over punched card sales for its business machines. When computer manufacture became the company's main business, the firm continued to thrive because of its manufacturing prowess and its strategic marketing. From the late 1950s onward IBM machines, with the 1400 and 360 series, were the first to offer standardization, compatibility, and upgradability across a developing range of computer systems. This made good sense not only from a technological perspective, but also from a business perspective. This was allied to a marketing and sales regime, particularly a leasing strategy, and services and peripherals provision, which effectively tied customers to IBM. When programming became a separate entity, IBM was careful to support and foster education and training—in IBM favoured languages—generating a labor pool where IBM literacy was the dominant requirement.

Government faced two conflicting problems here. The system was successful and globally popular, but as Usselman demonstrates, the totality and standardization of the system went against the natural inclination of smaller or innovative firms for the new and the nonstandard. Government had to decide between leaving a successful multinational to dominate global markets, or try to hold some sort of ring in terms of the free functioning of the domestic market. In the event IBM was challenged by government in the mid-1950s and again throughout the 1970s, principally in an attempt to get the firm to unbundle its services provision from its manufacturing. In an interesting twist, government intervention was unsuccessful in its primary goals, but may have indirectly forced a change in corporate culture at

IBM, which ushered in new openness when software grew as a discrete sector. Usselman is careful to point out however that technological change and competitive pressure may also be important factors, alongside the effects of government policy. Nevertheless, government intervention to break up monopoly—or the inherent threat of intervention—clearly have a part in shaping corporate strategy.

In some ways, the IBM story was replayed in the 1990s in regard to its progeny Microsoft. The acceptance of unbundling, which had emerged at IBM, paved the way for the firm's strategy when constructing its personal computer (PC) alliance with Intel and Microsoft, though this may have been a recognition of the technical and organizational limits of the firm when faced with the challenge of Apple's exponential growth in the new PC market. Microsoft posed the same problems for government that IBM had posed in the 1950s, that is, a highly successful global enterprise, based on standardized systems and compatibility, but one which stifled competition at home. When Microsoft moved belatedly and overtly to tie in internet provision, frustrating rivals such as Netscape, however, popular pressure led to direct intervention. The result of this intervention by government echoes that of the move to breakup IBM—limited success and unintended consequences. In both cases, the IT industry provided new challenges for antimonopoly legislation. Monopoly power was not wielded necessarily through prices and availability as in, for example, the case of Standard Oil. Monopoly was instead manifested in linkage—standardization, and compatibility—much more amorphous concepts, and in many ways desirable attributes for the economy and for government.

How did other nations respond to the "American Challenge"? During the postwar period, the exemplar of industrial policy, successful or not, has been that of the Ministry of International Trade and Industry in Japan (MITI). MITI is a pertinent example since it played a major role in attempting to protect and stimulate the Japanese IT sector from the 1950s onward. There are conflicting arguments over both the effectiveness of MITI, and its place in the pantheon of factors underlying the "Japanese economic miracle." Following Chalmers Johnson's championing of MITI, a host of studies have followed, providing correctives. Most of these studies have their own favorite to push to the fore—industrial organization and strategy, work cultures, political continuity, favorable geopolitically-shaped trade regimes, low defense burdens, a sense of national purpose following the defeat in the Second World War, long-term cultural and economic trends, and so on.[4] Many studies simply follow Johnson in their unicausality. The truth probably requires acceptance that a combination of factors contribute to the "miracle," but certainly MITI had an important role to play—if not always a positive one.

Despite the numerous revisions and correctives to the MITI story, Japanese government policy is still held by many to represent an ideal form of intervention. Jowett and Rothwell, for example, are unequivocal on this point. "By stark contrast to the incoherent British policy towards computer and telecommunications companies, those of the Japanese government were a model of consistent order."[5] MITI did employ a wide range of tactics and strategies to good effect in fostering indigenous IT industry.[6] Chapter 5 by Yonekura traces the history of MITI's intervention in

IT—from a critical perspective. He finds MITI's policies were not always successful, but did best when fostering coordinated competition rather than intervening too directly. In a rather more sophisticated analysis than usually applied to MITI, Yonekura's case study on computer policy shows how the ministry fluctuated between "planned coordination" and "market coordination" depending on the particular phase of industrial development and circumstances pertaining at the time. The focus of MITI effort switched from support of R&D to applied programs as appropriate. The ministry negotiated with IBM to trade off patent liberalization for rights to manufacture in Japan, in an intriguing piece of strategic maneuvering. This took place against a backdrop of rapid product evolution and market uncertainty, made more frenetic by an atmosphere of urgent struggle and the fear of being left behind. In addition, some of MITI's policies were executed against the background of trade liberalization—which threatened to expose the nascent computer manufacturing industry to the full force of US competition. Yonekura shows how MITI was prepared to concede ground to IBM where necessary in what they perceived to be the longer-term interests of the Japanese computer manufacturing sector.

In reality, MITI deployed a range of policy options—a blend comprising partly pragmatic maneuvering versus other departments of government, partly opportunism and horse-trading with American government and corporations like IBM, and partly innovative new strategies, which, seemingly indirect in nature, had a direct impact on the health of the sector. A good example of this was the setting up of the Japan Electronic Computer Corporation (JECC), a national rental/investment system which alleviated cash flow, supported domestic manufacturers, and managed to offset the leasing strategy which IBM had been so successful in employing.

National Champions

From the 1950s onward most of the leading industrialized countries were wrapped up in the idea of computers as a strategic good—important from a both a civil and military perspective. With the end of the Cold War comparative advantage was able to reassert itself to a certain extent and a pragmatic acceptance of dependency became the norm. Until then, however, there were strong national feelings of vulnerability intermingled with pride and status which drove policy. In some cases, economic prestige rather than strategic vulnerability was the dominant factor. In the case of Japan, it seems clear that military strategic considerations played little part in the effort to promote a national computer industry and, at one point, a national champion. Here the case was one of national economic pride alone, such was the deep belief in the computer as the symbol of all that was modern. Yonekura quotes one contemporary, "Japan cannot be proud of herself as a leading industrial nation if electronic computers were to be completely beaten."

The argument in favor of national IT champions gathered pace and reached its zenith throughout the world in the 1960s. Governments in Holland, Britain, Japan, and France made concerted efforts to create a computer manufacturer able to

withstand IBM. (Even in the United States the pro-IBM lobby, against unbundling and break-up, were essentially arguing to preserve a national champion.) The arguments deployed were a mixture of economic theory—economies of scale, etc.—plus a pragmatic response to the legacy and momentum of history. Numerous countries saw their national IT manufacturing bases as comprised of firms from different sectors, producing a series of competing designs with no national standardization, undertaking fragmented and uncoordinated R&D programs and generating a series of small market niches domestically. Companies were unable to compete internationally and generated a congeries of users, locked in to technologies which lagged behind the much more attractive systems on offer from the US producers. As we have seen, IBM kick-started this process both by seeming to prove that scale was the key and by being an exemplar of a national champion in itself. IBM was, at the time, the quintessential representative of American economic and corporate imperialism. The company provided an easy target in Europe, both for anti-US politicians and also for those interested in stressing the urgency of large-scale intervention. In some cases, notably Britain, and perhaps France, the idea of a national champion was underpinned not by the ambition to catch up with the United States, but rather to leapfrog in front and resume the (wistfully remembered) position of world leader.

Arguments against national champions came from a number of quarters and at a number of different levels. Both the target firms themselves and disaffected government ministries often voiced opposition. There was a strong line of resistance that stressed the inability of governments to track trends in such a volatile industry and the folly of trying to patch together the disparate sectors of extant industry—at best a patchwork of competing factions would emerge within any merged company. Also the emergent firm was likely to be the only firm in an economy, if sufficient scale was to be achieved. It would thus have little domestic competition—in contrast to the multiplicity of large firms in the United States (even if the other computer manufacturers were characterized as the seven dwarves next to IBM). Perhaps the strongest argument was that of the perils of creating a dependent firm—especially where the creation of a national champion was linked to a nationalistic procurement strategy. This would create a dependency culture within the new enterprise, instead of exposing it to the full-force international market competition, and worse, it might shackle the domestic computer market to an inefficient producer—creating a knock-on effect, which would insulate the rest of the economy from access to modernization through the purchase of the latest IT systems. Again this argument could be deployed much more effectively in IT than in, say, the car industry, since the former was viewed as an essential part of the economic infrastructure. In one important special case—the military sector—attempts to restrict procurement to favor domestic producers could be disastrous, if it meant a significant reduction in the effectiveness of the armed forces. This was certainly the argument most vigorously employed by those against the development of national champions cushioned by domestic procurement schemes. Procurement schemes could also come under pressure from competing nations, arguing against a form of disguised protectionism.[7]

Despite those counseling caution, the idea of creating a national champion to challenge IBM was put into practice in numerous countries in the 1960s. In the case of Britain, the national champion was eventually to emerge in the form of ICL.[8] In Chapter 6, Coopey outlines the extent to which the British computer manufacturing industry in the 1950s was a fragmented and diverse entity. Electronics firms like Ferranti and Marconi developed their own machines for data processing or control. Business machine companies like Powers Samas also developed a range of computers, and in seemingly the most bizarre diversification in business history, the teashop firm, Lyons, also developed a range of very successful computers under the banner of LEO. The shortcomings of this competing, nonstandardized and fragmented manufacturing base was recognized early on, and attempts were made in the 1950s under the aegis of the National Research Development Corporation (NRDC) to broker a merger. No compulsion was available at the time and the merger had to wait until the 1960s with the formation of ICL. This company was created under the leadership of the Ministry of Technology, spearheading a major push to restructure and consolidate the whole of British science and technology. ICL was favored with procurement support and investment funding. The company was moderately successful, though internal, almost cultural, differences between constituent firms, and decisions to pursue a non-IBM compatible line of technology, predicated on inflated ambitions in terms of world markets, meant the company only ever achieved moderate success and was eventually taken over by the Japanese firm, Fujitsu, in the 1990s.

In Holland it was not so much a case of creating a national champion as of supporting or redirecting one. Philips was the national champion extant. The company was already well-established as a multinational electronics manufacturer. In common with many electronics firms in the 1950s, Philips did embark on a program of computer manufacturing and, as Van den Ende et al. (Chapter 8) show, was supported through a procurement program throughout the 1960s and 1970s. Philips was moderately successful in computer manufacture, but came into its own as a component manufacturer when the semiconductor market took off.

Perhaps the most ambitious attempt to reestablish some form of national sovereignty over the computer industry was that of France from the 1960s onward. Between the mid-1960s and the mid-1970s, a widespread panic ensued in France over the issue of US hegemony in computer manufacture. As we have seen this was a widespread reaction shared in particular by Japan and Britain, but anti-Americanism in France was probably more virulent than anywhere else. The French, with their own imperial past now in question and their domestic markets increasingly susceptible to mass produced goods, saw a real threat from both economic and cultural imperialism by the United States. In some ways, Hollywood, blue jeans, and the IBM computer were all part of a continuum of erosion of French tradition and independence. French military independence from North Atlantic Treaty Organization (NATO) and the development of an independent nuclear deterrent were reflections of this attitude and came into play when the US government placed restrictions on the export of some US computers to France in

the belief that they were militarily sensitive. The reaction to this and the "Affaire Bull," when the French computer manufacturer Compagnie Machines Bull was effectively taken over by General Electric, led to a state sponsored attempt to construct a French national computing manufacturer. This strategy was also a reflection of the French penchant for planning and state control which had worked well in the postwar period. The Commissariat Du Plan had achieved good results with a system of indicative planning which was seemingly a factor in regenerating the French industrial economy. The Plan Calcul, formulated in 1965, set up Compagnie Internationale pour l'Informatique (CII) as a national champion. There were other aspects to the Plan, including an attempt to build on the expertise which had developed in the academic and military–scientific community. In this sense the Plan conformed to the same pattern as the "Plan" initially put forward by the Advisory Council on Technology at the Ministry of Technology in Britain around the same time.

ICL in Britain fared better than CII in France, though neither company achieved the initial goals which had been envisaged. Both companies suffered from a lack of internal cohesion and a clash of product trajectories and management styles. Both companies were insulated from the winds of full competitive pressure through a continued supply of funding and guaranteed public sector customers. Both companies sought in vain to capitalize on captive empire markets or markets in the Eastern bloc which were out of bounds to US companies. In the event, the former proved to be too small and the latter were both undeveloped and ultimately made unavailable through US political pressure. Both companies were forced into strategic errors in terms of manufacturing strategy, mainly by opting to attempt to develop new computer systems, independent of IBM. This path of noncompatibility was an integral part of the national champion strategy—systems had to stand alone and be unique if any form of dependency was to be avoided.

In the end, both the grand plans of the Ministry of Technology and the initial Plan Calcul had achieved very little in terms of the ambitions laid out at their inception. Indeed part of the problem lay in the extent of these ambitions—to restore to world leadership the computer industry in both countries. Both plans envisaged results in the short term, to a problem which was long term and structural in nature. Both episodes were salutary for government. Successive versions of the Plan Calcul, drawn up in the 1970s, and the strategy pursued by the National Enterprise Board (NEB) from 1974 onward, were more modest in ambition and recognized that the moment for intervention on a grand scale had passed.

Perhaps the most ambitious attempt to build a national champion was actually no such thing, but rather an attempt to construct a supranational champion. The Unidata initiative aimed to build a pan-European enterprise to take on IBM. There was in this an implicit recognition that in order to compete on the scale of IBM, a single national initiative would be insufficient. The Unidata scheme also conformed to trends toward economic as well as political unification of Europe, through collaborative enterprise. The company was eventually established in

1973—a composite of Siemens from Germany, CII from France, and Philips from the Netherlands. (Britain stayed aloof from Unidata, preferring to pursue its independent national champion strategy through ICL.)

The Unidata aim was to build a range of computers to compete with the IBM 370 system which was then taking over the mantle of IBM's epoch-making 360 series. Citing the establishment of Unidata against the wider background of the evolution of European industrial policy, Kranakis (Chapter 9) shows how such initiatives encounter difficulty in coordination at a number of levels. Factions within the European political framework such as the European Commission and the Council of Ministers, had conflicting aims and ambitions for the program. There were different national goals and priorities to contend with, and at the firm level, there were difficulties in reconciling corporate cultures, research regimes, and product strategies. In the event, Unidata only lasted until 1975. Kranakis' analysis also stresses the importance of understanding the volatility of the political environment as policy switched toward domestic industry protection in France and Germany. Unidata suffered from what Kranakis sees as an uneasy balance between nationalism and internationalism, which was impossible to reconcile. Other collaborative programs were established with more success where companies, rather than politicians and bureaucrats, were the motive force, as in the case of Philips' link with Siemens in memory chip development, for example.

Overall, policies aimed at fostering national champions fared poorly and were shelved, at least temporarily, into the 1970s. This was partly a result of the downturn in the world economy which also saw Keynesian certainties evaporate in the 1970s as government intervention came under critical scrutiny with the rise of New Right economics from the mid-decade onward. In Britain for example, the return to power of the Labour government in 1974 did not see a resumption of the large-scale technology rationalization programs of the 1960s but were instead characterized by the establishment of the NEB, essentially a government investment bank for selected enterprises and technologies, with a strategic bias toward IT and biotechnology. Though judged a failure overall—reacting to industrial decline and shoring up the "lame ducks" of British industry—the NEB, as Campbell-Kelly and Hamilton (Chapter 7) show, did make some important investments in the IT sector, notably Inmos, the chip manufacturing enterprise, and Insac, the software enterprise. Of the investments in which the NEB was involved some were moderately successful. The NEB was wound up however, a victim of political change, but it had marked the shift from general national regeneration to a more pragmatic approach to government support—one aimed at indirect support for high risk, leading edge, niche sector enterprises, a strategy more in tune with venture capitalism than state planning. In some cases the larger idea of a national champion *did* persist and reach an effective conclusion. Trade liberalization pressures in the 1970s imparted a new sense of urgency for Japanese policymakers. By the time the IBM 370 system was introduced (or at least promoted with great fanfare), a sense of crisis pervaded the offices of MITI. It was against this background that the ministry finally managed to broker a joint

agreement between Fujitsu and Hitachi, in an attempt to gain the concentration and scale to resist the encroachment of the American manufacturers.

The Japanese Challenge

Despite the failures of the large-scale rationalization programs of the 1960s, they did in fact experience a form of reprise into the 1980s. Panic began to spread throughout Europe as commentators and receptive policymakers began to fear that the continent's IT industry was once again to be left behind. Again IT was held to be the essence of modernization and international competitiveness. This time it was not an existing set of technologies as in the case of IBM's systems of the 1960s, but rather the announcement of the Japanese "fifth generation" initiative that was deemed to be the problem. The Japanese had already progressively eclipsed major portions of European, and some North American, industry in a series of progressively "complex" industries from shipbuilding and steel, through automobiles to electronics. In many industries, the Japanese method of work and corporate organization was seen as the exemplar for modern production, and government policy was also held up as the ideal paradigm. A new wave of microelectronics production and control commonly referred to as "new technology," seemed to underpin Japanese economic advance. In Servan-Schreiber style, alarmist papers proliferated pointing to the ambitions of the Japanese "fifth generation" IT programme,[9] and spurring on responses and government support for indigenous efforts. A sense of the level of panic involved can be gleaned from the case of Britain, where the Alvey program flew in the face of the dominant doctrine of free market economics and untrammeled private sector innovation.[10] Underpinning programs such as Alvey was the old idea that all the nations' resources—corporate, academic, and military—could be marshaled into a meaningful and cohesive national program. These programs eventually suffered the same fate as those of the 1960s—overambitious targets that could not be realized in the short term, disunity and a clash of cultures, and poor market applicability.

As with the Unidata response to the United States in the early 1970s, the Japanese challenge also drew a pan-European response—in the form of the European Program for Research in Information Technologies (Esprit). The Esprit program was established in 1983.[11] The program was partly a recognition that IT had become a diffuse sector. This program too was predicated on the notion that collaboration needed to take place at a number of levels. First there was a need for a framework where dialog between different sites of activity could take place encompassing academic, industry, and government institutions. Second there was a need to establish IT research networks across national boundaries. Since the essence of the scheme was collaboration, funding was provided for partnership schemes between two or more partners. As Assimakopoulos et al. point out the Esprit program sought to recreate the Japanese model in terms of cooperation and networks—but may have underestimated the level at which these operated. Japanese cooperation was embedded in Japanese culture and history, a mixture of tradition and obligation impossible to replicate by external

short-term pressure. MITI had not created the situation in Japan, but had rather exploited it, even exploited its own position within the networks of industry.

One way in which governments could intervene, and yet maintain the impression of noninterference in market forces, was to support research which was deemed to be at a distance from actual production. All research can be seen to operate on a spectrum of applicability. At one end of this spectrum lies basic or blue skies research, having no obvious purpose, but rather pushing the boundaries of knowledge. At the other end, applied or mission-oriented research is undertaken with specific goals or products in mind. The Esprit program sought to support research at a distance from the applied end of this spectrum—precompetitive research—essentially aiming at the building of core competences and network construction. In many ways, this research funding strategy—remote from production—echoed the Japanese policy strategy of managed competition, that is, intervention at one remove, rather than direct, hands on, intervention. In fact, as Assimakopolous et al. (Chapter 10) show, the Esprit program came to recognize that support for near market and competitive research could be more effective in a rapidly evolving sector like IT. Esprit also broadened its remit in terms of the sites of IT development and application to embrace a wider constituency including users as well as producers and social as well as industrial applications. As their chapter demonstrates, one of the successes of Esprit was this recognition that the networks intrinsic to the development and use of IT are very diverse indeed, and policy needs to recognize the complexity and interdependency of these networks.

IT and Development

If IT has been characterized by governments as a prerequisite to keeping pace with modernization, and maintaining the prestige of being a leading industrial nation, then for developing or newly industrializing economies it has been seen as the key to advancement *into* the ranks of modern industrial producers. The idea that a particular industrial sector can provide the key to modernization has a long lineage. Much of US postwar foreign policy was predicated on the notion of investment in "take-off" sectors—usually energy or transport—when directing Cold War overseas aid, following Rostow's historical analysis of the impact of railroads in kick-starting self-sustaining industrial growth in the West. IT provided the modern version of this idea—all the more so because of the dualities of the technology—as a foundation technology underpinning a wide range of social and economic activities. Chapters 12 and 14, respectively by Heeks, and Heeks and Grundey, outline two very interesting cases where considerable effort has been directed toward the IT sector. In India and Romania, IT was perceived as a flagship sector with the potential to lead the rest of the economy into modern global prominence. India in particular continues to provide an example of the successful development of an advanced IT sector, exploiting and creating a new international division of labor in IT.

The development of IT in India is acutely regional, concentrated around areas such as Bangalore, and as such conforming to the model of regional, clustered and

networked development evident in some advanced economies in the 1980s. Analyzing the history of both the software and hardware sectors in India, Heeks (Chapter 12) points to a judicious mixture of support for local firms through both demand and supply side measures, some measure of protection or support, for example, in negotiations with multinational firms, and taking a long-term view. Overall, success seems to stem from a light hand in terms of intervention—enabling rather than controlling. Heeks also points out, however, that the Indian experience may not be one which can easily be replicated elsewhere. The size and scale of the Indian economy and the long-term commitment to education and skill policies mark India off as atypical in many respects. Indian government has managed to formulate clear goals in policy and administer them through a competent bureaucracy, again difficult aspects to replicate.

The history of intervention in a different set of economies—all with a vigorous modernization imperative—presents a different trajectory altogether. If the US military did have a role in indirectly promoting IT manufacture at American enterprises, the other side of the Cold War saw the command economies developing computer sectors under direct state control. Such was the level of this control, however, and its predetermination of markets, that an entirely different set of issues emerge when assessing both the roots and the effectiveness of policy. In one key respect, the situation in the Eastern bloc was markedly different to that in the West. IT, as we have seen, remained an inherently networked and international sector[12]—to the frustration of many national attempts to control the industry. For much of the Eastern bloc, however, connections to this network were unavailable or deliberately severed.

From the early 1950s onward, Cold War trade embargoes placed severe restrictions on the export of computers to the Soviet Union and its allies.[13] Under the COCOM regime (the Coordination Committee for Multilateral Export Control), technologies deemed to have military links were restricted. Computers featured high on the COCOM technology lists, given their uses in weapons design and control. US companies like IBM, Burroughs, and Honeywell were prohibited from exporting even a limited number of machines due to fears that Soviet engineers would reverse engineer them. America's European allies were also restricted, though there was considerable resistance to this. The British company, ICL, for example, looked to penetrate markets in Eastern bloc countries such as Czechoslovakia and Romania and were supported by the British Foreign Office in attempts, albeit unsuccessful, to circumvent the embargo. In the event the Soviet countries did secure Western computer technology—often through intermediary countries, but not in sufficient volume to create a vibrant user culture attuned to technological developments in the West.

Another major problem emerged in the Soviet system to retard the development of IT in comparison to the West. Soviet computer development was dominated by demand from the military sector. Though the military sector was very influential in shaping developments in the West, it coexisted with, and was later superseded by a mature civil market for computers. In the Soviet system, with the suppression of

market indicators in favor of rigid planning techniques, there was a less effective demand from a wider market, including business users. On the plus side for planning, it was hoped that computers would greatly assist in the functioning of the iterative planning system of economic coordination and would lead to a more rational allocation of resources. Such hopes were rather forlorn, however.

In Chapter 13 by Boris and Lev Malinovsky we gain a unique insight into the history, pressures upon, and the shortcomings of, Soviet IT policy. Boris Malinovsky, an important participant in the development of computing in the Soviet Union from its early stages, puts the case for Soviet advance in computer production in the early 1950s, when machines may have been parallel, or indeed in advance of the West in some ways. The authors claim that Soviet achievements in computing were in fact shrouded in secrecy during the years of the Cold War and have lacked subsequent recognition in the West. A wide range of computers was produced, culminating in the BESM6 in the 1960s, though the authors acknowledge that design and production were frequently dominated by military priorities. Claims for leadership or parity in the early years of development of computing may well stand up to scrutiny, given that state control and planning was also partly driven by military priorities in the West and that directed production was more likely to be effective at this stage in the technological life cycle of the sector.

The Malinovskys' most telling point relates to the decision in the Soviet Union to attempt a copy of the IBM 360 series in the 1960s. Despite lobbying from those who wanted to further develop the Ural family of computers and accompanying language—which Boris Malinovsky claimed had a structural integrity which would outperform the IBM machines—the decision was reached to follow the IBM path. The authors point to the weakness of this strategy. IBM had no intention of cooperating with Soviet producers, indeed it was not able to, given US government restrictions. In addition, the limited availability of programming details and reverse engineered machines was no substitute for the intimate, and often tacit knowledge and support, which would come from official cooperation. A rival proposal to cooperate with ICL's SYSTEM-4, also failed to gain a critical mass of support, though external pressure from the United States also hampered this link-up. The decision to follow the IBM route was also strongly influenced by the envisaged availability of applications software. In the event the attempt to mimic IBM failed, machines were unreliable, take-up was poor and development programs would always be one step behind those of IBM.

In Lev Malinovsky's study of Ukraine we can see the way in which the Soviet Union remained a regionalized set of economies, even before the dismantling of the regime. Ukraine held the richest concentration of computer manufacturing in the Soviet Union, being the center for the military–industrial IT complex. With the break-up of the Soviet Union it might be supposed that Ukraine would emerge as the most likely country to benefit from modernization based on an IT sector. In reality transition saw the almost complete collapse of the computer manufacturing sector and rapid market penetration by Western manufacturers. A myriad of legislative proposals have come forward in attempts to foster and protect domestic production

and use of IT, and Malinovsky provides a comprehensive assessment of the likelihood of success. As in the case of other ex-Soviet economies, the information and communications infrastructure remains a serious barrier to modernization.

The lack of access to Western technology through the embargoes of COCOM may have been only partly responsible for the lag in development in the Eastern bloc. Romania, for example, was one of the most technologically advanced and modernized countries in the bloc following Ceaucescu's aspirations for independence. The country was on the embargo lists, but also pursued its own nationalist policy—in resistance to both the West and the Soviet Union. As Chapter 14 by Heeks and Grundey outlines, from the 1950s onward this isolationism was supported by considerable effort directed at domestic computer production. Romania developed its own hardware and software sector during this period, and in comparison with other less developed countries, did remarkably well. Isolation inevitably meant delay and limited development, however, and despite establishing a wide range of production facilities and research institutes, and possessing a captive market of state organizations and public enterprises, the quality of IT production was comparatively poor. There were also problems of lack of integration among producers and again a predominant influence by the military sector. Attempts to circumvent these problems by producing western designs under license provided partial respite, but suffered from creating a level of dependency in R&D and design, and still left the problem of poor market dynamics. Licensed designs tended to be for older generations of technology and production became frozen around a single model. Production of Honeywell Bull, Digital Equipment Company (DEC), and Control Data Corporation (CDC) machines seemed like advance for domestic producers but designs were often up to 10 years out of date.[14] The switch to microcomputer and semiconductor technology exacerbated the relative backwardness of production and use of IT, widening the gap between all the Soviet bloc economies and the West.

With the collapse of the Soviet political regime and the ushering in of liberalization, all the economies of the Eastern bloc faced the problems of transition. Again the IT sector was signaled as both a symbol and a foundation of modernization. In the transitionary process, lingering ambitions to continue production of IT hardware soon began to dissipate. The realities of quality standards and competence levels meant that envisaged joint enterprises with the West failed to materialize. Research and production facilities were closed down as an acceptance of the superiority of western technology took hold. The poor state of the telecommunication infrastructure also hampered efforts to extend the exploitation of IT opportunities in the economy. Also, liberalization and the lifting of travel restrictions meant that many IT personnel, who had knowledge of Western technologies, emigrated. This "brain drain" problem, particularly to the US economy, had caused considerable concern in the European economies in the 1960s.

Software sectors in the transitional economies, however, fared better, particularly for small enterprises. Software multinationals have also had less problems than those in the hardware sector in establishing a presence in the transitional economies. Government policy in this environment proved to be difficult, however.

Governments needed to strike a delicate balance between exposing old institutions to the full force of the market (which often meant collapse), or trying to identify and foster those new areas needing support. Heeks and Grundey outline the options available in more detail and show how some successes, for example, in the protection and nurturing of the Romanian software sector, have been apparent.

It was not only in the newly liberalized ex-Soviet economies that new right economics had an impact of course. The idea of market forces replacing a general interventionist paradigm gathered pace in the West from sometime around the mid-1970s. This was partly in reaction to the downturn in the global economy in the 1970s, particularly the rise of stagflation in some countries—the simultaneous rise of inflation and unemployment. The Keynesian certainties, in targeting unemployment through demand management and measured intervention, had been predicated on a trade-off between the two. Worse still, many critics thought that the years of intervention had simply stoked up stagflationary pressures which had now, inevitably, burst through. Against this background, interventionist ideas such as the construction of national champions, were increasingly judged to be a bankrupt strategy. Parties of both the Left and Right began to adjust to the new world. In Norway, for example, as Sogner (Chapter 11) shows, the Labour Party led the way in criticizing countercyclical policies and the kind of intervention that had attempted to create a large-scale IT effort built around the electronics company Tandberg. Similar failures in France, Britain, Japan, and elsewhere simply added fuel to arguments backing the supremacy of market forces. The most dramatic casualties of this tectonic shift in economic ideology remained, of course, the Soviet Union and its satellite economies, which as we have seen, descended into a complex transitionary spiral of retrenchment and closure.

Problems and Policy

As many of the studies in this book demonstrate, as the IT industry has evolved, the site of activity and the shape of firms have also changed and shifted. This changing shape of both markets and the firms serving them has had a profound effect on both the formation of policy and its effectiveness. There have been attempts to identify specific phases in the history of IT—usually predicated on the central processing technology—valve, transistor, semiconductor, and so on. The reality of the industry—its nature and its boundaries—are far more amorphous and complex, and paradigm shifts are a mixture of the fracture and the tectonic—of revolution and inertia. Sometimes different phases and firms within them have existed in parallel or overlapped. They may indeed have coexisted in close relationship—the most notorious example being established multinational industry leader, IBM's linkup with venture capital funded growth firms Microsoft and Intel in establishing the IBM PC.

Government intervention of a particular form may well work in certain phases, but not others. It may work in certain historical circumstances, but not in others. As Van den Ende points out, it is important to recognize the development of an industry life cycle and the impact this may have on the likelihood of policy being effective.

In general terms it is widely accepted that the indicative plan in France or the role of MITI in Japan, if successful, worked best in specific phases of the growth of economies and industrial sectors within them.[15] Policy may well succeed against a background of national emergency and other contextual factors such as benign international agreements in the case of Japan. Similarly, specific phases of international pressure may well retard development. While Japan undoubtedly benefited from US support over trade and development in terms of IT during the Cold War, the Soviet Union experienced the reverse in terms of restrictions placed by the COCOM system.

Predicting technological trajectories and trends is difficult enough for governments, but another important factor needs to be addressed—the nature of the enterprise. Governments have not always recognized that policies need to conform to the pattern of enterprises in the industry, or rather they have not been able to predict the shape of firms and markets in a rapidly evolving sector. The IT industry has seen the locus of entrepreneurial activity go through a number of distinct phases. As the industry moved from data processing to information processing and, more latterly through a phase of Information and Communications Technologies (ICT) convergence, the nature of the predominant firm has changed. In the early years of the industry, there was a range of typically fairly large firms established in related industries, often with strong links to the state, or traditions of cooperation or support. During these years governments could hope to intervene very effectively in promoting the computer industry while it was still in its infancy—as a scientific and military technology. They could also manage or attempt to manage the industry as IT overlapped into a civilian enterprise and business application. In later phases, probably from the minicomputer onward, but certainly with the PC and maturing software industry, smaller, often clustered, entrepreneurial firms began to feature—and these posed a whole new set of problems for government policy. Some firms have followed the evolution of the industry, IBM, for example, enduring or mutating from the business machine to the computer. Others have emerged into the industry from outside, or have themselves grown with the industry as it has metamorphosed or generated entirely new sectors. Examples of the latter are new enterprises in the software industry, applications, or server companies.

Firms within these different sectors or phases of the industry have posed a problem for government in terms of diverse business cultures and competencies. Electronics and business accounting machine firms, defense contractors, start-ups, etc. all required a different emphasis in terms of policy, which the grand plan that so often emerged could never hope to employ. Policy that expected firms to move seamlessly between one sector and another—a simple transfer of competences—was always problematic. Philips is a good example of this, less successful when it came to manufacturing computers, but more successful when it came to components. It is also important to remember that a computer system, from the earliest time, was just that—a system. Perhaps it was easier in the early days, when firms attempted to produce the computer in its entirety, rather like the classic automobile example of Ford and its River Rouge Plant. IBM, for example, used this approach early on as

a distinct market strategy, trying to foster an embedded compatibility of central processing unit (CPU), peripherals, services, and software, in order to keep competition out. Such a strategy could only work for a limited period though and later on clones prevailed and forced compatibility from peripherals to emulators, and common languages opened up markets.

Despite the efforts of IBM, the industry always exhibited strong phases characterized by bundling or clustering of technologies and firms, and a complex exchange of technologies. This bundling was often international in nature, again a big problem for government policy. Policies aimed at fostering domestic capabilities were caught in a complex mesh of international product flows, technological capabilities, and comparative advantages. One fundamental problem for all government initiatives aimed at fostering a national industry is the porousness of international networks and markets. When the British government tried to protect ICL, for example, they found to their embarrassment that ICL machines contained a much greater proportion of imported components than Honeywell's machine. The latter was ostensibly a US firm—though operating as a multinational through its manufacturing plant in Scotland.[16] As Assimakopoulos et al. point out in their study of Esprit, only belatedly did the European Commission recognize that global networks and diffusion of technologies were far more important than regionalized initiatives. Attempts to hermetically seal a series of programs and foster a localized (albeit pan-European) IT sector, were predicated on forlorn hopes of isolation.

One way in which governments have been more successful perhaps is when they take a less "hands on" or *dirigiste* approach and limit involvement to providing funds—essentially taking on the role of bank, or venture capitalist, the latter function becoming more applicable if the state takes some form of equity in the enterprise. We can see many examples of this approach, including some of the more successful cases—the NEB in Britain, the Japan Development Bank (JDB), and Dutch policy aimed at fostering small- and medium-sized enterprises; with the credit program initiated in 1979, all enjoyed a degree of success. Again, it is vital to recognize the life cycle of the industry when formulating policy. As the IT industry approached maturity, governments were faced with an ideal investment model increasingly centered around regional clusters and networked firms.[17] This role as a banker or investor may not, of course, exclude other policy initiatives. In many cases in the history of IT policy, a range of initiatives were implemented by one or more government departments or subdivisions within departments, at different times or simultaneously. MITI policies in Japan, for example, included the control of imports through restrictions on the flow of foreign exchange; tariff and import license regulation; and direction of investment capital and leasing schemes through the JDB and later the JECC; and procurement for itself and other government departments and institutions.

Policies are neither conceived or implemented in a vacuum. We need to take account of the people in government who both envisage and set up policies, and those who administer them. In the first case policy may stem from individual political ambitions. This might be the case, for example, in the centrality of IT policy in Britain in the mid-1960s under the sponsorship of Prime Minister Wilson and his

vision of a total reform of national science and technology. Senior bureaucrats may also be prime movers in certain cases. Here the ideas and activities of Morihiko Hiramatsu at MITI in Japan may be indicative. As Yonekura shows, some of the strategies and policy changes implemented at MITI bear the strong imprint of Hiramatsu's ideas, for example, the switch from the strategy of trying to create a national champion to that restressing free enterprise in response to the IBM 370 challenge.

Influence may not be limited to individuals in government. There may well exist a form of "corporate" culture within departments or institutions. Certainly, there were rivalries between "technical" ministries and financial ones in many cases. MITI, for example had to struggle to get policy accepted by the Ministry of Finance in Japan, the Ministry of Technology (Mintech) had a strikingly similar relationship with the Treasury in Britain.[18] We can see this rivalry within and between government departments in its most graphic form in the debates outlined by the Malinovskys in Chapter 13, in relation to the seminal debate over whether to attempt to copy IBM's 360 family, to go with ICL's SYSTEM-4, or to consolidate independent technology trajectories. The story is one of political power and influence, dramatically shaping the key decision at the turning point of Soviet IT development. There is also a question here about permanent government versus politicians. In the case of Norwegian plans for the modernization of the IT sector, for example, Sogner (Chapter 11) outlines the conflict between a modernist bureaucracy and "old fashioned" politicians in the 1970s.

One of the key questions then, in determining the origins and ambitions of government policy in an area such as IT—being heavily science and technology based—is who *precisely* delineates policy programs. Here it is partly a question of expertise. Almost always politicians need to act under advisement in shaping and administering policy. The history of IT is replete with expert advice pushing funding in one way or another. Ostensibly, science and technology policy should be the one area of government most amenable to neutral, factual advice. In reality, it is probably the least. As we have seen, the question of market trends has continued to defy accurate quantification or prediction, the effect of one technology on those linked to it have been equally difficult to predict. Moreover, advisors usually have a range of ideologies, motivations, and loyalties, either individual or institutional, which shape their recommendations. The history of IT policy advice is one replete with special pleading from military services, government departments, research institutes, enterprises (large and small), and individuals, each vying for a share of the pie—or for a larger pie. Often individuals can cross between sectors. Sogner, for example, traces the dual role of individuals involved in both private enterprise and government initiatives. Similarly in Britain in the 1970s and 1980s, entrepreneurs and government advisors seemed to merge into one in the programs of the NEB and the Alvey initiative. Evidence also suggests that the firms involved in the Esprit program in the 1980s managed to set the funding agenda to suit their own purposes. The Big Twelve of the European IT industry were certainly criticized for excluding a wider range of stakeholders in the program. It may also be the case that lobbying *against* policy may be evident, and may significantly alter government strategies.

Japanese companies, for example, did not always welcome the interventions of MITI. As Yonekura demonstrates, the majority of Japanese firms strongly resisted the formation of a national champion, forcing the government to settle for a split between intervention in the investment/leasing strategy and partial R&D funding, but leaving private firms to control manufacturing.

One important factor shaping policy is political ideology. Initiatives aimed at a programmatic response to perceived national failure were always bound to prove effective at the ballot box—or effective in securing funding if promoted by industry or interested parties. It might be fair to suggest that a great deal of political capital could be gained from posing as the party of modernization, and hence promoting a strong IT development policy program. As we have noted IT is the quintessential sector in this regard. In addition there is the obvious question of party ideology in relation to intervention—or the site of intervention. We can see evidence of both effects in IT policy history. But we can also detect trends that seem to gainsay the above and suggest that IT policy was above ideology in many respects—appealing to a deeper sense of national purpose. In the case of the Ministry of Technology initiatives, for example, we can clearly see a fracture between political ideologies in Britain. The consensual Keynesian approach to macroeconomic strategy may have existed throughout the 1950s and 1960s, but a radically more interventionist, almost classic Fabian approach underpinned the modernization and technological reverence of the Wilson years, which was unmistakably Labour in nature. In contrast, in the United States, initiatives both in support of IT in terms of Pentagon funding, and in opposition to IBM's monopoly seem to supersede party electoral platforms, operating at a deeper rhythm. Policy changes are evident at a superficial level—as in the case of the imperative to switch defense research away from general research to more precisely defined defense projects—in effect uncoupling the defense and civil sectors, under Nixon in the 1970s. As Norberg shows there were identifiable changes in the emphasis of IT research funding in the civil and the defense sectors with each change in administration from the 1970s onward, and the end of the Cold War signaled a switch to research with a more diffuse impact and more utility for general society from the outset. Nevertheless, policy in the United States seems to conform less to the electoral cycle than that in the European nations during the period under study.

One of the central debates within the history of technology is the role played by the military sector. The military sector is axiomatically the government sector, and though military policy is driven by strategy, power, and national protection it has also frequently been equated with economic strength. Increasingly, technological power and the reverse—technological dependence or vulnerability—have come to be equated with military power or national security.[19] There are a separate set of ideas which stress the reverse, of course, that is, that military spending is a burden on technological and economic development and that a "military industrial complex" may retard or distort firms' or national capabilities.[20]

The computer is emblematic—more so than any other technology—of the complex relationship between the military and civil sectors in terms of technological

and industrial development. It is fairly widely accepted that the earliest computer development was a military thing and that the US computer industry, particularly IBM, received substantial, even critical, levels of support from the Pentagon. As Usselman shows, however, the relationship between military sponsorship or support may be more complex than it appears. IBM, for example, may certainly have benefited from Pentagon sponsorship of the computer in the 1950s, but it may have benefited primarily because the company had the organizational capabilities and culture *already in place* to exploit the advantages offered by government funding as those opportunities came along.[21] In other words, the Pentagon did not create IBM, rather the company already had the attributes that enabled it to exploit Pentagon funding and further extend the firm's growing advantage in the mainframe computer sector. Other national IT industries were affected by the fallout from the military–industrial relationship which had developed from the earlier periods. This could take the form of company R&D and funding dependency, the infiltration of new programs by the personnel with the highest level of familiarity with government generated programs, as in the case of the Plan Calcul, for example.

In conclusion, the history of the IT industry is one of great complexity. A wide range of corporate forms and technologies are involved in the industry, overlapping and interacting, locally, nationally, and internationally. Government policy aimed at fostering or controlling this sector has taken many forms historically—some more successful than others. Such is the unique position held by IT in terms of its symbolism of modernity and economic progress, that policy has often been amenable to populist influences and reactive calls for national independence. In terms of independence there has also been a strong synergy between the military and civil sectors in terms of industry development and policy formulation and execution.

If we can identify broad themes or phases in the history of IT they are perhaps characterized by a high point of aspirant state interventions in the 1960s and 1970s, in the face of perceived US dominance, followed by a period of more considered and less ambitious initiatives, in turn followed by a continual tenacious appeal to policy promising or urging rationalization. The studies in this book illuminate this process in detail, but also demonstrate the need for a nuanced approach to IT policy history. A wide range of policies, direct and indirect, have been attempted in different countries and in widely differing contexts. The IT sector still holds a special place in the mind of many policymakers—it can still attract as the leitmotif of modernization or development. The lesson from this history may well be that fundamental and dispassionate assessment of technological trajectories, competences, and institutional cultures is vital before any national or international policy responses can be formulated.

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Notes

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6. The most comprehensive study of MITI in this area remains M. Anchordoguy, *Computers Inc.: Japan's Challenge to IBM*, Boston, Harvard University Press, 1989. See also D. Okimoto, *Between MITI and the Market: Japanese Industrial Policy for High Technology*, Stanford, Ca.; Stanford, 1989; M. Fransman, *Japan's Computer and Communications Industry: The Evolution of Industrial Giants and Global Competitiveness*, Oxford, Oxford University Press, 1995, pp. 126–161; E. Abe, "The State as the 'Third Hand': MITI and Japanese Industrial Development after 1945," in E. Abe and T. Gourvish, eds., *Japanese Success? British Failure? Comparisons in Business Performance Since 1945*, Oxford, Oxford University Press, 1997; E. Arnold and K. Guy, *Parallel Convergence: National Strategies In Information Technology*, London, Pinter, 1986, pp. 84–101.
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8. M. Campbell-Kelly, "ICL and the American Challenge: British Government Policies for the Computer Industry, 1949–1985," in W. Aspray, *Technological Competitiveness: Contemporary and Historical Perspectives on the Electrical, Electronics and Computer Industries*, Piscataway, NJ, IEEE Press, 1993.
9. See M. Fransman, *The Market and Beyond: Cooperation and Competition in IT Development in the Japanese System*, Cambridge, Cambridge University Press, 1990; Fransman, 1995, op. cit., pp. 161–202; M. G. Borrus, *Competing for Control: America's Stake in Microelectronics*, Cambridge, MA, Ballinger, 1988, pp. 97–171. These fears of a growing Japanese challenge developed into a generalized fear of an Asian challenge with the growth of the "tiger" economies into the 1980s. For an example of the accompanying, almost alarmist, literature see J. Dedrick and K. Kraemer, *Asia's Computer Challenge: Threat or Opportunity for the United states and the World?*, Oxford, Oxford University Press, 1998. See also J. A. Matthews and D. S. Cho, *Tiger Technology: The Creation of a Semiconductor Industry in East Asia*, Cambridge, Cambridge University Press, 2000.

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14. The IT sector mirrored the car industry in these respects. The ubiquitous Dacia automobile, a copy of a Renault 12, dominated the roads of Romania 20 years after the model had gone out of production in France.
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17. This may not necessarily have been a new phenomenon—there was certainly a dense labor market cluster of scientists and engineers in the Thames valley region in the late 1940s and 1950s in Britain, for example.
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19. See Norberg and O'Neill, op. cit.; for the influence of the US military on microelectronics in general see Borrus, op. cit., pp. 63–73.
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2

The Shifting Interests of the US Government in the Development and Diffusion of Information Technology Since 1943

Arthur L. Norberg

Introduction

In any evaluation of research and development (R&D) in science and technology after the Second World War, at least three significant episodes need to be considered as pivotal. First, there was the successful use of the scientific and technical community in the development of implements and techniques for use during the war. This success led to a reevaluation of the relationship of science and technology to society, to government, to defense, to the economy, and to health. A significant definition of this relationship came in the essay, *Science, the Endless Frontier* by Vannevar Bush.[1] Even though much of Bush's argument was rejected by the political community in the aftermath of the Second World War and most of his recommendations were not implemented by the US Congress, the debate surrounding it and arguments about how science and technology should be employed set a new compact between the science and technical community and US society.[2] Science and technology, henceforth, were to be supported largely from public monies because of the benefits they would surely bring to society.

Second, the Cold War reached its full intensity with the hysteria following the successful launching of Sputnik by the Soviet Union. Some of the arguments about targeted R&D, especially for military purposes, which had been used to blunt the edge of Bush's arguments for pure research, took on greater force after 1957, and became the justification for many programs in the 1960s and 1970s. Other, secondary events on a global scale such as the US involvement in Vietnam and the economic troubles at home tended to reduce R&D funds for basic research and shift what remained further in the direction of targeted projects.[3]

The third defining point coincided with the collapse of the communist governments marking the end of the Cold War. This "event" seemed to coincide with a deepening conservatism and an emphasis on individualism in the United States. Embedded in this conservative trend was concern for the changing global economy and competitiveness in it, which some thought would be better addressed if

R&D were shifted more to a use-based strategy. To accommodate this, the compact had to change. Researchers sensed, if not openly recognized, this change and proposals to funding agencies contained more justifications of early, if not immediate, use; they contained more attention to overriding societal problems such as AIDS, the environment, and biomedical/pharmaceutical R&D. Systems such as the Internet were touted by political and industrial figures as a key to better situate the United States in the rapidly expanding and highly competitive global economy, therefore, money should be invested in spreading its use. Tagged on to these three events were all the little tremors and earthquakes that come with a range of opinions and interests in society's daily competition.

In the midst of this exciting 50-year maelstrom of political give-and-take on all levels of world society, the electronic digital stored program computer was born and came to its present maturity. There is a parallel to the growth of the computer system and these pivotal events, enough of a parallel to bracket the development of computing as consisting of three phases also.

The literature on government policy and technical progress grows annually, as historians, political scientists, economists, and others address the rapid changes in technologies and the effects of government decisions on these changes. In the case of the computing enterprise,[4] the impact of government support and purchases was exceedingly important in the growth of the area. As we know, of course, governments take many kinds of decisions that affect and effect change. Changes are implemented through funding R&D, purchase of large numbers of artifacts, requiring the use of artifacts by those outside government through legislation or practice, supporting or penalizing use through the tax code, etc. Often these effects can be positive in one direction and negative in another.

Consider an example from another well-known industry: That of internal combustion engine vehicles and catalytic converters. Government agencies took the decision to force a reduction in environmental pollution through control of exhaust from these vehicles. This added to the price of the vehicle due to the policy of requiring converters on all vehicles (a negative effect viewed economically by the consumer) and stimulated development of new products to improve reductions (a positive effect both environmentally and for some economic sectors). A complete analysis of the impact of this policy requires that we look at policies of other government departments with respect to vehicles, fuel supply and prices, tax incentives and disincentives for the automobile industry, etc. The crossover impacts of one policy on another can be substantial, and unpacking these impacts can be a messy task for the historian. This unpacking may be essential to understanding the impact of a policy in one particular area, say that of R&D. The difficulty in this unpacking sometimes prevents us from achieving a complete picture of the government's role in any given area of technology. To this example of environmental policy, we can add many others for aircraft, housing, computers, day care, health care, and education, to name only a small sample.

Our understanding of the government's role in computing between 1945 and 1999 still lacks several dimensions, both in the dominant role—support for R&D,

and in the secondary roles—such as education and tax policy on computing diffusion. To investigate all the roles at once is a daunting task. Therefore, in this chapter, I wish to examine only the dominant role of government agencies in support for computing in the last four decades. By extending the discussion over three phases, the chapter will enlarge our historical appreciation of the role of government in R&D for computing. This 50-year analysis will also illustrate the similarities in approach to selecting problems and funding R&D over the three phases. The changes discussed resulted both from sophistication within computing and from altered attitudes and circumstances in the society around the computing enterprise.

This approach to examining the effect of government policy through R&D first has been the more customary one in earlier studies. Consider the following examples. Perhaps the most frequently cited study of government policy for computing R&D is the work of Kenneth Flamm. In virtually all of *Creating the Computer*, published in 1988, Flamm examined the role of the Department of Defense (DOD) in R&D for computing.[5] The most recent study of government support for computing research, this time by the National Research Council (NRC), *Funding a Revolution*, takes the same approach.[6] A complementary area in aid of R&D is education. Here the principal historical analysis is that of William Aspray and Bernard Williams on National Science Foundation (NSF) policies, the primary funder of programs directly aimed at education.[7] Aspray and Williams draw inferences about the relation of education to R&D activities from their deep knowledge of both, but no explicit connections were drawn, probably due to space limitation. We can ask, however, what are the connections? And are they reinforcing? The same question can be asked of the activities of the National Institutes of Health (NIH) and the National Library of Medicine in computing. What effect did the development of database developments in medicine have on R&D for new systems, or was it expected that new ideas in medical informatics would be built on emerging database developments in the general area of computing? Even if we had the answers to these questions at this stage, I believe they would show that the emphasis was on R&D in each of these agencies.

Phase 1: Government Sponsored Programs for Understanding and Designing Machine Systems in the Period 1943–1960

Whether intended or not at the outset of the federal (initially military) effort to develop computers in the United States, the effort quickly became a partnership between the government, on the one hand, and industry, university scientists, and individual computer developers and entrepreneurs on the other. This joint effort, initiated prior to the Second World War, broadened and deepened over the next two decades. The effort provided all of the elements needed to create a full-blown computer development and commercialization activity—programmatic direction, specific task assignments, broad and sustained funding both for production of specific hardware and for the pursuance of broad areas of new ideas that did not always offer either immediate applicability, or a large and certain market for products.

Fortunately for the nascent computer industry, the government's interest and financial support were sustained through the late 1950s and continued in certain directions until the 1970s, even though a robust commercial computer market began to emerge in the latter part of the 1950s. Nor was government interest confined to the military. The Department of Commerce generally, the Bureau of the Census, the Social Security System, NASA, and a number of other federal agencies all undertook computer development initiatives after the close of the Second World War. As so often happens in the case of the creation of major new technologies in the United States, this was a case where government personnel saw the great potential benefit of a technology to the work of their agencies and undertook to bring the technology into being.

Had computer development been left to private industry, the rate of progress and even the outcome would have been markedly different. For one thing, early computers were extremely large, generally could be applied to only a narrow range of similar problems, were hugely expensive, and they appeared to compete with existing product lines of the companies that ultimately came to develop them under government auspices. For instance, IBM had a highly established business in punched-card technology, toward which its production facilities and its management and sales staff were oriented. National Cash Register (NCR) was heavily into (mainly) mechanical inventory control and information systems; Burroughs was involved with mechanical controls, and so forth. None of these firms would have been expected to make an investment of many millions of dollars in a totally new technology that proffered extremely high commercial risk (there being no commercial market whatever at the time) and would have rendered their established production facilities and staffs obsolete. And apart from all these considerations, private industry lacked the resources for the undertaking. So, in hindsight, it is fortuitous for the United States that enlightened government officials appreciated the potential of computers for their operations, and that they had the authority to proceed.

Even a cursory look reveals that federal R&D support and programmatic direction not only created the electronic computer enterprise in the United States and laid the groundwork for initial computer design and development, but also played a continuing dominant role in the further development of computers until the mid-1960s. Military needs, later augmented by the computing needs of NASA, the Federal Aviation Agency, and the NIH, as well as the huge data processing needs of the Census Bureau and Social Security System, produced large amounts of federal funds for computer development. This support was considerably greater than the amounts provided by industry, and remained dominant until the early 1960s. Thus government funding and the large government-created markets for computers literally created the industry and set its initial direction. Perhaps equally important, government support fostered creation of an unusually skilled cadre of computer engineers and scientists and encouraged them to venture into new areas of hardware design, operating protocols, and software possibilities. No private concern, operating strictly in the commercial market, could have been as productive of new ideas and of skilled personnel. Apart from the government's activities promoting the development of the aerospace and nuclear power industries, the federal support of the computer industry is virtually unique.

In the first phase of computer development, military needs were so overriding that the government specified the function and performance of the computers to be developed and purchased. Thus early commercial computers were literally outgrowths, or redesigns of, computer systems that had been developed and purchased by the military or other government agencies.

Without question, government financial support and enlightened management during the period 1945–1960 promoted continuing advancement and change, created the necessary markets for computing technology, and encouraged industry growth. Among the advances created or promoted by careful government support were:

- the basic concept for the stored program digital computer
- support for construction of all prototype US computer models in the years 1945–1960
- magnetic memory technology, including core memory
- transistor development and integrated circuits
- graphics
- instruction pipelining
- major programming languages like APT, COBOL, and BASIC
- early US supercomputers.

While this is not an exhaustive list of computer development in that 15-year period, it contains both specific system designs and the foundations of computer developments of all kinds, exploited by manufacturers both in the United States and abroad.

The mainframe computer emerged in the 1940s as a solution to the compelling computational needs of defense agencies. The defense community, working hand-in-hand with the academy and industry, stimulated the invention, design, construction, and markets for the many mainframe computers of the 1950s. Even though the computer is a remarkably complex device, requiring intricate adjustment across many of its subsystems, stable designs were reached and machines were constructed in a surprisingly short time in just over a decade. We can only remark at the foresight of the war and defense department people who seized on the concept to fill urgent requirements.

During the early 1940s, the army and navy, already immersed in the application of electronics to defense, promoted various projects working on computers for artillery firing control mechanisms, artillery table construction, tables of mathematical functions for use (among other things, in ballistics and ship design), complex number calculations for communications systems, detection and minimization of the error in aiming antiaircraft fire at a moving target, intelligence and other applications. To the rising generation of computer designers after the war (and to the public), all this effort came to be symbolized by the ENIAC, designed and built by a group at the Moore School in the University of Pennsylvania, funded, and in some respects guided, by the US Army from the Ballistics Research Laboratory of the Aberdeen Proving Ground.

The story of the ENIAC has become well-known since its demonstration in 1946. Indeed, one can mark this as the start of an exciting and productive decade of computer design. By 1956 a number of commercial computer models, based on the designs sponsored by the federal government, were available for use in many sectors

of the economy. Spurred on in this decade by government needs in nuclear weapons, missile design, missile defense systems, nuclear power, aircraft design and monitoring, logistics, intelligence assessment, and a myriad of other problems needing solution in a postwar world, the defense community continued to support the design of this great behemoth, which filled rooms with flickering lights, clacking typewriters, whirring paper tape machines, and air conditioning fans to keep the temperature down lest the machine stop even more often than it was wont. Every problem seemed to require some special features in the computer system, further marking the continuing emphasis on R&D.

Other government agencies also early saw the value in these machines, in part through demonstrations by and encouragement of the designers. The Census Bureau and the National Bureau of Standards (NBS) were among the leaders in the postwar period, sponsoring R&D for and acquisition of computers. Postwar support for research in computing was part of a broad pattern of government encouragement of R&D in the United States. Without this support, the enterprise would very likely have been much slower in starting and developing, and no doubt would have had a different ending.

The Departments of the Navy and Air Force led in the post-Second World War promotion of R&D activity. Even before the cessation of hostilities in 1945, the Office of Naval Research (ONR) was planning postwar R&D programs. ONR's Naval Research Laboratory, for example, pursued its interests in naval-related weaponry. While waiting on the outcome of congressional debate over the establishment of a foundation to support research, the ONR began a funding program to provide support for scientists and engineers at universities and in industry to maintain the flow of knowledge considered important to national security, including computing. ONR sponsored a major project at the Raytheon Corporation; the army funded EDVAC at the University of Pennsylvania, as well as the Institute for Advanced Study (IAS) machine at the IAS in Princeton; and the navy supported Harvard's project on the Mark III computer. ONR promoted the spread of computing information about ENIAC and EDVAC through sponsorship of a series of lectures at the University of Pennsylvania in the summer of 1946 and a symposium at Harvard in January 1947. The focus in both these meetings was on hardware design. Application emerged from the interests of commercial/government/military users in exploiting this information in commercial and research settings.

With the establishment of the NSF in 1950, this extramural role of ONR became muted and less funding was provided by Congress for the ONR external funding program, but ONR continued to be an important funder of research. NSF gradually came to assume a critical role in support of computing for scientific and technological research. In the 1940s and 1950s, ONR and NSF supported critical computer research facilities that spread the use of computers among scientists and engineers. These facilities substantially improved science research programs requiring large computational capability around the country, and were platforms for training a cadre of scientists, engineers, and computer designers in their use.

The Army Air Corps emerged from the war as the Air Force with an expanded defense mission. To accomplish this, the Air Force mounted an extensive research

program that spread over many Air Force facilities plus organizations outside DOD. Air Force personnel, like their counterparts in the Navy, came to believe that a broad R&D program that included research sponsored within organizations outside the DOD was needed in these new technological areas, again including computing.

Perhaps the Air Force's most famous and lasting contribution to the growth of computing was their support for the Whirlwind computer project at Massachusetts Institute of Technology (MIT). Whirlwind engineers contributed many new concepts to computing, including magnetic core memory; a fast, random access memory; early graphics display systems; and direct access for programming. The Whirlwind computer was the centerpiece of the Semi Automatic Ground Environment (SAGE) air defense system of the 1950s. Whirlwind contributed much to early commercial computer systems, especially by IBM, because IBM was the prime contractor in building the SAGE computers.

With support from the US Army, von Neumann assembled a group at the IAS in Princeton to design and build a computer. Von Neumann and his associates systematically evaluated the parts and the relationships among the parts of a computer design. Von Neumann's concepts were perhaps the best articulated from a theoretical perspective. Indeed, it was his group's discussions and writings over the next 3 years that influenced the entire computer community. Most of the designs since have followed the principles laid down by this group at this time. The group's work has been honored by the community with the eponymous title of von Neumann architecture. When these men moved on to other projects, many of them joined companies like IBM and Burroughs. In the late 1940s, the Air Force organized their own "think tank," the Rand Corporation. Rand built the JOHNNIAC computer, based on the von Neumann machine constructed at the IAS.

The US Census Bureau expressed an early interest in a computer system, and sought advice from the government's technical agency, the NBS, which in turn organized a committee to analyze the available designs. In fact, all the designs of the period were based on the ideas incorporated in the EDVAC design done at the University of Pennsylvania under army sponsorship.

Thus, the attention paid to the military services funding of computing activities in the late 1940s and early 1950s is appropriate and informative. But is the search for new adjunct devices in weapons systems or computational techniques for logistics and planning schemes a government policy? Support for the EDVAC at the University of Pennsylvania, the IAS machine at Princeton, and the early Whirlwind at MIT went for development of devices. Seen from the perspective of the scientists and engineers on these projects a substantial amount of research was needed to achieve the result, but this was not the intention of the army and navy groups who supported these projects. It was not until 1950 and the design of an air defense strategy to include information processing as part of the command and control aspects of the defense system that endorsement and promotion of such policies were achieved at high levels.[8] Often in the United States, a distinction is made between policy of the government and policies by agencies of the government. But even if we accept such a distinction, and I do, we still cannot say that the early support for single machines constituted policies of each of the services.

The closest the US government came in the 1940s to development of a policy for computing was the attempt by the NBS, acting as agent for the Census Bureau, several other service groups, and itself, to develop an industrial policy for design, development, and fabrication of computers for sale to government and other groups. Atsushi Akera presents a persuasive argument for this position in his analysis of the NBS interaction with the National Academy of Sciences, on the one side, in evaluating computing activity and the NBS program to involve companies like Eckert-Mauchly, Raytheon, and others in computer development.[9] In the end, NBS was not successful, partly because of the newness of the field and the unexpected length of time needed for design and development, and partly because the work of others like IBM and MIT superceded the emphasis placed on Eckert-Mauchly and Raytheon. But the efforts of NBS and ONR helped to bring the enterprise to a state where sustained commercial activity took hold by the mid-1950s. Some credit for this commercial development can go to air force support of groups on the West Coast of the United States as well. Projects at North American Aviation and Northrop resulted in the formation of companies such as CRC, Logistics, and Alwac. Meanwhile, the navy supported the data systems development activities of another new company, Engineering Research Associates in St Paul, Minnesota. After a few years, this company, too, agitated to build computer systems, and did so.

In the late 1950s, Cold War policies directly affected computing activity. As Robert Seidel has shown, the nuclear weapons laboratories of Los Alamos and Livermore had a direct impact on computer development through their policy of stimulating, indeed actively participating in, computer design and development at the frontier of high-speed machines.[10] They let contracts for new machines have extreme characteristics relative to the market machines available at the time. From these contracts came IBM's Stretch and Sperry Rand's LARC. Both machines aided in the achievement of Cold War defense aims, and not unexpectedly played a large part in subsequent commercial machine designs. The appearance in the 1960s of machines with larger and more effective memories and greater speeds can be traced directly to Stretch, LARC, and Whirlwind.

The number of computers and their capabilities grew rapidly in the last half of the 1950s. While there were fewer than 5000 computers operating worldwide in 1959, the growth rate was significant: The number of computers had increased by more than 50 percent from 1958 to 1959, after having increased tenfold between 1955 and 1958. Some present day commercial computer systems can be traced back, family by family, to the IBM 701, ERA 1103, and the Univac:

- IBM 700, 7000, 360, and 370 successive families of computers
- Eckert-Mauchly's Univac and ERA's 1100 computer families that merged eventually in subsequent 1100 families sold by Sperry Rand and now Unisys
- Burroughs machine designs merge into Unisys's new designs: The 9000 family of computers.

By the time fundamental design of computers was accomplished and time-honored machines were in place—the IBM 701, IBM 650, ERA 1103, Univac—government agencies supporting R&D began to shift away from the immediate direct military

needs of the DOD, which began to buy more "off-the-shelf" computers, to the much broader objectives of the NSF, NIH, the Atomic Energy Commission (AEC) and its successors, and the Advanced Research Projects Agency (ARPA) in the Pentagon. These agencies, especially ARPA, launched the next phase of development, which transformed the computer into a more flexible, reliable, intelligent, and interactive device. But the legacy of the government's early involvement in computing R&D remained. As in semiconductors, aircraft, and nuclear reactors, early military and other government agencies provided R&D support for computers built by US companies and these machines became the prototype for a line of subsequent commercial computers sold to government, industry, and educational institutions.

Except at the high-performance end of computing in the 1950s, design and development shifted from government sponsored projects for one-of-a-kind machines to industry development of commercial products, led in the United States by IBM, Sperry Rand, Burroughs, NCR (NCR acquired CRC in 1953), and the new firms of DEC and CDC. With this shift, government agencies began to focus on other problems, both in computing and for use of computers elsewhere.

The interests of government agencies ranged from design and construction of independent computer systems to a less well-known concern for language and programming. Perhaps the best known example of the latter at the end of the 1950s is the design of a new system to provide language compatibility across incompatible machines. A committee of computer scientists inside and outside of government, virtually all from industry and government, designed the COBOL language, an English language software system to handle all types of business transactions. Bubbling up from the industrial community was an interest in creating a common business language for computers. Already in existence was FORTRAN, a common scientific language, operating for some 5 years at this time. The group, which met in April 1959, sought the help of the DOD to make the process among several manufacturers possible. Less than 2 months later, a meeting occurred in Washington, DC, at the DOD with about forty people in attendance. Within 6 months, a version of COBOL was ready, and in early 1960 preliminary specifications were published. At this time, the developers thought these specifications were a stop-gap measure to solve a problem.[11] Little did they know that the language was to take on a life of its own and serve many useful functions.

Besides managing the process of development for all these many actors, the DOD played a role in the acceptance of the language, because not everyone was pleased with COBOL. The report on COBOL in April 1960 was issued by the DOD. This report specified that within DOD agencies COBOL would be the preferred language for problems in business data processing.[12] This insistence, along with moves by computer manufacturers to ensure that the language could be used on their products assured its diffusion throughout government and the business community.

Initially, the NSF's goal in supporting computing was to promote the use of computers by scientists and engineers. In 1955, NSF appointed a panel, headed by von Neumann, to advise on university computing facilities. The committee recommended programs to provide computing facilities to universities, train scientists

in computing methods, and provide for computer operators. Such programs gained momentum only after the Sputnik affair in October 1957, after which NSF programs increased in magnitude. Programs to aid training of computer scientists also became prominent in NSF over the next decade. As given in Aspray and Williams's report, between 1959 and 1970, NSF provided $2.8 million through thirty-seven grants in support of computer science course content improvement. These grants ranged from the teaching of analog and digital principles to development of the BASIC programming language.[13]

During this first phase and similar to other industrialized nations, the United States at no time had a unified policy about supporting the development and diffusion of computers and their accessories. Whatever policies were evident at the time resulted from the interests of some agency or set of agencies of the government. These policies can be grouped into categories, but the time spans and the agents behind the policies vary over time. The historical literature focuses mostly on those initiatives which emerged from military stimuli for computer development, but the military is an amorphous concept and a close examination demonstrates that military influence itself is not consistent, uniform, or coordinated. Nor were programs sponsored by Pentagon agencies always designed and promoted by military personnel. As we have also seen, civilian agencies also supported development programs for specific purposes, some of which were related to the public sector and some to the defense sector. Given the sharp focus given by historians to activities in the United States, which they label military, it is important to view the history of the government's various roles in computer development to appreciate the various interests. It turns out that activity in the second phase does not allow any clearer distinction between defense and civilian R&D in computing.

Phase 2: The Search for Interactivity of Computing Systems

It is remarkable how the first phase of development came to an end just as an international event—Sputnik—sparked a debate that began a redefinition of the compact between the science and technology community and US society. This debate opened the way for a new emphasis on use-inspired R&D, which still contained a sizeable element of fundamental research, and out of which came many dual-use results, a hallmark of the R&D endeavor of the 1970s. This was especially true in computing.

When the space program accelerated after the launching of the Soviet satellite Sputnik in October 1957, digital computers became an integral part of that activity as well. The more sophisticated the various military systems became, the greater the demands placed on their computing elements; and the greater those demands became, the more apparent were the shortcomings of the systems' computing elements. The need for a major research program for advanced computing technology useful in noncommercial computer systems became more and more evident. It was not until after the US response to Sputnik that the momentum for such an R&D program took shape in the DOD.

The United States responded to the Soviet Union's launching of Sputnik in a number of ways. President Eisenhower appointed James A. Killian, president of MIT, as a presidential assistant for science, and Killian's first action was to create the President's Science Advisory Committee. With its aid, Eisenhower set about separating the various space and ballistic missile programs, because of his belief that separation would facilitate an early successful launch of a satellite. Eisenhower, well versed in the rivalry between the services, approved the organization of a new agency in the DOD to oversee the development of the US space program and separate it into distinct military and civilian components. While this was its first task, the new agency's mission was soon to be more broadly designed, and it came to play a very significant role in further R&D support for computing.

The new agency, the ARPA, was the result of an effort to rationalize R&D at different levels within the DOD, and to stimulate new elements in frontier technology development in response to Sputnik. ARPA later became the Defense Advanced Research Projects Agency (DARPA) and in 1993 it was renamed ARPA. DARPA's mission throughout the period 1960–1993 was to prevent major technological surprises such as Sputnik, and to serve as the mechanism for high-risk R&D in cases where technology was in its early stages and where the technical opportunities crossed the military department role and mission lines. Along with the space program task, DARPA received a handful of additional presidential directives in the areas of nuclear test detection, missiles, satellites, and materials. And after it completed the space program task, the agency focused on these areas and served as a research arm of the Office of the Secretary of Defense. DARPA's objectives in these and subsequent areas were to maintain technical vigilance and to provide a quick response to technical developments abroad.

The DARPA programs have been a source of research support for projects with possible multiservice-oriented needs. This research was carried out on the high-technology frontier, so as to give DOD operations a distinctive edge. DARPA has pursued its mission by stimulating R&D support programs, but it has had no research laboratories of its own. Instead, it has supported R&D programs in organizations outside the DOD and has participated in these R&D efforts through close cooperation between DARPA personnel and members of the research organizations. While contributing substantially to the DOD mission throughout its history, DARPA has also contributed to the general economy by supporting the development of generic technologies useful well beyond military systems as the starting point of new products for the civilian market.

What success DARPA has had resulted from the nature and range of its research-support programs and from its management style. Its programs focused on R&D at the frontier of high-technology systems for defense. Consider the range of its programs in the 1960s, which dealt with ballistic missile defense, nuclear test detection systems, special technologies for use in the Vietnam conflict, materials science, and information processing. In the first three areas cited, many, if not all, of the programs supported were classified, had a specific DOD mission, and rarely contributed beyond their defense mission. However, the materials science and information

processing programs, by deliberate design and occasional good fortune, contributed to both the military and civilian sectors of society.

In all of these program areas, DARPA was devoted to the study of problems on the R&D frontier. More than that, DARPA involved itself consistently with high-risk projects. The usual definition of high-risk projects concerns the economic aspects of a project or program. When a firm invests in R&D for a new technology, it commits resources that are irretrievable if the project fails. The loss of these resources can affect the entire company adversely. For example, when IBM set out in the early 1960s to develop a family of compatible machines, it invested heavily in the System 360. If that system had not come to market or if customers had not accepted it, it is generally believed, IBM would not only have lost the market for 360s but would have had no new products to counter the developments of other firms.

The DARPA used the term high risk in a different sense. The DOD did not have an economic interest to preserve. The limitations it worked under were those imposed by congressional budgets. DARPA's high-risk projects were those with ambitious objectives that existing technology was not adequate to achieve. High-risk projects in DARPA dealt with the development of fundamental or enabling technologies with which to reach newly defined DOD objectives. It is important to note that when DARPA judged success, it applied technical rather than economic measurement standards. Because it could ignore cost, a number of high-risk projects were deemed successful; hence DARPA was judged a success.

The other important factor in DARPA's success was it management style. In virtually all offices and programs, the agency had a lean administrative structure. Personnel used extensive field contact, sought fast turnaround times for proposals, and supported high-risk concepts and development projects. DARPA assembled an exceedingly capable staff, which accumulated a history of block grants and multiple-year contracts, employed a proposal evaluation mechanism that was largely internal rather than dependent on peer review, and in some offices showed a consistent ability to fund new technological concepts that have had major effects in society.

Several developments, events, and explorations shaped the DOD response to the need for more R&D in information processing. The most important of these was perhaps a recognition inside the DOD of shortcomings in command and control systems. By 1960 the DOD recognized that it had a problem with respect to large amounts of information requiring timely analysis, and DARPA received the task of examining how to meet this need. Command and control denotes a set of activities associated, in military contexts, with rapidly changing environments. These activities include the collection of data about the environment, planning for options, decisionmaking, and dissemination of the decisions. Increasing the amount of strategic information that could be controlled would improve the command decisions needed in a rapidly changing environment; and computing technology had the potential for controlling greater amounts of information and presenting it in effective ways to aid decisionmaking. The military services regarded computers as important components of modern warfare. Weapons systems and missile guidance systems used computers as the central control element. The capabilities of computer systems

made them a natural adjunct to command and control problem analysis. While concerns for command and control problems had existed throughout military history, it was only in the late 1950s that the area received general recognition and the term command and control became common. Earlier military concern with the processing of information and the use of the results in command decisions had focused on the problems of human relations. In the early 1960s, however, the focus shifted to the informational aspects, and computer use in military systems expanded. Military interest in computing technology was heightened by the merging of information technology (IT), command techniques in the new military weapons environment, and missile control systems.

A survey of the information sciences and their relevance to defense concerns requested from the Institute for Defense Analyses (IDA) by the DOD revealed five critical problem areas. The areas were: Pattern recognition and formation of concepts on the basis of data; decisionmaking; communications; control; and information storage and retrieval, data handling, and data processing. The report described some research activities concerning information sciences already supported by agencies of the DOD. They ranged from mainstream applications of psychology, the social sciences, and biology, to specific projects in encoding of basic information, self-organizing systems, and heuristic and adaptive computers. No immediate action seems to have been taken on this report pending a new administration in the White House and in the secretary of defense's office.

The arrival in the White House of the Kennedy administration shaped the DOD response to needs in information processing because of the new administration's concerns about defense and a desire for new programs. In March 1961 President Kennedy, in a special message to Congress on defense spending, called for the improvement of command and control systems to make them "more flexible, more selective, more deliberate, better protected, and under ultimate civilian authority at all times." In June 1961, the Office of the Director of Defense Research & Engineering (DDR&E) assigned a Command and Control Project to DARPA. By the end of June, DARPA had assigned IDA to do a "Digital Computer Application Study" to explore how to apply computing to command and control problems. One of the report's recommendations was to expand research in computing. The areas of computing that seemed "potentially fruitful" included the development of improved techniques in problem (or algorithm) formulation, analysis, and programming, and the development of procedures and languages for communications between machines and their users. The report called for basic research in pattern recognition, concept formulation and recognition, problem solving, learning, and decisionmaking, as well as research directed toward improving computer dependability.

Yet another factor in the DOD's response was the growing interest in companies such as MITRE and Systems Development Corporation (SDC) in information-processing research, which led to proposals requesting DOD support. As a start in implementing the recommendations of the IDA study and in response to these proposals, DARPA gave SDC in Santa Monica, California, a multi-million-dollar contract to pursue research on the conceptual aspects of command and control systems

in August 1961. While a division of the Rand Corporation, SDC had been responsible for operator training and software development for the SAGE computer air defense system of the 1950s. In 1957, SDC had become a separate organization. In November 1960, it submitted a proposal to DARPA for "Research into Information Processing for Command Systems." It proposed to establish a command and control laboratory using the SAGE Q-32 computer that had been part of a canceled program for SAGE Super Combat Centers. SDC's proposal called for "conceptual and operational studies; surveys of related experiences and plans by military commands; research in organization of command, information flow, and system description; modeling and simulation of different command networks, and operation of a command laboratory for experiments and verification." The principal justification for the SDC command and control research program in the DARPA program plan was that the "application of automation is threatening to usurp the commander's role, stultify command organization and response, and make more difficult the modernization and exercise of an integrated, strong, selective national command."

The SDC proposal was typical of the period: The research it advocated had several overarching objectives and lacked focus. SDC researchers proposed five initial tasks. The first involved the creation of models of information flow and organization, and of information use in command situations. The second task concerned studies on interactions between humans and machines. Research in human–machine studies attempted to ascertain which duties were best performed by people and which by machines, the best techniques of presentation of data to commanders, and the impact of introducing automation on command structures. The third task was research in new areas of gaming, simulation, and information retrieval to assist commands, as well as the investigation of new needs. The fourth was the establishment and operation of a command system laboratory. The last task was simply "research," and called for SDC to "conduct research in the analytical techniques related to system definition and evaluation, information organization and languages, artificial intelligence, and man–machine and machine–machine relations." These research tasks, and the language used to describe them, are typical of the command and control research activities supported by the military in the 1950s. DARPA funded the SDC project with an initial $6 million contract, and provided one of the SAGE Q-32 computers.

Since the Q-32, like the other computing machines of the period, did not come with a complement of software, much of the research to be done was in software and applications systems. In 1960, for many of the well-defined problems of interest to large organizations—accounting, inventory, logistics—existing computing methods were adequate. But a range of poorly defined new scientific and engineering problems—those being investigated by university research departments, the space and missile programs, the military's command and control proponents, and the nuclear weapons program—stretched the capability and capacity of the installed computer base to the limit. Computing, as it was practiced *c.* 1960, was not equal to the task of information management when there was a need to analyze large amounts of data in a rapidly changing context. SDC and DOD personnel

knew that a great deal of work was needed to define the tactics to meet the objectives, hence their proposal. There were guideposts to follow, however.

The SAGE system, designed at MIT, had indicated in the 1950s what was possible in the handling of large amounts of changing data by means of faster and more capable computing. But as of 1960 not much progress had been made in exploiting these possibilities. Most computing R&D in 1960 focused on the problem of massive data processing, either for business or scientific research, where a large amount of processing was done to yield repetitive or individual results. For these uses, large new machines were under development; new languages for greater efficiency were in design; better data input/output and display techniques were reaching the market. Advances in computing made at universities, where a computer system was seen as a specialized scientific instrument, tended to be separate from computing advances made in corporations, where the computer was seen as a large business machine. Moreover, these developments had minimal effect on computer use in command and control operations in the late 1950s. Bolder, more imaginative steps than those proposed by SDC were needed. Machines needed to be more intelligent, able to interact with each other to gather relevant information, solve problems, anticipate data requirements, communicate effectively across distances, present information visually, and do all of this automatically. These steps required both imaginative individuals and substantial funding.

At the beginning of the Kennedy administration in 1961, Eugene Fubini became the DDR&E and Jack Ruina moved from a post in that office to become DARPA director. These two men were responsible for implementing the new administration's program for new defense systems, and sought ways to improve computing technology to control greater amounts of information and to present it in more effective ways to aid decisionmaking. Instead of continuing to develop specific computing machines, as the DOD had done in the 1940s and 1950s, DARPA officials generalized their interest in computing into the Information Processing Techniques Office (IPTO). In 1962, IPTO became the newest, and perhaps the most significant, of the DOD's activities in computing.

From its founding in 1962 to the mid-1980s, DARPA's IPTO provided substantial research support for bold and imaginative development of computer science and engineering. It did so by exploiting the partnership between the defense and academic communities. When IPTO began in 1962, computing was a group of loosely related activities in fields such as theory, programming, language development, artificial intelligence, and systems architecture. Researchers created advanced architectural systems by designing new logic circuitry and developing new connections among component systems, better numerical techniques for the solution of problems, new input/output designs, and new concepts for more efficient use of the entire computer system. For convenience, all these computing activities in 1962 can be referred to as "mainstream computing." In the 1950s, several areas of mainstream computing made rapid advances. Systems became more reliable, more efficient, and less costly, and computer companies introduced a wide variety of models for business and for scientific computing.

Some researchers, however, were starting to view computers as partners in creative thinking: They sought to explore the interaction between people and computers, to create artificially intelligent systems, and to develop natural language (i.e. human language) and machine translation processing systems. The university researchers were interested in smarter, more flexible, and more interactive systems. These objectives were of vital importance to two groups: The university computer researchers, who were interested in achieving better interaction with computers in order to make progress in many areas of computing research, and the DOD, which was interested in integrating computing into command and control.

The IPTO's early program emerged from the goals and desires of these university researchers eager to investigate new computing techniques. Through the IPTO program, these researchers cooperated with the DOD to achieve a new kind of computing. Although the initial DOD focus prescribed for IPTO was on applications of computing to command and control, IPTO, as we noted above, altered the focus to a concern for the general nature of computing, and as a result many new techniques entered the practice of computing. In the end, the military also benefited from these techniques. Because these new techniques became useful not only within the military but also outside it, in many areas of computing, IPTO achieved a reputation for being able to target its funding to areas of computing that had broad implications for both the civilian and the military sectors.

From the outset, IPTO substantially affected computing by investing in selected problems to provide more capable, flexible, intelligent, and interactive computer systems. While contributing to the content of computing, IPTO's R&D focus changed the style of computing. Hence, when we think of IPTO's achievements, we think about those elements that involved changing both the content and the style of computing—time sharing, networking, graphics, artificial intelligence, parallel architectures, and very large scale integration (VLSI) components. This new style of computing was intended for use in computer science research and ultimately in military systems, and it has been effectively used in both.

The IPTO set ambitious objectives for new computing technology and, to attain them, supported the R&D efforts of outside contractors. Following DARPA practices, IPTO employed a dynamic, highly effective, well-respected, and insightful approach to R&D funding. The characteristics of this approach resulted from several factors: The DOD's policies and practices with respect to R&D funding, the ample size of IPTO budgets, the quality of the people brought in to manage the office, and the response of the research community and industry to IPTO's ambitious objectives. Starting with a clear vision of its mission, IPTO never lost sight of its responsibility to support the objectives of the DOD.

As one of its prime practices, IPTO promoted an array of high-risk R&D projects to expand the frontiers of computer science and engineering for both civilian and DOD needs. At the outset, the office instituted research projects to investigate, among other things, modes of displaying images other than text, the partitioning of memory, symbolic processing to improve the machine's capacity to assist humans, the linking of machines to share resources, and new architectures. At

the time, all of these projects were uncertain of success. Attempts were made to increase the intelligence of computers through natural language communication techniques, understanding of human problemsolving, and new graphical interfacing techniques. During the 1960s, IPTO and its contractors made substantial progress toward more flexible and interactive computer systems. For example, by the end of IPTO's first decade, time-sharing was part of every IPTO-sponsored center, and the ARPANET emerged as a functioning communication medium.

High-risk projects often require long-term support. Because of its place within the DOD, IPTO had significant budgets to expend on programmatic objectives and thus could sustain these projects. In their pursuit of ambitious objectives, IPTO directors and program managers took advantage of several elements in the DARPA management style to advance specific embryonic areas in the field of computer science and engineering. This combination of elements provided the context for IPTO's success. IPTO employed an amalgam of approaches used by other military agencies in the 1950s, and some new ones designed for the special circumstances in DARPA. Among these approaches were fast turnaround times for project approval, and extensive personal initiative on the part of program personnel. The strategy applied to program development and change remained consistent over time in spite of, and maybe as a result of, all the changes in staffing and funding.

Perhaps most important of all in the DARPA management credo were the agency's personnel policies. For IPTO, DARPA chose managers with foresight, experience, and ability, and gave them substantial freedom to design and manage their programs. Often the difference between programmatic success and failure came down to the person managing the program, and the way in which he or she managed it. The fact that IPTO recruited capable and technically able members of the research community and allowed these people, within the context of DARPA's mission, an unusual amount of freedom to promote research as they saw fit, seek advice as they felt the need, and manage the office as they thought the program required, was the deciding element in IPTO's success. No other federal agency has had this kind of freedom.

After DARPA organized IPTO in 1962, the early IPTO directors, Joseph Licklider, Ivan Sutherland, Robert Taylor, and Lawrence Roberts, believed that they could influence the development of significant improvement in command and control systems by focusing on certain areas of their own interests in basic computing technology. They exerted such influence because they were themselves very able members of the research community. The early program evolved in directions related to each of the IPTO directors' strengths. IPTO's approach to research support was to focus on a few centers. Licklider began this program with MIT and Carnegie-Mellon University. Over the years, other directors selected additional educational centers for specific areas of research: Stanford University, the University of California at Los Angeles, the University of Illinois, the University of Utah, the California Institute of Technology, the University of Southern California, the University of California at Berkeley, and Rutgers University, to name a few. The number of centers grew over the two and one-half decades after 1962, but by

1986 the centers were a small percentage of all the institutions engaged in R&D for computer science and engineering. Similarly, IPTO sought help of a few industrial R&D programs in the 1960s, and this group also grew in number over the next two decades.

The addition of new groups resulted in part from changes in the environment inside and outside the DOD. In the 1970s, in response to these changes, many of the dominating themes of the 1960s dropped from DARPA's agenda and were replaced by a new set of themes. DARPA abandoned counterinsurgency research, which had been stimulated by military interests during the Vietnam conflict. It also de-emphasized the Defender Project, a program to study ballistic missile defense. In place of Defender, DARPA organized a new Strategic Technology program. The authors of a 1975 study of DARPA, commenting on the early 1970s, concluded, "In essence, the door was closed on the original 'Presidential issues' that had been the foundation of ARPA's work for a decade. No comparable mandates on broad new issues were assigned to the Agency."[14] DARPA's new assignments were in specific defense problem areas, with a new emphasis on joint service-DARPA projects. The Strategic Technology Office, the Tactical Technology Office, and the IPTO became the core of the DARPA organizational structure, requiring a greater emphasis on application systems and attention to DOD needs, rather than the needs of basic research only.

During IPTO's first decade, DARPA's demands for applicability to military objectives were expressed quietly. After Stephen Lukasik became DARPA director in 1971, and the winds of change were beginning to be felt in the DOD, he paid more attention to the relevance of DARPA research programs to military needs. For example, the Nixon administration adjusted its priorities in R&D, insisting that military R&D programs tighten their focus to military missions. In addition, congressional demands for greater accountability from DOD, and a sharper focus on military mission research topics, stimulated closer examination of DARPA projects. Lukasik addressed these new policies with more concern for application, while trying to maintain the funding levels of the research program. Lukasik was always a strong promoter of research in IPTO. His successors did not always have that luxury, as the DOD began to respond to greater congressional and executive branch demands for even more military relevance under constrained budgets.

The inclusion of "Exploratory Development" as a budget category in the fiscal year (FY) 1971 IPTO budget, signaled a shift to greater emphasis on development in the program. Previously, IPTO had operated with only basic research funds. The DOD included in the category "Research" (known as category 6.1) all basic and applied research directed toward expanding knowledge in several scientific areas. The Exploratory Development category, known as category 6.2, included studies, investigations, and exploratory development efforts, varying from applied research to sophisticated breadboard hardware, and was oriented to specific military problem areas. The 6.2 funding category for IPTO reflected IPTO's role in the "increasingly critical defense requirements in communication, high-speed computation, secure time-shared systems, and advanced signal processing." Despite the differences

between the funding categories, it was possible to have considerable overlap between them.

In the 1970s, command and control was still considered the key to effective utilization of the armed forces. In a new emphasis, DARPA directors constructed a strategy to fill the perceived gaps in the technology base by way of "a synergistic relationship among computer science, communications, and information sciences." To advance the technology base, DARPA management at all levels believed it necessary to attend to four areas. First, IPTO program directors saw a need for still more research in fundamental computer science. IPTO officials believed that basic research in areas such as intelligent systems, VLSI, and software technology would result in the ability to automatically interpret images and to abstract text material, and develop advanced tools and techniques for engineering real-time microprocessor software and systems.

Second, more research in advanced network concepts for communications was also seen as necessary. For example, IPTO wished to extend the proven technology of the ARPANET to packet switching in a satellite communication environment, and to packet radio in order to provide a mobile, distributed, and secure network. In addition, IPTO sought teleconferencing and advanced automated message-handling capabilities.

Third, DARPA believed it necessary to develop an experimental system to evaluate new ideas for command and control technologies that emerged from IPTO research. To accomplish this the agency established "testbeds," the goal of which was to allow the military to evaluate new technology in a "try-before-buy" fashion. Such testbeds would bring the work of the computer scientist, the communications engineer, and the information scientist together to achieve the synergism that DARPA thought was lacking in the development of command and control systems. Another goal of testbeds was to make possible the assessment of a variety of competing technologies. Testing new technologies in a testbed would also provide feedback about the users' needs.

Finally, DARPA wanted to stimulate work on advanced digital components. Faster, more complex semiconductor microprocessors would allow the inclusion of more instructions in the integrated circuits. Furthermore, if feature sizes of semiconductors below 1 micron could be achieved, microprocessors could become even faster and more sophisticated. IPTO proposed a program to design advanced VLSI architectures so as to make possible integrated circuits that would far surpass existing silicon-based circuits for achieving high-data-rate signal processing. Not only were components needed, but also major new systems employing these components would have to be designed and tested.

While the overwhelming majority of R&D funds for computing came from DARPA/IPTO, attention to computing issues came from other areas of the government in the 1960s as well. We should call attention to the interests of the Johnson administration in education and in his Great Society program generally; to the NIH and the construction of large library databases in the health sciences; and to NASA's computer/communication systems and the beginning of research into

what came to be called expert systems. All these areas need research to fit their results into the history of the government's role in computer development.

In the 1980s, with the advent of the Reagan administration, new members of the policy structure of the DOD expressed concern not just for the development of new computing for defense purposes, but also for the continued strength of the defense industry. This new policy emphasis transcended computing, and went across all areas of the high-technology base. The department's concerns were consistent with national concerns of the later 1980s: Concern for the standing of American high-technology industry, and concern for the competitiveness of the United States in world trade. Computing had by this time become so ubiquitous that the DOD wanted to secure its continued advancement and a quick passage of useful ideas from universities E-research programs and IPTO testbeds to industry. The announcement by the Japanese of the Fifth Generation Computer Program rang alarm bells at the Pentagon in the early 1980s. When the Reagan administration began in early 1981, Richard DeLauer, deputy secretary of defense for science and technology, and Robert Cooper, DARPA director, among many others, wanted a new program to help maintain the US position in computing, especially as it related to the defense industry. Robert Kahn and his colleagues in IPTO and other DARPA offices responded with the Strategic Computing (SC) Program, which received congressional funding in 1984. Thus, IPTO's horizons expanded even further. IPTO coupled its university and testbed programs to programs in the defense industry. The number and variety of programs increased significantly, and many more projects were pursued by companies for specific applications.

The IPTO budget expanded to accommodate these new desires. The total IPTO budget in FY 1971, for example, was approximately $28 million, up from $14 million in FY 1965; $17 million went to category 6.1 research in information processing techniques, image processing, intelligent systems, speech understanding, and the like. IPTO spent another $11 million on category 6.2 projects in distributed information systems, mostly for work on ARPANET and ILLIAC IV, the supercomputer at the University of Illinois. The IPTO budget grew in the next 4 years, reaching more than $38 million in FY 1975.

Like computer science today, the more recent IPTO program (after several name changes) under Kahn, Saul Amarel, and their successors was a complex, highly interrelated set of activities. It included intelligent systems; advanced digital structures and network concepts; distributed information systems; advanced command, control, and communications; and strategic computing. Some parts of the program, such as its intelligent systems component, had changed only their projects, not their objectives. This IPTO program contained an array of projects on satellites, semiconductors, machine representation and utilization of knowledge, and generic hyperspeed computer applications. The program continued to focus on more capable, flexible, intelligent, and interactive computer systems.

In spite of the budget increases tendered to IPTO, these increases and the reallocation of funds from the basic research program left the basic R&D budget with not just a smaller piece of the pie but with an actual decrease in its funds.

Needless to say, this began to concern the computer science and engineering community, and they began to lobby for change. This lobbying came after another shift in computing research from a focus on DARPA/IPTO to a multi-agency program known as the Presidential Initiative for High Performance in Computing and Communications Program.

Phase 3: Application, Diffusion, and Policies for Affecting the US Position in the Global Economy

In the mid-1970s, the computer had spread widely into US society, and many government agencies were now advocating its use and supporting R&D to focus the activities more to their needs. Whereas in 1970, virtually all funding for R&D in artificial intelligence came from the DOD, in 1975, funds also came from NSF, NIH, various of the military services, and NASA. The same distribution of sponsors was true in several other areas of computing as well. Industry had grown in the United States and had a bustling non-US market as well.

During the 1970s, the changing economic situation and the perception of greater problems emerging from the increased use of science and technology led to a readjustment in priorities for R&D. The largest funder of R&D, the DOD, came under sharp criticism to fund only R&D that was directly related to its defense mission. The enactment of the Mansfield Amendment imposed this requirement on the DOD, and, although few major agencies and programs were affected by it, DARPA personnel experienced the effect directly. Further, the appointment by the Nixon administration of new managers who were sympathetic to this approach to mission R&D effected the shift away from basic research. Monies added to NSF also fell prey to a demand for more targeted R&D, and new programs like Research Applied to National Needs (RANN) were designed, so the new money in NSF could not make up for the reduced support from DOD. Inflation, the increased cost of the war in Vietnam, costs of social programs, all took their toll on federal budgets, further reducing funds for research. While the Carter administration in the late 1970s tried to reverse the trend with increases in funding for basic research, these funds were insufficient to make up for the losses to inflation.

Another shift in the Nixon administration was the transfer of authority for science and technology policy out of the Executive Office of the President to the NSF. By the time of the Ford administration, congressional concern for the lack of overall direction led to the reestablishment of the Office of Science and Technology Policy (OSTP) in the Executive Office, and a requirement to evaluate the important science and technology areas ripe for major development, and to do this in a report to be redone every 5 years with updates each year in between.[15] So many of these areas depended on computing to accomplish their work, it was apparent to some that to continue these advances would require more R&D in computing as well. To ensure that attention would be paid to those areas with potential for commercial advances as well, the Council on Competitiveness assembled a list of the critical

technologies with dual use implications, a list that agreed well with a similar list published by the DOD. In effect, NSF charged with the responsibility to produce these 5- and 1-year reports, leaned heavily on the national academies to generate the substance of the reports. As part of this effort, the NRC analyzed the needs in computing, partly for R&D in science and technology, but mostly for R&D in computing, a continuation of the concerns of DARPA/IPTO. As part of its study, the Council did a complementary analysis for semiconductors and materials that are the backbone of computer systems.

The incoming Reagan administration in early 1981 espoused greater funding for defense systems with early deployment. This attitude placed more pressure on DOD to further shift to more D and less R. More money in DARPA, for example, went to industry or organizations with higher overheads. With the Strategic Defense Initiative, more money became available, but what basic research was funded was directly related to achieving the goals of this program. Inside DARPA/IPTO, the situation was the same. The focus of the SC Program was the use of artificial intelligence in various contexts to achieve new design capability through computers and automated weapons for use in combat. Some greater knowledge of artificial intelligence resulted from these efforts, but on the whole the SC Program was not a success. The weapons were not built and implemented and artificial intelligence has yet to obtain substantial credibility outside the field. All of this is to illustrate the slowdown in R&D funding for basic research and the shift to targeted use projects. By the mid-1980s, this shift was causing great concern among computer scientists and in the computing community generally. This concern converged in the studies of the National Academy of Sciences/National Academy of Engineering, the private Council on Competitiveness, and the OSTP in the second Reagan administration.

Indeed, within the Reagan administration in the 1980s, many policy figures, some responding to the Japanese Fifth Generation Computing Program, maintained that R&D in the United States needed to focus on two areas. First, the nation needed to preserve a strong technology base to continually upgrade weapons systems that contain computing systems, which meant strengthening the portion of the defense industry involved with computers. Second, it was just as important to preserve the position of the United States as the world's market leader in those areas, like computing, at the frontier of technological development. As the 1980s proceeded, and the SC Program of DARPA seemed not to answer the growing R&D needs of computing for the 1990s, agencies grouped their energies to coordinate R&D programs in computing to engage in these two areas. The OSTP of the Executive Office of the President issued a document in November 1987 specifying certain goals to guide efforts of government agencies in high-performance computing.[16]

Typical of the trickle-down attitudes of this administration, an attitude that what happened at one end of an activity, in this case at the high end of computing, would beneficially move down to lower level activities, the report opened with a

broad statement that: "A strong domestic high performance computer industry is essential for maintaining U. S. leadership in critical national security areas and in broad sectors of the civilian economy." Work should focus on architecture, software, and algorithms to keep pace with new developments in microelectronics, networking, and the need to support greater and more effective scientific collaboration, and more training of personnel and support for laboratories where major innovation has occurred should be undertaken.

Simultaneously with the preparation of this report within the government, and overlapping it, the NRC of the National Academy of Sciences issued their own thoughts on "The National Challenge in Computer Science and Technology."[17] In a strongly worded statement, the Council noted that the "U. S. position in this field [computer science and technology] [is] threatened from without by external competition and from within by underappreciation of the need for basic research. The challenge before us is to assure continued U. S. preeminence in computer science and technology." The report asserted that the nation could expect major advances in the areas of machine systems including software, artificial intelligence, and knowledge-based systems, and theoretical computer science "with adequate investments in research." It provided a set of broad, strategically oriented recommendations in line with those of the 1987 OSTP strategy for computing R&D, calling for enhanced networking and a greater investment in people.

The program planned in 1989 and finally established in 1991 bore the title High Performance Computing (HPC) Program. High performance stood not just for supercomputers or highly intelligent computers, but for the bringing of more powerful computing technology to bear on a given problem. This came to involve a focus on speed, in spite of the equally important desire to increase the overall capability of computer systems as well. The designers of the program viewed high performance computing as a "powerful tool to increase productivity in industrial design and manufacturing, scientific research, communications, and information management."[18] The programme's goals included an attempt to maintain and extend US leadership in computing, encourage innovation by increasing diffusion of high performance computing into the US science and engineering communities, and support for greater utilization of networked computing in analysis, design, and manufacturing. The program had four parts to accomplish these goals:

- High Performance Computing Systems
- Advanced Software Technology and Algorithms
- The National Research and Education Network
- Education and Training

The first three of these parts are a close analogy with three parts of the earlier SC Program of DARPA/IPTO, just then winding down. Specific goals in each part were to be achieved through the cooperation of government, the academy, and industry, again not unlike the SC Program. From a policy perspective, a major difference between the new program and the SC Program is the HPC Program,

which gained the specific endorsement of the White House and became the focus of a congressional bill: The High Performance Computing Act of 1991 (Public Law 102–194), signed into law in December 1991.

Another feature of this policy was the coordination of activities inside government and support for R&D outside, again a deviation from the DARPA/IPTO model. Under the program, federal agencies would conduct research along with groups in the academy and in industry. Primary funding would go to universities and federal laboratories. Commercialization would come in the usual manner—capital investment by private firms in response to market opportunities. The government would continue to serve as a market for any new products; it would assist industrial R&D consortia; and it would promote and fund centers of excellence, similar to the early days of DARPA/IPTO.

Arguments for justifying the program in computing focused on the possible effect of computing on what the science and technology community grandiosely called the "Grand Challenges." These challenges ranged from the need to understand how intrinsically faster semiconductor materials operate and change their characteristics to understanding genomes and the molecular basis for disease to problems in artificial intelligence in speech and vision research. In fact, to get maximum effectiveness from high performance computers to meet these challenges, it would be necessary to push computers to speeds of 1 teraflop (1 trillion floating-point operations per second) and memories of 10 Giga-words. The attainment of greater memory capacity has proved more susceptible to achievement than higher speeds, but advances in both objectives are evident in 1999 machines. Each of the grand challenges, and hence the computing goals to help meet them, were identified with the agencies that had an interest in them. For example, the semiconductor activity came under the programs of DOD, the Department of Energy (DOE), and NSF; the genome study under DOD, Health and Human Services (HHS), NSF; and vision under NSF, DARPA, and NASA. Such interests led to a compartmentalization of the HPC Program. Yet, the sponsors expected "an unprecedented level of coordination" among federal agencies.

The many computing R&D activities in existence in agencies when the HPC Program was proposed meant that agencies would simply fold these into their plans for the program.[19] For example in NASA, two-thirds of its program in HPC was an extension of earlier work and one-third was new activity to meet the HPC objectives. Under the new program, DARPA would continue to focus on advanced computer systems and technology development for parallel algorithms and software tools. NASA, concentrating on problems in aerodynamics and space application testbeds, would handle software coordination, while performing computational research in the aerosciences, and earth and space sciences. NSF would continue its focus on basic research into architectures and the prototyping of experimental systems, while coordinating facilities and deployment of the NREN. When the strategy was proposed in 1990, a collaboration of NSF, DARPA, DOE, NASA, and HHS, called the Federal Research Internet Coordinating Committee (FRICC) was already working to transform the Internet into NREN, through the sharing of

communications circuits, network access points, leading to streamlined operations. These efforts were expected to lead to an operational national network in the gigabit range by the mid-1990s. To emphasize both halves of the initiative, the program name changed early to the High Performance Computing and Communications (HPCC) Program. Also in the later FY 1993 budget submission, crosscutting R&D support areas of the federal government were all referred to as part of the Grand Challenges program. The goals and the strategies to reach them remained intact.

The incoming Clinton administration began to emphasize the nation's information infrastructure as the road to the future. The concerns of President William Clinton and Vice President Al Gore seemed more focused on diffusion and use of the Internet and the emerging World Wide Web than in basic research for computer science and engineering. They repeatedly referred to the information superhighway as the key to the future. The administration promoted programs for further diffusion of Internet technology, while maintaining support for the HPCC Program. But the emphasis in this administration was even more on targeted use than on basic research. Tomorrow, in effect, would look like today, if its agenda was heavily pursued. The computing community expressed deep concern about this attitude. For it, not enough was being done to ensure that R&D would allow the United States to maintain its lead in IT. These concerns reached members of Congress, which decided to ask the NRC in 1994 to evaluate the HPCC. The NRC submitted its report in February 1995.[20]

Although the HPCC Program was only 3 years old at the time of their evaluation, the committee, a stellar panel of computing people, judged that the program was generally successful in this short time. They noted that the activities were concentrated in three areas: Parallel computing, networking, and education. The results were incremental across each area of the program. The one new unexpected development was the creation of the Mosaic browser for the World Wide Web, the first new major application that promised to greatly increase access to the resources available on the Internet. At the same time, Gigabit network testbeds attached to the NREN demonstrated the intimate link between computers and communications, if such a demonstration was needed. Perhaps the most significant finding was that all the activities contributed to the fast developing large-scale integrated information infrastructure to serve the entire nation. The enlargement of this infrastructure revealed many new problems in performance, management, security, interoperability, and reliability. To handle these problems, the HPCC had shifted focus somewhat and added a new element, the Information Infrastructure Technology and Applications program. The administration's emphasis on the infrastructure caused agencies to downplay somewhat the computing side of the HPCC, and this worried the committee. They called for a maintenance of the momentum on R&D established in the HPCC Program, which would allow greater synergy with the infrastructure when it was fully capable. The committee made a number of recommendations about strengthening the program overall, especially in computing R&D, communications R&D, and coordination activities of all the participants in the program. Funding for the HPCC Program continued. The authorizing legislation for the

HPCC program expired in 1997, but the Clinton administration continued the program as an administration initiative. The program was renamed and called the "Large-Scale Networking and High-End Computing and Communication" program to further emphasize its commitment to networking concerns.

A further change occurred when the Clinton administration submitted its budget for FY 2000. Government spending for R&D in computing had shifted again, against the advice of the NRC 1995 study. The new budget includes an amount touted as a 28 percent increase for computing and communications research, though it is difficult to compare budgets across program changes, because some elements of HPCC continue along with the new program. The new initiative is called IT for the Twenty-First Century or IT2. If the budget measure is passed as proposed, the government will invest $366 million for support in three categories. First, $228 million support will be provided for long-term IT research on fundamental issues in computing and communications. Second, the administration, through six agencies, plans to promote research on supercomputers and provide for the purchase of new systems. The agencies involved are NSF, DOD, DOE, NASA, NIH, and the National Oceanic and Atmospheric Administration (NOAA). Lastly, funds are requested for training additional IT personnel and study of the economic and social implications of IT. The objective of the initiative is to invest in long-term fundamental research in computing and communications, and increase development and purchases of extremely fast supercomputers. But this is a bit deceiving. NSF is already spending $206 million in the Computer and Information Sciences and Engineering directorate. The added $146 million from this initiative would go to research on software systems, scalable information infrastructure, high-end computing, the social, economic, and workplace impacts of IT, and the development of terascale computing systems, all significant R&D areas of contemporary computing. In the information about future budgets, the HPCC is slated for phase-out over the next few years.

Conclusion

Commentators on IT development over the last 50 years usually emphasize the military beginnings of R&D and the resulting fall-out from this of a range of products for both military and civilian use. The discussions state or imply that a significant portion of this R&D was in basic research, basic research that went beyond the needs of the development projects funded. Further, they cite the size of the information sector of the economy, which had reached $750 billion by 1996,[21] as justification for a proactive role for the government in support of R&D. But the role in R&D for IT has always been conflicted, sometimes supporting basic research in computing for its own sake but mostly supporting project-oriented R&D, at least since the mid-1950s. So past events may belie the force of the argument for more basic research in the information sciences.

Our three phases show the following foci. Phase one involved product oriented support, specifically construction of one-of-a-kind machines. The services did support

computer development at the outset. Beginning in 1943, the US Army supported the new approach to electronic digital computing at the University of Pennsylvania. The US Navy began a cooperative effort with the MIT, which turned into the famous Whirlwind project at war's end. In the first two decades (1940–1960), each of the services funded one-of-a-kind projects to support specific requirements of their own.

But they were not alone. The Census Bureau and the NBS, both civilian agencies, supported one-of-a-kind machine projects also. Some research was needed to design and build these computer systems, but most of the emphasis was on development. These system designs blended with the efforts of several commercial firms to produce the basic design of computing systems that was the standard after 1955. While defense concerns in the 1940s dominated interest in computer development, by the 1950s a broad range of government actors had entered the picture. Each still had their own mission objectives uppermost in planning for IT however. Without participating in an organized, centrally pursued program in computer system design and development, the US government agencies individually, at the very least, sped up the appearance of the "standard" machine. It is difficult to sort out which funds went for research and which for development. Moreover NSF's attention to diffusion of the computer in scientific research is another aspect of this emphasis on target use even in the first phase.

After the appearance of the standard design for computer systems, R&D shifted focus. In phase two agencies sought for an increase in capability and integration of computer systems, plus deployment of these systems in scientific and engineering research. During the period 1960–1986, R&D support programs took on a more organized cast, though up to 1975 still largely the province of one agency, the DOD. The focus of activity was in DARPA's IPTO.

However, part of this defense context is the famous weapons laboratories: Los Alamos, Livermore, and Oak Ridge. Here, sponsored by the AEC, later the DOE, many new ideas for faster, more comprehensive computational schemes came into being. Moreover, the effects of these laboratories stimulated industry partners to develop machines to implement their new ideas. From this R&D, new weapons designs containing more sophisticated computer systems were developed during the Cold War and companies contributed to the national economy as larger numbers of products came to market.

As phase two proceeded the focus was more on development than research. Indeed, for an agency like DARPA/ITPO development dominated its objectives in the 1970s and 1980s. Fortunately for people interested in computing, the increased sophistication of the field continued at a fast pace and continued to be very successful in stimulating development of new products, hiding the role of basic research.

Simultaneously, computers were becoming more significant to everyday life, and budgets for computing in other government agencies increased accordingly. Computers increasingly appeared everywhere after 1960, from the workplace to the bank, hospital, and shopping mall. Computers became ubiquitous after the

appearance of the microcomputer in the late 1970s. By 1975, other government agencies increased support for R&D and use of computers, making IPTO's piece of the pie smaller in percentage of total support, even if its dollars still far outweighed those of other agencies. For example, to respond to the needs of researchers, NSF established NSFNET and CSNET, and began a program to support national supercomputer centers. Later, these became part of NREN.

During phase three there was a continued search for increased capability of computer systems, plus integration with communications systems (networking), and active programs for diffusion. In phases two and three there was greater stimulation of the industry in IT to increase products available for purchase both by the government and others. Particular attention was paid to the export market, and IT continues as a significant portion of exports.

With the end of the Cold War, government policy for R&D shifted its emphasis back to those of the pre-Sputnik days. There seemed less need for grand R&D projects that contribute to defensive systems to compete with nonexistent superpowers. Moreover, the increasing integration of the world economy meant the nation requires more and more frequently new consumer products to compete successfully in this world economy. Add to this the weight of past national fiscal policies and the decreasing flexibility in the US budget. All three of these circumstances led to a change in the policy environment for R&D in the United States, and for R&D in IT in particular.

In this new environment, the White House and the Office of Management and Budget sought for ways to rationalize government R&D for computing. Add to this the rising star of networks and the stage was set for the emphasis of the third phase. In 1990, President George H.W. Bush proposed the Presidential High Performance Computing and Communications Initiative, a seemingly rational approach to computing R&D. While advertised as the means for a great leap forward, similar to the rhetoric of the Japanese Fifth Generation Program of a decade earlier, most agencies repackaged existing programs and made them a component of the new initiative. The arrival of the Clinton administration, seeing the potential in the new World Wide Web, brought with it a call for a more democratic spread of access to the Internet and the Web.

The shift to the HPCC, the NSFNET, and programs to outfit schools with Internet connections affected the overall R&D efforts of the government. Each of these programs emphasized mission objectives, with little or no attention to basic R&D that would provide the knowledge for future leaps forward in computer systems. The computer science community became restive about this, and began to make their concerns known through NRC committees, White House councils, and DOD evaluations. Clinton administration budget proposals for FY 2000 presented in January 1999 attempted to remedy the situation with a new initiative for long-term fundamental research in computing and communications. This program is somewhat more defined than the Bush administration's HPCC, and much more specific than the early role given to IPTO. Perhaps this should be expected, given the greater sophistication of computer science and engineering today.

In the late 1990s, we may be entering a fourth phase of activity in IT R&D. The federal government continues to invest in R&D for computer science, engineering, and its integration with communications. But relative to the earlier phases, the amount appears to be less than the need—if the need is defined to be keeping the United States preeminent in the area internationally. The Clinton administration seems to want industry to carry a bigger share of the R&D burden, under the assumption that widespread access to the World Wide Web will provide the synergy necessary to keep the field advancing, and advancing in ways to enhance global competitiveness of the United States in IT. The fact that the field of computing has become so much more sophisticated, in the way other sciences and engineering have done (consider aviation as an example), means it is more difficult to select R&D areas in IT, when limited funds make such choices necessary from a budgetary perspective. As we enter the twenty-first century, computing people may be just another voice at the budget banquet table each year as computing becomes embedded everywhere, and policymakers' interests in R&D shift to newer fields.

Notes

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19. See the description of agency programs in "Grand Challenges 1993: High Performance Computing and Communications, The FY1993 U.S. Research and Development Program," a supplement to the President's FY 1993 Budget from the OSTP.
20. NRC, *Evolving the High Performance Computing and Communications Initiative to Support the Nation's Information Infrastructure*, Washington, National Academy Press, 1995.
21. NRC, 1999, op. cit., p. 25.

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The Supply of Information Technology Workers, Higher Education, and Computing Research: A History of Policy and Practice in the United States

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Introduction

During the late 1990s, the supply of Information Technology (IT) workers has been a major policy issue in the United States. The Department of Commerce, following the lead of a major trade association (the Information Technology Association of America, ITAA), identified a serious shortage of IT workers and argued that this shortage could do serious harm to the economic fortunes of the nation. However, the General Accounting Office questioned the evidence cited by Commerce and expressed skepticism about the existence of a shortage. Debate crystallized around proposed legislation to increase the number of visas awarded annually under the H1B temporary visa program for high-tech workers, with the trade associations in favor of an increase in the number of visas and the labor unions opposed. Compromise legislation was signed into law, but lobbying began within months to increase the number even further.

Several related policy issues have also been under scrutiny at the national level. The number of workers from minority populations (other than Asian Americans) entering the IT workforce is very small. The percentage of women training for jobs in IT has been declining throughout the 1990s, after some promising gains in the 1980s. Many people are worried about a "seed-corn" problem—that industry will siphon off so many college faculty and graduate students from computer science departments that there will not be an adequate supply of faculty to train the next generation of students for the IT workforce. Concerns about the negative features of the current academic research environment—such as inadequate research funding, the focus on short-term results, and onerous teaching and administrative responsibilities—have led to proposals from the White House, now under consideration by Congress, for an unprecedented increase in federal support for computing over a 5-year term. The Department of Education and the National Science Foundation (NSF), meanwhile, are bolstering institutions, such as community colleges, that produce low-end IT workers. Legislation is also under consideration to

provide tax credits to companies that invest in training for their IT workers. Numerous studies conducted at the state and regional level have resulted in programs to develop a larger and better-trained workforce for the local employers.

The current policy issues concerning IT have been discussed elsewhere and are not the main subject of this chapter.[1] Instead, this chapter presents the history of policies and practices in the United States concerning the supply of IT workers, especially as they relate to policy for higher education and computing research. There is no direct worker policy that mandates how many workers of various types will be trained. Instead, policy about the supply of IT workers is vested in other kinds of policy: National research output, education, defense, social welfare, immigration, national economic competitiveness, and taxation. Concerns about the national supply of IT workers is tied directly to scientific research and higher education policy, and these are the topics that are investigated most extensively in this chapter. Both the NSF and the National Academies of Science and Engineering have been key players in this discussion.

Some caveats should be mentioned. In several places, the chapter diverges from worker policy to cover the more general history of policy concerning higher education and research. The chapter is heavily slanted toward the NSF. It perhaps pays too little attention to the Department of Education (and its predecessor organizations) and the National Academies (and their research arm, the National Research Council, NRC), whose computing policies and programs have not been seriously investigated by historians. The chapter does not consider the fellowship programs for graduate students offered by the National Air and Space Administration, the National Institutes of Health (NIH), the Department of Energy (DOE), or the Armed Services. In considering NSF programs, the chapter does not track all the general fellowship programs and infrastructure to community colleges and historically black universities, which have some bearing on computer training. The chapter also ignores general immigration policy and tax credit policy to industry for research and training, which probably has had modest bearing on IT workers. The focus is primarily on supply issues and, in particular, on support for higher education.

Not Enough Mathematicians! (1945–1959)

The supply of IT workers was not a national policy issue in the 1940s and early 1950s. At most, there was limited monitoring of the situation by research-oriented agencies, such as the NSF and the Office of Naval Research (ONR). The reasons are straightforward. First, there were few computers, and hence few people were needed to build, operate, or use them. By 1954, there were at most a few hundred computers, even when one counts automatic, electronic calculating devices that are not stored-program computers, such as card-programmed calculators. Second, the expense, size, power consumption, and high maintenance of computers seemed at that time to limit the future market to large companies, research universities, and government. Third, the computer was originally conceived as a giant computational

engine, rather than as a data processing machine; and the number of scientific applications would turn out to be much smaller than the number of business applications. Fourth, it was hard to obtain a computer, even if you were willing to suffer the expense and inconveniences; only in the mid-1950s did an industry coalesce to build computing machinery.

The idea of the computer as a machine for business applications began to emerge in the early 1950s. This combined with the anticipated need for more computers and more computer workers led to the first conference on training personnel for the computing machine field, held at Wayne University in 1954. Wayne University had an active, early university computing program, strengthened by its partnerships with the local Detroit industries; thus it was a logical choice to host this training conference. The conference provides a good snapshot of the supply of computing workers at the time.

Remarks made at the conference indicate that some people still regarded the computer as a mathematical instrument, while others were beginning to recognize its role as a data processing machine. Representatives of the federal agencies that support science, perhaps not surprisingly, examined the training issues entirely in terms of the computer as a mathematical instrument. For example, NSF's Leon Cohen wrote: "First, the effective use of the computing machine depends on the development of appropriate mathematical methods. Second, the development of mathematical methods depends on the development of mathematicians."[2] F. J. Weyl, ONR, argued: "Particular scrutiny has been given by this conference to our current mathematical education—and rightly so."[3] However, others at the conference believed that the supply of workers was an issue primarily because of the growing commercial applications. The conference chair, Arvid Jacobson of Wayne University, indicated this in his opening remarks: "With the new applications of electronic techniques in accounting and business management during the past year, it is timely that the problems of training and manpower should be examined."[4] G. T. Hunter of IBM stated: "In the next few years there will be considerably more men required for the commercial field than for the scientific field."[5] Lt. Col. C. R. Gregg from the Air Material Command chose to restrict his comments about computing in the federal government to the "non-scientific areas of use" in part because "the real quantity requirements for personnel, with the possible exception of maintenance technicians and electronic engineers, will be in this area."[6]

Even for those participants who saw the business applications as the growth area of computing, the emphasis was on training mathematicians to do the work: "We cannot ignore—or even for a moment forget—that sophisticated mathematical techniques have a very definite place in the nonscientific as well as in the scientific applications."[7] Several speakers, including Leon Cohen from NSF and Franz Alt from the National Bureau of Standards (NBS), pointed to the small supply of mathematicians in the United States as a serious labor problem for the burgeoning computer field. A survey conducted in 1951 had shown that there were approximately 2000 PhD mathematicians in the nation.[8] The 1950 national census had counted about 5600 professors and instructors of mathematics, as well as 1700

other mathematicians. Cohen noted that the average age of a PhD mathematician was 41, indicating that most of these mathematicians had completed their studies before the computer was invented.[9]

There was great uncertainty about the present and future demand for personnel in the computing field. One of the more outspoken members of the profession, Herbert Grosch of General Electric (GE), estimated the number of current jobs in the computing field at between 2000 and 4000. He argued that the number of positions would double annually for the foreseeable future and would reach 1 million jobs by the end of the 1960s. (In fact, although the computing field grew rapidly, the number of IT workers did not reach 1 million until 1985.)[10]

At the conference, Milton Mengel of the Burroughs Corporation presented a talk on "Present and Projected Computer Manpower Needs in Business and Industry," based on a survey he conducted of 500 of the largest manufacturing companies in the United States. Banks, insurance companies, utilities, and retailers were excluded from the survey primarily because Mengel believed them to have special computing needs. Responses were received from 139 companies (28 percent). Of that number, twenty-seven were currently using computers or had them on order, while another twenty-three were considering the possibility and six had studied computers and found them uneconomical. Of these companies that already had computers in use, 65 percent were using them for engineering calculation, 30 percent for scientific and research studies, and 5 percent for business data processing. But it was clear that the trend was toward increased use in business applications. When those computers that were on order were added in, the percentages for engineering, scientific, and business applications shifted to 58, 26, and 16, respectively. The business applications that were most commonly mentioned were those that are computationally most demanding, such as sales and production forecasting, personnel evaluation, shop load, and production scheduling—as opposed to payroll preparation, invoicing, and other arithmetically simple business problems.

The survey asked a number of other questions. The types of workers that would be needed by computer users were reported to be: Analyzers 43 percent (1000), engineers 8 percent (175), programmers 17 percent (400), operators 25 percent (590), technicians 3 percent (70), and others 4 percent (90)—total 100 percent (2325). The numbers in parentheses represent the number of workers of each type that would be needed by all 500 of the companies surveyed, based upon a linear projection from the 28 percent sample. Mengel noted that a greater percentage of the responses came from larger companies, meaning that the linear projection might overstate demand slightly. Asked whether they had difficulty in fulfilling their manpower requirements, fourteen companies replied in the affirmative and nine in the negative. Companies with computers recruited their computer workers from a variety of sources: Colleges and universities 37 percent, company training programs 37 percent, suppliers of equipment 12 percent, government agencies 7 percent, and advertisements 7 percent. Company-operated training programs were regarded as very important. Asked to what extent their company had found it necessary to train its own personnel, 50 percent reported they trained all of their

workers, 35 percent trained at least half of their workers, and 15 percent trained less than half of their workers. Out of twenty-seven companies, twenty-six stated that they believed colleges and universities should pay more attention to training for the computer field, with one company having no opinion.

Although the response to the survey question about the difficulty in finding computer workers does not suggest a serious problem, a number of conference participants indicated that they believed there was a shortage. G. T. Hunter argued that there is "a general shortage of technically trained people."[11] W. H. Frater (General Motors) opened his presentation speaking about "a universal feeling that there is a definite shortage of technically trained people in the computer field."[12] E. P. Little (Wayne University) stated:

> You have heard at this conference the estimates of manpower needs for computer applications. The figure is astounding compared to the facilities for training people for this work. Less than twenty institutions of higher learning have formal courses directly related to large automatic computing machines. Less than half of these have a large machine available for the use of teachers and students, and few of these machines are being used in the study of problems related to the data processing and management decision requirements of business.[13]

Speaking of government needs in the computing area, Col. Gregg indicated "our biggest difficulty in this area . . . is the attracting of adequate numbers of qualified people. This is particularly so in localities where we are placed in competition with industry salary-wise."[14] This surprised Gregg somewhat because "the primary importance is their [the computer's] ability to perform . . . without human intervention . . . However, depending on the types of problems being solved, we may find no decrease in the overall numbers of people required. As a matter of fact, in a pure 'job-shop' there may be an actual increase."[15] Gregg notes that the need varied by occupation—the government had a great deal of trouble getting enough qualified programmers, but no difficulty in obtaining enough data-preparation people. A few government organizations that were heavy users of computers formed their own training programs.[16] Aberdeen Proving Ground, for example, carried out 21,000 hours of machine computation in 1953 and employed seventy people in its Analysis and Computation Branch. Aberdeen preferred to hire people with at least a master's degree in mathematics. Those hired with only a bachelor's degree in mathematics were given training at the BRL Ballistics Institute (organized in 1948) to ensure that they would be effective programmers.[17]

Mission agencies, including the Army, Navy, Air Force, and Atomic Energy Commission (AEC), sponsored a limited number of university research projects in the first half of the 1950s. This funding provided some support for graduate students and for university infrastructure, thus helping to establish the universities as part of the supply system. The principal purpose of this funding, however, was to meet the needs of the government agency, not to train a national workforce of computing professionals.

The federal agency most concerned at the national level about scientific education and research was the NSF. But NSF did not have a program in computing at this time. Computing was then the responsibility of the agency's mathematics program. The program in mathematics included funding for sabbatical leaves for faculty, release time for research, research assistantships, group research grants, predoctoral and postdoctoral fellowships, and summer conferences for mathematics teachers. Although these kinds of funds each could have been applied to computing, there were virtually no grants of these kinds made for computing prior to 1955. Despite Col. Gregg's statement that "often repeated interest is shown in this field by Congress, by the Office of the Secretary of Defense, and by active groups within each of the military departments and in other departments of the government," there was no indication that the federal government recognized any national computing labor shortage at this time, and there were certainly no federal programs to increase supply at this time.[18]

By the mid-1950s, the computer had become an important tool of national defense. Had the federal government experienced a shortage of people to staff the construction and operation of its computers, there might have been federal action. However, the number of personnel needed to operate and program the machines in government organizations was still modest. This was due, in part, to the fact that the construction of large computer systems for the government was contracted out to private industry. IBM, for example, was contracted to design and build the computer hardware for the Semi Automatic Ground Environment (SAGE) missile defense system. Thus, much of the labor requirements devolved from the federal government to private industry. Companies, such as the System Development Corporation (SDC), did indeed have difficulty in finding enough computer personnel to staff these projects.

The SDC, formed in 1956 to carry out the programming for the SAGE missile defense system, was perhaps the largest employer of programmers in the 1950s. The company employed 700 programmers in the late 1950s, and the number rose into the thousands in the 1960s. It originally sent its new employees to a short course in programming offered by IBM, but soon it formed its own training school. Between 1956 and 1961 it trained 7000 programmers and systems analysts. Turnover was high, and many of the programmers working in the United States had learned to program at SDC. A company advertisement of the late 1950s indicates that it was looking for mathematicians: "Use your past math background for your future in computer programming." But, like many other large employers of computer workers, it also used aptitude testing (the Thurstone Primary Mental Abilities test) and personality testing (the Thurstone Temperament Schedule) to screen applicants without mathematics backgrounds for programming jobs.[19]

By the late 1950s, business applications were growing more rapidly than scientific applications.[20] The Bureau of Labor reported that there were several thousand programmers in the United States in 1958, mostly located in metropolitan areas where the main offices of companies and government agencies were located.

A company would typically employ from ten to thirty programmers if it had a large computer system, but only two or three if the computer was of medium size. Companies were using aptitude tests to measure general intelligence and special tests to measure "ability to think logically and do abstract reasoning." There were also personality tests to seek out individuals with patience, "logical and systematic approach to the solution of problems," "extreme accuracy," close attention to detail, and imagination. Organizations seeking scientific programmers tended to hire new college graduates (e.g. 89 percent of the people trained at SDC between 1956 and 1961 were between 22 and 29 years of age); while companies hiring for business applications were mainly taking people with subject knowledge and giving them programming training. The Bureau of Labor reported:

> Men are preferred as programmer trainees in most areas of work. Although many employers recognize the ability of women to do programming, they are reluctant to pay for their training in view of the large proportion of women who stop working when they marry or when they have children. Opportunities for women to be selected as trainees are likely to be better in government agencies than in private industry.[21]

Training was provided primarily at company expense, mainly through courses offered by the computer manufacturers, but sometimes in courses offered by the companies using large computers once they had several years of experience with automatic computing. For business programmers, the government required all new recruits to have a college degree or equivalent experience. Industry was not as strict as government about educational credentials. For those who did have formal training, they were most often seeking out people with courses in accounting, business administration, and statistics. Mathematics was losing its privileged place in the training of computer professionals: "Many employers no longer stress a strong background in mathematics if candidates can demonstrate an aptitude for the work. However, programmers of scientific and engineering problems are usually college graduates with a major in one of the sciences or in engineering and some course work in mathematics."[22]

The Sputnik Era (1957–1963)

The most important issue shaping US science and technology policy in the United States in the late 1950s and early 1960s was the launch of the Soviet artificial satellite Sputnik in 1957. It made American lawmakers rethink their assumptions about US world domination of science and technology. It also led to a major federal investment in academic science and technology—to improve research funding and infrastructure, to enhance science education from the K-12 through the university level, and to increase the number of practicing scientists and engineers.

After the Sputnik crisis in 1957 and the passage of the National Defense Education Act, NSF became more heavily involved in all areas of science education. It increased the direct support of students with fellowships and traineeships, devoted more effort to improving the science curricula, and expanded teacher-training

institutes. Fellowships for computer science students came originally from the mathematics program, amounting to 10 percent of their fellowships awarded in 1965 and 20 percent by 1974.

The NSF sponsored approximately 140, 1- and 2-month summer institutes for teachers each year as part of the response to Sputnik. The first one on computing was held in 1960, and the number of teachers in institutes on computing grew to five or six each year between 1964 and 1968. Curriculum development grants in computing began in 1959, and typically two to six grants were awarded in this area each year during the 1960s.

As early as 1953, NSF had begun to receive research proposals calling for support for computing time as an aid in carrying out some other kind of scientific investigation. As the interest in using the computer as a research tool increased in the scientific community, the NSF formed an Advisory Panel on University Computing Facilities under the direction of Institute for Advanced Study mathematician John von Neumann. The panel reported back to NSF in 1955 that computers should be treated like other high-capital research equipment, such as radio telescopes and particle accelerators, and that it was appropriate for NSF to supply computing machines to universities for scientific research. For the next 3 years, NSF reprogrammed modest funds to support campus computers and computer training programs, but the agency could not keep up with university demand.

The NSF established a regular computer facilities program for colleges and universities in 1959.[23] Funding was fairly strong in the early 1960s, presumably because of the political climate that favored national infrastructure investments to assure the place of the United States in the scientific race. The facilities program continued until 1973, and during most of its years it was NSF's most important activity in the computing area. NSF awarded 414 computer facilities grants during this period, about equally divided between first computer acquisitions and equipment improvements for established computer centers. This was an era when campus computing grew rapidly. The number of academic computer facilities in the United States grew from 100 in 1961, to 300 in 1963, to 700 in 1965, to more than 2000 at 1600 institutions in 1969. NSF's facilities program was constantly challenged by this rapidly growing demand in both the number of academic users and the amount of computing power they required, and by new technologies such as time-sharing. Time-sharing computers were much better suited for instructional purposes than batch-operating computers, but they were expensive. NSF placed computers on campus primarily to support research in the various scientific and engineering disciplines, but these facilities also served—both intentionally and unintentionally—to educate future computer workers.

The other major change in federal computing support in this period was the emergence of a major new funder of academic and industrial computer research. The new entrant was the Defense Advanced Research Projects Agency (DARPA).[24] Because of the Sputnik crisis and the inter-service rivalry between the military branches, which was seen as creating inefficiency and waste in the development of advanced technology for the nation's defense, in 1958 President

Eisenhower formed the Advanced Research Projects Agency (ARPA), which later added "Defense" to its name. DARPA's first task was the military space program, but it soon became involved in advanced research on materials, reconnaissance satellites, nuclear test verification, and other projects.

DARPA began to support research on computing in 1962, when it formed its Information Processing Techniques Office (IPTO) under the guidance of J. C. R. Licklider, a psychologist from Massachusetts Institute of Technology (MIT). DARPA poured massive funding into computing because it believed computing was the solution to the military's need for advanced command-and-control systems. The best-known computing project supported by DARPA in its early years was Project MAC at MIT, which developed time-sharing computers and an environment for using them effectively. Within a year, DARPA was providing more funding for extramural computing research than all other federal agencies combined. While DARPA projects made fundamental contributions to research on time-sharing, networking, graphics, and artificial intelligence, DARPA was a mission agency; its support for research was intended to build up the basic technologies that would be needed by the military in coming years. DARPA provided large grants, sustained over many years, to a few, preferred academic principal investigators. This support enabled many of the universities receiving this support, such as MIT, Carnegie-Mellon, and Stanford, to become leaders in computer science. DARPA did little, however, to strengthen the ability of the larger higher educational system to supply large numbers of computer workers.

Establishing Computer Science as an Academic Discipline (1946–1972)

The first university courses on computing were taught at Harvard, Columbia, University of Pennsylvania, and a few other universities within the first several years after the Second World War. Dozens of universities became interested in computer science and computer engineering research and education in the 1950s. Research and teaching was carried out primarily in computer centers, which first appeared in most research universities in the 1950s. Some universities offered computing within existing departments—most often mathematics or electrical engineering, but occasionally in departments ranging from business schools to agronomy. Of the sixty-eight universities with some activity in digital or analog computing identified in a 1954 survey by the Institute of Radio Engineers Professional Group on Electronic Computers, twenty-nine offered one or more computing courses, and nine offered at least three courses.[25] These courses were offered by twenty-two electrical engineering departments, ten mathematics departments, and by other departments at eight universities. The first doctoral degree in computer science (University of Pennsylvania) and the first departments of computer science (Purdue, Stanford) were formed in 1962 and 1963, respectively. The number of schools forming computer science departments grew rapidly, and half of the computer science departments that exist today in the United States were formed in the decade 1962–1972.

There had been considerable discussion in the professional community since the 1950s about the kinds of instruction to give in computing. There was no well-formulated body of knowledge known as computer science (or computer engineering), and there were different views about the degree to which it was a discipline about mathematics, engineering, programming, and applications. At first, courses were offered primarily at the graduate level and usually involved training in either machine design or numerical analysis. Later the curricula expanded greatly, and in the second half of the 1960s most of the enrollment growth in computer science was at the bachelor's and master's levels. By 1970 there were more students graduating with a bachelor's degree in computer science than with a doctorate.

Professional societies began to address curricular issues in the 1960s as the need for computer education in the nation's colleges and universities became more acute. The Association for Computing Machinery (ACM) was the first to do so when it established a permanent curriculum committee in 1964. NSF supported this effort by subsidizing the committee throughout the 1960s and 1970s. Between 1967 and 1972, the COSINE committee of the National Academy of Engineering developed a curriculum for computer engineering. In 1977 both the ACM and the IEEE Computer Society proposed curriculum revisions.[26] ACM's Curriculum 68 was very influential and widely adopted in US universities and colleges.

Computing Becomes a National Concern (1962–1967)

During the decade of the 1960s, computing emerged as a concern of the federal government. It was growing in importance, not only to scientific and technological research and national defense, but also to education and the general welfare of US citizens. This is manifest not only in the growing budgets for computing research, education, and facilities at DARPA and NSF, but also in the emergence of white papers and data collection projects on computing. No fewer than six studies were conducted in the 1960s by NSF or the National Academies on the nation's computing needs and on the past, present, and future role of the federal government in meeting them, whereas none had been conducted previously.[27] From the 1960s, until well into the 1990s, discussions about national needs for computer personnel have been phrased largely in terms of support for academic computing. Because NSF historically has been the agency most closely associated with science education, this is largely a story in the 1960s and 1970s about NSF policy and programs. The National Academies of Science and Engineering also played a role by carrying out studies on computing funded by NSF and others.

The first of the six studies undertaken in the 1960s was initiated by the NRC in 1962. The report was released in 1966 under the title "Digital Computer Needs in Universities and Colleges." It was known more commonly as the Rosser Report after its chairman, J. Barkley Rosser, a mathematician who moved from Cornell to the University of Wisconsin during the study.[28] The report documented the rapid growth of computing, including computer personnel, both nationally and on campus: national investment in computing had grown from $700 million in

1958 to $7 billion in 1964; 35,000 computer staff positions were being created each year in the United States; the number of university computing centers had grown from 40 in 1957 to 400 in 1964; and campus expenditures for computing were doubling every 2 years, at twice the rate of growth of overall campus expenditure for research. The report noted the critical role that universities had played in the development of key computing technologies—having conceived and built many of the first computers in the 1940s and 1950s and having developed new modes of operation (time-sharing) to improve access in the 1960s. The report argued that academic computing is a national concern because the growth of computing had already outstripped the financial means of universities and the shortfall was being met by federal support.

Federal investment in academic computing had amounted to $65 million in 1964, and future investment was regarded as critical. The federal government would need to pay the majority of costs for academic computer centers for several reasons: (*a*) The high cost of computers placed them beyond the means of normal university budgeting; (*b*) their rapid obsolescence made them poor candidates for philanthropic donations or large appropriations by state legislatures; (*c*) the rate of product innovation and pricing variation made it difficult to work within the multiple-year budgeting lead time associated with public funding; and (*d*) the expanding support costs, which frequently exceeded the original purchase price, further deterred state legislatures.

The Rosser Committee's principal recommendation was to double the nation's academic computing capacity within 4 years. Some new funding was to be spent on research computing facilities, but an ever greater amount was to be spent on educational computing, in order to more than double the number of undergraduate students trained annually to use computers in their professional careers. In 1964, only 10 percent of academic computer time was devoted to educational purposes.[29] The report recommended as rapid an increase as possible in the number of students being trained as computer specialists. Use of regional computer centers was promoted to both leverage the effect of federal computing dollars and share the computer expertise at the research universities with local 2- and 4-year colleges. The committee called for better coordination of auditing and funding among the eight federal agencies currently supporting academic computing and with the universities.[30]

The report had some value as a planning tool for staff at the granting agencies—particularly at NSF—but it was politically ineffective. It sounded too self-serving to the Bureau of the Budget for a committee of academics to argue that they needed hundreds of millions of dollars to do their research and teaching.[31] Another NSF staff member recalled: "They botched the job . . . [Rather than providing] the kind of talk that any Congressman would understand and appreciate . . . instead, Barkley [Rosser] . . . had I don't know how many people submitting reports, and eventually [these were] distilled into 200 pages of highly technical language—completely mystifying to any legislator. And I don't think anything ever came of it."[32]

In order to respond to the Rosser Report and a National Science Board request for a survey of total federal computing support (caused by some problems in the way that federal auditors required universities to charge for computer time), NSF organized a Working Group on Computer Needs in Universities and Colleges.[33] The Working Group, which first met in May 1965, found that little information was available on federal support for computing, and that the Rosser Report projections and recommendations had been based on very few reliable data. NSF itself could not ascertain with certainty how much it was spending on support for computing, mainly because it did not know how much of the funding in its Institutional Grants Program was being spent on computing. Data on funding of academic computing by other federal agencies were even more difficult to obtain.

If NSF could not appraise national support for academic computing by querying the suppliers (the federal agencies), it decided it would have to query the recipients (the universities). Thus it commissioned what became the first of a series of surveys, prepared by John W. Hamblen of the Southern Regional Education Board. The first survey covered the period 1964–1965 and made projections for 1968–1969. Hamblen found that in 1965 universities expended $103 million on computing, while computer manufacturers contributed an additional $41 million in the form of gifts of equipment and allowances on purchases and rentals. Of the $103 million, $43 million (40 percent) came from federal agency grants and contracts. Of the federal funds, $25 million had been earmarked for computer activities: $13 million for buildings and equipment rental or purchase, $7 million for operating costs, $3 million for computer time for research and graduate teaching, $1.5 million for computer science activities, and less than $0.5 million for undergraduate instruction.

Hamblen's study indicated that the main focus, up until this time, had been on providing computing facilities to researchers in the sciences. In the mid-1960s, however, there was a widespread new interest in the role of computers in undergraduate education—mainly in teaching undergraduates about computers, but also in using the computer as a general instructional tool. One expression of this interest occurred during 22 days of congressional hearings about NSF, held during the summer of 1965.

One of the key witnesses, Jerome Weisner, Dean of Science at MIT and former Science Advisor to President Kennedy, testified that the situation in computing was the "most serious single problem in higher education."[34] He pointed out that most universities needed additional computing equipment, and that even well-positioned institutions such as MIT were involved in "a series of maneuvers involving ad hoc arrangements to keep its computational activities solvent and to provide some time for academic use." He noted that all schools were searching for a means to pay for instructional use of computers. Under questioning, he estimated that the computing problem "is several times the scale of the [National] Science Foundation's resources to deal with."[35]

Others also addressed the educational aspects of computing in their testimony. Richard Sullivan, President of Reed College, reported the growing faculty consensus

that not only science students needed to understand computers as a research tool, but that all students should be made familiar with computers "as a problem that they are going to have as citizens."[36] Reacting to the trend to save money by sharing academic computing facilities, such as through regional computing centers, he noted that off-site computing facilities were sometimes satisfactory for research but were not very effective for instructional purposes. In the closing round of questions, during a discussion of NSF's support for "big science," NSF Director Leland Haworth testified that "one field that I wouldn't classify as big science, because of its usefulness all across the board, but it is big money, is the computer field."[37] Haworth argued there would be a "terrific growth" in the need for computers for the current scientific applications, the social sciences, and education. He tied this growth not only to the advancement of the natural and social sciences, but also to the training of skilled personnel for industry.

The sentiment expressed in this testimony was consonant with President Lyndon Johnson's ardent desire to improve the nation's educational system. In direct response to President Johnson's educational platform, the President's Science Advisory Committee convened a Panel on Computers in Higher Education, chaired by John R. Pierce, an electrical engineer at Bell Telephone Laboratories. This panel emphasized higher and secondary education rather than scientific research in the universities, which had been the main topic of the Rosser Report. The Pierce Report updated the projections in the Rosser Report and addressed some of the same issues, including the need for graduate education in computer science.

The Pierce Panel found that in 1965 less than 5 percent of the nation's college students had access to adequate computing facilities, and virtually all of those who did were located "at a relatively few favored schools." They contrasted this figure with the 35 percent of all undergraduates who they believed could benefit from exposure to computers. The report recommended that the government cooperate with the universities to supply adequate computing facilities for educational purposes by 1971. The Panel expected the cost to escalate to $400 million per year by 1971 and proposed that the federal government bear most of the cost. The report also called for extensive training of faculty by sponsoring intensive 2–6-week courses and through other means to meet the anticipated rising demand for computer courses. Finally, the report called upon the federal government to expand its support of computer research and education, and for NSF and the Office of Education to "jointly establish a group which is competent to investigate the use of computers in secondary education."[38]

Many years later, Milton Rose, who headed the computing program at NSF in its early years, assessed the impact of the Pierce Report:

> The thing which led . . . to OCA [the Office of Computing Activities] . . . was the growing realization by a number of people that computing was . . . not just another thing but really was going to have a significant role in all of . . . science and education, that actually its influence would extend beyond science to the general culture. And while all of those things were said, they would not have had a political influence . . . The thing I think that transformed the argument very successfully was John Pierce's and John Kemeny's [report], what

became known as the Pierce Report . . . Now that was significant because it not only highlighted things we had been trying to push up through the system, but because . . . of John Pierce's contacts . . . at the highest levels of the Science Advisor and therefore into OMB [Office of Management and Budget] . . . And, as anyone who has ever worked in these systems know[s] . . . trying to push something from the bottom is [like] trying to push spaghetti upward that has been cooked for five hours. But if you can grab it from the top then you can really do something. And so the significance of the Pierce Report and Kemeny's influence in that was enormously important. Well, in fact, that led . . . to a reevaluation at NSF by [Director] Lee Haworth, and in part also from pressure I think from OMB.[39]

President Johnson saw the computer as a tool that could be used to advance the aims of his Great Society program, giving the rich and poor alike a chance to get ahead through education. The influence of the Pierce Report was reflected in his 1967 message to Congress on Health and Education, where he directed NSF to "establish an experimental program for developing the potential of computers in education."[40] The Bureau of the Budget, planning for this activity to begin in fiscal year (FY) 1969, proposed the formation of an interagency advisory group led by NSF to coordinate support for computer education. The most visible outcome of this activity was the formation on July 1, 1967 of the OCA at NSF to pursue programs in computer facilities and education.[41]

The Pierce Committee found that there was a growing disparity in the quality of computing facilities, and therefore in the quality of education, between the have and have not institutions of higher learning. Bringing to all American undergraduates the kind of facilities available to students at the most computer-privileged institutions, such as Dartmouth or California-Berkeley, would require a major infusion of money—projected to increase to $400 million by 1971–1972. The Pierce Committee recommended that the federal government share in this cost.

The OCA sponsored a combination of old and new programs. It continued the program to provide computer facilities to universities that had been started in the late 1950s. There was a new priority on the development of regional computing centers that could connect universities, colleges, junior colleges, and high schools. The regional centers were to include not only computing machinery, but also faculty training and curriculum development programs. OCA also gave a new emphasis to the development of computer science departments. The development of computer science research was closely linked (at least rhetorically) to the educational program during the first several years of OCA. OCA estimated in 1967 a 50 percent shortage of faculty to teach computer science.[42] Thus the program, as originally established, supported individual research projects, research conferences, and computer science curriculum development.

A Hostile Climate for Science (1968–1976)

The late 1960s and first half of the 1970s were not a favorable time for federal support of computing. In order to pay for the Vietnam War, the administration began to cut spending for domestic programs during the summer of 1968. In FY 1969,

NSF made its reductions by cutting back grants on capital items such as buildings and equipment, in order to preserve funding levels for individual research grants. This action jeopardized the computer facilities program, which for a decade had been the hallmark of NSF's computer program.

The financial pressure on university computing centers was worse than this cut in the Institutional Computing Services program suggests. Over the previous several years, computer manufacturers had reduced their educational gifts and discounts. By 1969 industry was providing only 15 percent of the support for academic computing, whereas only 4 years earlier industry had provided almost 30 percent of the support. At the same time, the universities were experiencing other across-the-board cuts in funding from government agencies. Faced with smaller research grants from federal agencies, faculty researchers reduced the budget lines in their grant proposals to pay for computing services, figuring that the operating costs of a computer center are fixed costs that the university would have to absorb in some other way. These various factors concentrated the financial pressures of the computer centers, which were not only unable to purchase new equipment, but were also having trouble meeting their operating costs.

The NSF's computer advisory panel called for a new federal policy on academic computing. The panel noted that ARPA was spending $20 million annually on a small number of research projects at universities, but usually was not providing support for general campus facilities. NIH was spending $10.5 million annually on computing facilities for medical schools, but was relying on university computing centers to serve its sponsored academic biomedical research. The grants of these and other federal agencies increased the load on academic computing centers, while NSF alone among the federal agencies was providing general support for these facilities. The advisory committee urged the National Science Board to issue a report to Congress to "illuminate the profound implications of computer developments and clarify the major scientific, technological and educational problems," as well as to propose a coordinated federal policy for supplying universities with computers for research and education.[43] It encouraged NSF to take the lead in setting federal policy for academic computing because the Bureau of the Budget had too limited a view of academic computer needs and the White House Office of Science and Technology had not developed a plan. For whatever reason, the National Science Board issued a report on this matter.

The political climate in Washington in the late 1960s was drifting in a direction that was less sympathetic to basic science. Support for academic science slowed throughout all the federal agencies. After 1966 NSF's allocations for the Mathematical and Physical Science Division increased at a rate slower than inflation. Congress was becoming progressively interested in supporting the *application* of science rather than basic research, and it looked increasingly to NSF to support scientific research aimed at solving national problems such as environmental pollution. Congress was also dissatisfied with NSF's practice of defining its programs and projects according to the guidance and initiative of the scientific community; Congress felt itself held captive by the very academics it was supporting. There

were various calls from Congress for greater political control over the Foundation's agenda. It is in this context that one can understand The National Science Foundation Act of 1968 passed by Congress (known commonly as the Daddario Bill, after Congressman Emilio Daddario of Connecticut). It expanded the Foundation's responsibilities to include applied research and the social sciences. Congress believed these subjects had relevance to contemporary national social problems.

Computing fared better than most of the sciences in the support it received from NSF after passage of the Daddario Bill—probably because computing was regarded as having practical applications. The Daddario Bill explicitly directed the Foundation to foster and support the development of computer science and technology, primarily for research and teaching in the sciences. This was the first piece of legislation explicitly authorizing NSF to support the computing field. Nevertheless, the Daddario Bill sliced the NSF funding into more pieces, leaving less for computing.

The Daddario Bill instituted annual authorization hearings before Congress to determine NSF's budget. Milton Rose gave testimony at the first of these hearings (for the FY 1970 budget). Training appeared as a priority for the first time because of the increasing demand for academic computing courses being felt across the nation, and because of projections of rapidly escalating national needs for trained computer personnel of all types.[44] Rose called for "grants to enable department units to develop a concerted and integrated revision of entire curricula for major science areas, including specialized computers and programming support . . . particularly in the development of computer science programs." As for facilities support, he pushed the economies of scale that could be achieved through regional computing centers. His briefing notes included a call for establishing ten new regional centers each year. A program with this objective was begun several years later.

The election of Richard Nixon as president in 1968 affected the administration of NSF and its computing programs more than any presidency until that of Ronald Reagan. The Nixon administration appointed William McElroy as NSF director. He pursued the administration's interest in using the Foundation as a tool to apply science to problems of national importance. To that end, the president nominated non-scientists and industrial scientists in record numbers to the National Science Board. The Daddario Bill had increased the policymaking role of the National Science Board, giving greater autonomy to the director and his staff in the operation of the Foundation. Under the Daddario Bill, the president not only appointed the director, but also a deputy director and four assistant directors.

During the Nixon presidency, the OMB wielded unprecedented power over federal programs and agencies. By manipulating the purse strings of various agencies, including NSF, OMB exacted programmatic changes. The assault on the computer facilities program was part of an all-embracing attack by OMB on institutional grants awarded by NSF. OMB argued that by replacing general-purpose institutional grants, which subsidized academic resources including computers,

with individual research grants, which paid directly for all but only the resources used, grantees would be more directly accountable for controlling costs. This may have been true, but it also served to dismantle the substantial federal programs to aid education built up during the Johnson administration. Whatever the motive, this change imperiled academic computing centers, which relied heavily on these institutional grants.

In the early 1970s, the NSF advisory committee assigned highest priority to expanding computer science research and training. The committee reasoned that, despite growing industrial dominance in the computing field, there was still a place for academic research on both hardware and software, and that a strong academic research center would provide a strong environment for training. The OCA had an uphill battle to support the training of computer scientists because computing's need was out of synch with those of the other sciences. By 1970 there was perceived to be a glut of mathematicians and physical scientists, and in response OMB slashed Foundation funding for fellowships and traineeships. However, computer science had a critical shortage of trained personnel. A National Academy of Sciences meeting on Computer Science Education in 1969 projected the need for 1000 new PhDs per year by 1975, at a time in 1970 when the national output was under 100.[45] In response, the OCA advisory board recommended expanded support to graduate education in computer science.[46]

Congressional authorizations did not match this perceived need to grow. The FY 1971 budget continued the pattern of decline for the third year in a row. The total budget for OCA in 1971 was $15 million, approximately $7 million less than the allocation for FY 1968—all while the computing field continued its rapid expansion. There was no new support for facilities; the only facilities grants were the residuals from earlier, multiple-year awards. The computer education budget held about steady at $6 million, while there was a modest increase in the research budget to $4.5 million and a significant rise in support for applications.

John Pasta, who was appointed director of OCA in 1970, set a number of changes in motion. He arrived at the Foundation at a time when the staff and the OCA advisory committee were fighting a rearguard campaign to retain the facilities program, which had been the Foundation's most successful computer venture since the late 1950s. If the Foundation could not afford a full-scale facilities program to place a computer in every university, the advisory committee believed the Foundation should at least aggressively pursue a program to put a computer in every regional consortium of colleges and universities. Pasta decided to let the facilities program go: "The Bureau of the Budget has attacked this program and my personal opinion is that they are right. As a compromise with the Committee position we are proposing a reoriented program which will hopefully answer the objections of the Bureau (and my own private misgivings)."[47] As a replacement for the specialized social problem-solving centers advocated by the advisory committee, Pasta advanced his own plan for cross-disciplinary computer centers.[48] But the economic and political environment of the early 1970s laid waste to Pasta's 5-year plan.

The only real funding increase came in FY 1972, and this was a one-time exception created by the Mansfield Amendment. This amendment to the Military Procurement Authorization Act of 1970, introduced by Senator Mike Mansfield of Montana, narrowed the scope of research pursued by mission agencies to only those scientific research projects that could be justified as directly relevant to their missions. Although the amendment applied specifically to the military, it reflected the mood of the Congress; and all the mission agencies, not only the military ones, narrowed their support of basic research.

The amendment created considerable havoc because NASA, AEC, ARPA, and the three military service research agencies (ONR, Air Force Office of Scientific Research—AFOSR, Army Research Office—ARO) were all providing sizeable support to projects that did not meet the Mansfield criterion of mission relevance. On short notice, each of these agencies divested itself of a considerable number of projects. The Foundation was the recipient of many of their "dropout" projects. Congress provided an additional $41 million to the Foundation research budget in FY 1972 for this purpose. This amount included $3.5 million for computer activities, which the staff used toward supporting some of the thirty-seven computing research projects, costing a total of $5.5 million, dropped by the AEC, NASA, and the DOD. Thus, of the $4 million increase in the OCA budget from 1971 to 1972, $3.5 million is attributable to a one-time adjustment caused by the Mansfield Amendment.[49] Because these projects were scattered across OCA's programs, there was little change in the complexion of NSF's computing grant portfolio. If anything, these one-time transfers disrupted Pasta's plans.

Foundation Director McElroy needed congressional approval to reprogram these funds to OCA, and his request to do so occasioned an inquiry from the House Committee on Science and Aeronautics about total federal support for computing research. The House findings provide a context for understanding NSF support for computing through 1972. NSF support for physics, chemistry, mathematics, astronomy, and engineering research only sometimes increased as fast as inflation during the period 1968–1972. But in this same period, support for computing research tripled. Whereas the budget for computer research had been one-eighth of that for mathematics research in FY 1968, by FY 1972 the ratio had grown to two-fifths. Probably as would be the case with any rapidly emerging discipline growing from a small base, Congress saw these increases as generous, while the practitioners regarded them as miserly.

In the 1950s AEC, ONR, and AFOSR supplied almost all of the funding for computing research. During the 1960s, support from these three agencies was essentially flat. NSF funding grew from practically nothing in 1960 to the point in 1971 where it almost equaled the total support from AEC, ONR, and AFOSR. The most significant change in the 1960s, however, was ARPA support, which grew from zero in FY 1961, to slightly more than the total support from all other federal agencies combined in FY 1963, to approximately triple the support of the NSF in FY 1971. Historical figures by year were not available for NIH or NASA. However, by interviewing program officers at all the federal agencies sponsoring computer

research, the OCA staff was able to provide a statistical portrait of computer research support in the federal government by subject area for 1 year, FY 1971, including support from NIH and NASA. The total government expenditure on computing research and development (R&D) in 1971 was $52 million. ARPA spent $26.5 million and NASA $13.1 million. Each of these agencies spent half its total on system developments. NSF led the remaining six sponsoring agencies with a total of $4.3 million. NSF's share continued to grow. By 1976, NSF and DARPA were each providing approximately 40 percent of the total federal investment in basic computer research. The remainder was coming from the combined efforts of NASA, NIH, Energy Research Development Agency (ERDA), AFOSR, ONR, Naval Research Laboratory (NRL), and ARO.

Under Pasta, NSF tried to build up academic computer science programs, and hence their abilities to train personnel, by building up computing research. Congress, the General Accounting Office, the OMB, and even the National Science Board repeatedly sought justifications for spending public money on computer research. Questions were lodged about the arcane nature, practical relevance, and social impact of computing research.[50] Also questioned was why a public investment was needed when industry was already carrying out an extensive research program. It was known that the computer industry expended a greater percentage (7 percent) of its gross revenue on R&D than any other major industry, including aircraft, chemicals, and transportation. The closest follower was the aerospace industry—at 4.5 percent.

In order to address these concerns, NSF surveyed industrial computer research in 1975. The findings supported the continuation of a computer research program at the Foundation: Large R&D expenditure was devoted to the essential and unique business cost of software development. When software was factored out, computer industry R&D expenditure was comparable to that in other industries. The survey found only eight computer companies that were engaged in any basic research, and some of that was done in conjunction with universities.[51] The nation's industrial personnel assigned to basic computing research numbered only 150 scientists (and an equal number of support staff). Without exception, the industrial researchers who were surveyed stressed the importance of academic research. Special note was taken of basic research that was not of interest to industry at one time, but which became so after being developed by academic researchers.[52]

The high rate of inflation exacerbated the problem. Although NSF budgets were growing in these years, they could not keep pace with the double-digit pace of inflation—and the budget declined in real dollars by approximately 15 percent between 1968 and 1976.[53] This caused minor disruptions for fields such as mathematics and physics, where the number of practitioners was shrinking slightly. It had much more serious consequences for computer science, which was experiencing explosive growth in undergraduate enrollments and slow growth in the number of faculty. For example, in mathematics the number of bachelor's degrees granted annually fell from 21,000 in 1973 to 11,000 in 1979, and doctoral output declined from 1000 in 1973 to 724 in 1979. By comparison, computer science bachelor's degrees rose from 4700 in 1973 to 11,000 in 1979, while doctoral output rose

slightly from 198 in 1973 to 239 in 1979.[54] In the late 1970s, the level of support for computer time, equipment, and student assistants, as well as overall award amounts, was reduced in individual research grants in order to increase the number of researchers receiving awards. This practice was in contrast to those of other NSF offices, which were awarding larger grants to offset the effects of inflation.

Meeting National Needs for Computer Scientists (1967–1977)

The previous section has described some of the national political context as it shaped computing at NSF. This section focuses more specifically on computer labor issues as they were addressed by NSF during the same era. NSF carried out a number of programs in computer science education in the name of national "manpower" needs: Support to professional societies to design model curricula for computer science and computer engineering; and numerous efforts to help individual computer science departments and programs to establish uniform and effective curricula and, more generally, to build up institutional size and strength. Although national needs to build up the professional community had not been entirely neglected by either the computing community or NSF in the 1950s and early 1960s, this did not become a priority until the mid-1960s, when the tremendous growth in the computing field began to create demands for computer professionals in all sectors of American society.

Alan Perlis, a computer scientist at Carnegie-Mellon and a member of the OCA advisory committee, identified eleven strong graduate computer science departments in 1967 and projected that eighty-one graduate programs of varying quality would exist by 1968.[55] In 1967, 200 computer science faculty could be counted. Altogether they produced forty new PhDs in 1967—of which 80 percent accepted faculty positions. Perlis estimated, however, that the nation's colleges and universities would need 400 computer science faculty in 1968 just to keep up with the teaching demand—an impossible doubling of faculty in 1 year. These estimates were based upon Perlis's assumptions that there was a national need to teach one course in computer science to 223,000 undergraduates and 61,000 graduate students, as well as to provide further course work for 5560 undergraduate computer science majors and 4328 computer science graduate students.

In 1971 OMB noted that there had been a significant surplus of American scientists in the late 1960s, compared with the availability of scientific research funds; and that consequently scientists with graduate degrees were left unemployed, underemployed, or leaving their field of training altogether.[56] To rectify this situation, the Nixon administration pressured NSF into terminating its student traineeship program in 1971. This may have been appropriate for physics and mathematics, but it only exacerbated an already acute shortage of computer scientists with graduate training.

At the end of the 1960s, training in computer science emerged as a priority for the OCA because of the unremitting increase in demand for computer science course offerings. The shortage of computer personnel at all levels—from machine

operators, to programmers, to computer scientists—created a demand that the colleges and universities could not meet. In 1964–1965, national enrollments in data processing and computer science programs had totaled 4300 undergraduates and 1300 graduate students. At the time, these enrollment figures had been projected to quadruple by 1969. But the growth was more rapid than anticipated, and quadrupling occurred by 1967.[57]

In October 1969, NSF Director William McElroy asked the OCA advisory committee to identify new areas for emphasis in planning for the FY 1972.[58] The committee gave first priority to supporting computer science departments with research funds, and second priority to specialized centers for both disciplinary and interdisciplinary research. Education was also very much on the minds of the advisory committee. It explained the pressing demand for academic training and new research capabilities, contrasting the "adequate . . . or very close to it" support for training of mathematicians and scientists with the "completely inadequate" support for training new computer scientists. The committee called for NSF to provide special allocations for student fellowships and traineeships in computer science. When budgets were cut, these fellowships did not materialize.

While there was a general belief in the 1970s that there were grave shortages of computer scientists at all levels, the top-ranked graduate programs, such as Cornell, Purdue, and Stanford, were reporting acceptance rates of less that 25 percent (which the Foundation attributed to shortages of graduate fellowship support and faculty), compared with acceptance rates of about 60 percent in other graduate departments in these same schools. Although many of the computer science departments had been founded only in the preceding 5 years, they had already grown as big as the largest science and engineering departments. The national enrollment at the graduate level increased fivefold between 1964 and 1967, while the undergraduate enrollment also quintupled to more than 21,000. More than half of all students taking a bachelor's degree in mathematics, but not going on to graduate school, had been drawn to employment in the computing field.

The problem was not only a shortage of faculty and lack of support for graduate students. This new field was so unlike the traditional disciplines that it was difficult for university administrations and computer science departmental administrations alike to assess its intellectual merits. As soon as OCA was formed, it began making grants to help universities improve graduate computer science programs and establish undergraduate programs.[59] Following 2 trial years of support for departments, the OCA advisory committee recommended a continuing program to expand computer science education. Because of the unrelenting demand for undergraduate course offerings, the most severe problem was the shortage of trained faculty. Thus the committee recommended that OCA begin by supporting the expansion of graduate programs.[60]

By 1975 there were sixty-two departments in the United States granting doctoral degrees in computer science and an additional fifty-three departments (of mathematics, engineering, information science, statistics, etc.) granting degrees with a computer science emphasis.[61] These departments employed 1500 computer

science faculty and 600 research faculty and research associates. There were also 500–600 computer scientists in other science and engineering programs at these institutions. Approximately 2000 graduate students were enrolled in computer science PhD programs across the nation. Approximately 200 computer science PhDs were produced in 1974. Of these, about 50 percent accepted academic positions, 40 percent took industrial positions, and the remaining 10 percent went to government and other positions. Very few of those entering industry were involved in basic research. Most were involved in design, development, or supervision instead.

A Crisis in Computing (1977–1990)

By 1977, there was a widely held belief in academic and industrial circles that a crisis was at hand in computer science. One manifestation was a personnel problem. Expansion of computer science programs in the universities had reached its peak around 1976 and had begun to fall off. The national production of doctorates in computer science was in stasis. At many schools computer science teaching loads were extremely heavy, and it was not uncommon for computer science departments to have five or more faculty positions they could not fill.[62] There was also an insufficient number of computer scientists at the bachelor's and master's levels to fill available government and industry positions. The crisis was also manifest in academic research, which had become dominated by theoretical studies. No longer were academic researchers contributing as significantly to systems design or other experimental research areas as they had from the late 1940s through the early 1970s.

The increase in the national production of computer science doctorates that had been anticipated widely by the professional leadership throughout the 1970s did not materialize.[63] By the mid-1970s the expansion of computer science in the universities had peaked. The number of doctorates granted in 1975 totaled 213, only slightly more that the previous year. Doctoral production peaked in 1976 at 244, then declined to 216 in 1977, and 196 in 1978. At the same time, the number of bachelor's degrees granted in computer science continued to increase (from 4757 in 1974 to 7201 in 1978), but at a linear rather than at the exponential rate it had before 1975. Master's degrees were more erratic in their numbers than bachelor's or doctoral programs. The annual number of master's degrees awarded in the mid-1970s was generally in the 3000s.

The rapid increase in computer science enrollments and the shortage of faculty made university teaching less attractive. An NSF survey of people who had left the university for industry found that heavy teaching loads and job insecurity were the major complaints, far above salary considerations. While the entire engineering field was experiencing a loss of faculty to industry in the late 1970s, computer science losses were twice the percentage of any other field. Fewer than half of the new doctorates were entering teaching careers—and this rate was thought to be insufficient to train the growing number of students. For those who chose academic careers in computer science, attaining tenure was complicated by the fact that few university administrators understood the characteristics of hardware and

software research, which had high cost and time requirements but a low yield of scientific publications.

The focus in the remainder of this section is on the response of the NSF. It should be emphasized that NSF was not the only organization to respond to the crisis. The problems were studied by the computing research community at the 1978 and 1980 Snowbird Conferences.[64] As a result, industry as well as NSF began to provide graduate student support. Universities added significant numbers of faculty positions. Companies agreed informally to restrain themselves from hiring away faculty and to provide incentives for graduate students to complete their degree programs.

In order to formulate its response to the crisis, NSF convened a special workshop in November 1978. The published results are known as the Feldman Report, after the principal editor, computer scientist Jerome A. Feldman of the University of Rochester.[65] The workshop organizers asked all PhD-granting computer science departments for comments and suggestions on the problems they faced with experimental computer science. The replies indicated that many of the best faculty, staff, and graduate students were being recruited away from the universities by industry; and while larger industrial salaries were a factor, the greater availability of good equipment in the industrial laboratories was more significant.

The Feldman Report recommended building academic strength in experimental research and the infrastructure to sustain it. The proposal was to build, over a 5-year period, twenty-five "centers of excellence" with multimillion dollar grants that supported coherent, multi-investigator research projects in experimental system design research and that built up a research group with "critical mass." The report proposed taking funds from other programs, if necessary, to build up this "critical mass." This recommendation ran counter to the NSF's policy of limiting the size of computer research grants in order to spread the money to as many researchers as possible. The report also called for new government policies that would encourage industry–university interaction. These included new tax laws, patent procedures, and antitrust legislation that would not discourage industry from contributing equipment to the universities.

Not everyone was happy with the recommendations of the Feldman Report. In particular, there was strong disagreement from the Executive Committee of the ACM. Its criticism was especially notable because the ACM's flagship journal, *Communications*, had been the publication venue for the report. The ACM Executive Committee agreed that there was a crisis, that the solution lay in invigorating the PhD programs, and that government policy changes to encourage industrial investment in the universities were desirable.[66] However, the ACM leadership preferred the correctives recommended by the Foundation's Advisory Panel for Computer Science at its May 1979 meeting: Traineeships, expanded equipment grants, and a research computer network.

The nexus of the disagreement between the ACM Executive Committee and the Feldman Report was whether to concentrate or distribute resources. The Feldman Report recommended fellowships, which went to the institutions at which the

"fellows" enrolled and hence tended, by natural selection, to be concentrated in the elite institutions. ACM favored a traineeship program, in which the support was given directly to the institutions and so could be distributed more evenly across a large number of institutions. Even more in dispute was the report's recommendation that a considerable concentration of capital at a single institution was necessary to support adequate facilities and sufficient numbers of students. ACM believed the Foundation's Research Equipment Program, initiated in 1977, had already begun to mitigate the problem by providing modern equipment to computer science departments.[67] ACM proposed an extension of the equipment grants, but it did not support a competition for a few large grants:

> we have serious doubts that huge grants to the so-called "centers of excellence" would achieve the desired objective. The Feldman Report envisions up to twenty-five centers being started over a five year period. There are now, however, sixty-two universities in the United States that grant Ph.D.'s in computer science. We believe that the embittered feelings of, and the drain-off of resources from the institutions not favored by this program would severely divide the community just when unity and common programs are most important. We believe that the community is best helped by providing that all available research funds, whether from existing sources or from new ones, be available equally to all qualified computer science research groups.[68]

The ACM proposed networking as an alternative tool to free-standing centers of concentrated equipment: "Modern minicomputer technology and common carrier data networks can be combined to permit research groups to connect at modest costs that are well within the reach of an equipment grant program."[69] NSF Director Richard Atkinson wrote in July 1979 to twenty-five industrial computer research directors, enclosing a copy of the Feldman Report and asking them to assess possible NSF actions. The research directors favored supporting experimental research facilities and large research projects, regarded additional fellowships as having some value, but showed little enthusiasm for an increase in the number of small research grants of the type the Foundation was currently awarding.

When it came time to act on the Feldman Report in the fall of 1979, the NSF staff had to make hard choices on how to implement its recommendations within the constraints of the budget. NSF decided to fund a scaled-down version, called the Coordinated Experimental Research (CER) Program, on a total budget of approximately $1 million it cobbled together from existing resources. It recognized that this amount would not buy much equipment and that it would create a loss of support in constant dollars to the individual-researcher, small-grant program.

> The original idea was to fund large research projects like MIT had . . . Project MAC and so forth—at places other than MIT, Stanford, and CMU. MIT, Stanford, and CMU, it has always been said, volunteered not to compete in this program. That's the legend. I believe it, but I think they were volunteered by . . . the computer science advisory panel. But anyway, the idea wasn't just infrastructure, just buying equipment and paying for some support staff . . . these were to be Project MAC style—some of them. Some of them were going to be straight infrastructure-centered, but some were going to be centered around a particularly large research project or another operating systems research project.[70]

As NSF funding became tighter, much of the support requested in CER proposals for other than infrastructure was scaled back. The CER program continued throughout the 1980s. Four or five new awards were granted each year; however, the level of support to individual centers was not as high as the Feldman report recommended. By 1989 twenty-nine schools had received grants, and eleven of these were awarded a second 5-year grant. The well-coordinated research programs called for when the CER program was established (and present in some of the early CER proposals) were largely absent in later awards. The program shifted away from an emphasis on coordinated research and focused instead on the provision of equipment for experimental research. The total collection of proposed research projects had to warrant a major grant, but no single project had to be large; nor did the many experimental projects have to be closely interrelated. The notion of a "critical mass" became a less significant factor in making the awards.

In 1986, the program title of CER was changed to Institutional Infrastructure and the scope was broadened to cover all facilities needs in computer science and computer engineering. In 1988 the Minority Institutions Program and the Small Scale Program were added. The Minority Institutions Program supported planning, establishment, enhancement, and operation of experimental computing facilities to support research and education in colleges and universities with large minority enrollments. The grants in the program ranged from 1-year, $50,000 grants to improve proposal writing and planning up to 5-year, $1.5 million grants to fund faculty positions, curriculum development, equipment, maintenance, support staff, expert consultants, network membership fees, and other research and educational costs. These grants have had a salutary impact on such institutions as North Carolina A&T and the University of Puerto Rico. The Small Scale Program was intended to provide facilities for small facility research groups within a computer science department.

> Most programs beyond [the top] 20 or 25 [schools] . . . don't have enough breadth . . . to mount a general infrastructure proposal . . . they may have a strong group of a half dozen people. They may have 25 faculty, but they don't have 25 *good* faculty. They would come up against Wisconsin's 33rd renewal and they would get blown out of the water because Wisconsin not only was good when they started, but, two CERs in a row, perhaps three, have been successfully started. It has done them a world of good. I mean, they are a first-class department, and [the second tier institution] just doesn't hold up.[71]

Thus, a smaller infrastructure grant would be given to support the small core of strength within the second-tier institution.

The main criterion that has been used within the Foundation to gauge the success of the CER program has been the annual production of PhDs in computer science. On this measure, the program has been a success. Beginning in 1980, the number of PhDs granted in computer science began to increase at approximately 10 percent per year, after a decade in which production remained in stasis at an annual rate slightly above 200 graduates. Departments with CER funds were expanding their PhD production twice as fast as departments without these funds. The first nine departments to receive CER grants reported a two-thirds increase in

the number of students passing qualifying examinations from 1980 to 1985. By 1990, the number of PhDs produced each year was around 600.[72]

There were other indications of the success of the CER program.[73] CER grants provided departments with leverage to obtain more positions, more space, and more support of other kinds. The newly found strength made the departments more competitive for DARPA and ONR funding. Many CER schools developed new interactions with industry, which led to gifts or large discounts on equipment as well as joint research. Faculty teaching loads decreased, and faculty had more time for research and individual interaction with graduate students. The CER schools attracted more and better graduate students.

Despite the efforts of NSF, industry, the universities, and the professional societies, the attempts to train an adequate supply of PhD computer scientsts were not entirely successful. Doctoral graduates produced increased steadily during the 1980s, but the goal of 1000 doctorates per year established in 1967 was not met until 1995. Computer science struggled to achieve adequate financial support for graduate students, and the faculty workload remained much higher than in other related disciplines.[74]

The CER program was tailored to make the university environment attractive for research. The justification was based on the fact that academic posts are specialized and involve a long preparation process of education and training. Only by keeping an increasing number of the highly trained people in the academic system would there be any hope of increasing the teaching labor pool and of eventually expanding the number of advanced students to meet the industrial demand. Even if this strategy were to be successful, it was acknowledged that it might take a generation to reach any sort of equilibrium even in the face of a serious economic decline that would reduce the demand.[75]

Scientific Research Tools and National Competitiveness (1980–1996)

Computing had originally been of interest to the federal government as a tool of national defense. While defense and national infrastructure issues are still an important part of federal computing policy today, the range of policy issues that touched on IT has grown over time. Since the 1950s, support for computers has been seen as a way to strengthen the nation's research base. In the 1960s, the Johnson administration regarded the computer as a tool of social welfare—to facilitate education to poor, rural, and minority communities. Federal programs to use the computer for social purposes proved to have limited success in the 1970s, primarily because of shortcomings in the technology at the time. Indeed, one might argue that the computer has driven a further wedge between the "haves" and the "have-nots." However, the spirit of affirmative action and equal opportunity programs, which was so strongly supported by the Johnson administration, did continue in the late 1970s and early 1980s. As a result, a climate was created to give women an opportunity to participate in the computing field at all levels in strong numbers for the first time (see the next section). In the 1980s, during the administration of

President Ronald Reagan, the computer became a factor in another kind of policy concern. The computer was seen as spawning an industry that was critically important to the nation's economic well-being, as well as being a tool that drove other industries both directly and through the results that came from research carried out using the computer as a tool.

Both scientific and economic issues drove federal computer policy in the 1980s and early 1990s. In 1980, the NSF Physics Advisory Committee appointed a subcommittee to investigate the availability of advanced computing facilities for physics research. Physicists obtained most of their computer time either because they were conducting directed research for an organization with these kinds of facilities or because they were able to make special arrangements to beg or borrow computer time from government or industrial organizations that owned supercomputers. The advisors worried that these kinds of ad hoc arrangements to gain access to supercomputers were drying up, just as the computation required in physical studies was exploding in scale. They noted that many American physicists were forced to travel to Europe to do their research calculations because they were unable to obtain the needed facilities in the United States.[76] They recommended that NSF build a network with a supercomputer at its center and connect it to other centers that owned medium-scale computers.[77]

To obtain a broad perspective on what might be needed and to attract wide support, a meeting was convened in June 1982 by NSF and the DoD, with additional support from NASA and the DoE. It was chaired by Peter Lax, a mathematician from New York University.[78] The Foundation issued the "Report of the Panel on Large Scale Computing in Science and Engineering" (commonly known as the Lax Report) in December 1982.[79] It recommended increased access for scientists to the most advanced supercomputers, new research on computational methods and software for supercomputer use, training of personnel to use supercomputers, and development of more advanced supercomputers that would meet the needs of scientists. It proposed that government agencies with an interest in supercomputing should form an interagency coordinating committee to act on these recommendations.

In April 1983, an NSF Working Group on Computers for Research was formed to act on the Lax Report recommendations and more generally to assess the situation of computer facilities for scientific research and graduate education. The Bardon–Curtis Report was the result. Published in 1983, it called for a widely cooperative effort, across government agencies and into the private sector, to provide better local computing facilities, national supercomputer centers, and networks to link research laboratories with one another and with the supercomputer centers.[80] The cost was expected to be in the hundreds of millions of dollars.

The political environment was favorable to this kind of investment in 1983 because high technology was beginning to be seen by the Reagan administration as important to national strength and international competitiveness. As soon as some security restrictions on use by Eastern bloc scientists were worked out, supercomputer centers were established in 1985 and 1986 at five locations: Princeton,

Pittsburgh, Cornell, Illinois, and San Diego.[81] During the first 3 years of operation, the five centers supported 2000 research projects at a total cost of $92.2 million. Physicists consumed nearly 35 percent of the total resources. The supercomputer centers program received strong support from Congress and NSF. The start-up of these centers, when aggregated with the computer research funding, amounted to an increase of 129 percent for computer science at NSF. Funding continued at high levels in subsequent years.

Beginning in 1987, the federal supercomputing program began to have competition from individual states, which saw supercomputer acquisitions as part of the infrastructure needed for the state and its educational institutions to be competitive—to produce research and train workers. Ohio State University, for example, established a center with state funds and attracted Allison Brown and Kenneth Wilson, the wife and husband team who had previously led the Cornell supercomputer center, to manage their operation.

The Office of Advanced Scientific Computing, which was responsible for the initiation of the supercomputing program at NSF, was also responsible for the establishment of NSFNET. Initiated in 1984, it was intended originally to provide access to the national supercomputer facilities. However, its scope was soon expanded to connect the nation's scientists with one another. This amounted to a realization of the "network for science" that NSF staff had envisioned since the mid-1970s, but had been prevented from building by the OMB. OMB had been concerned about NSF's ability to manage an ongoing network and some political leaders did not want NSF competing with private industry in this area.

At first, existing networks were used to interconnect the supercomputer centers and to provide access to remote users.[82] A new physical network was built, including a "backbone"—a high-speed data communications link—connecting the five supercomputer centers, the National Center for Atmospheric Research in Boulder, Colorado, and eventually other centers. The total investment approached $50 million.[83] Federal interagency cooperation, which was unusually close and effective, was enabled by a Federal Research Internet Coordinating Committee (FRICC), consisting of representatives of NSF, DARPA, DOE, NASA, and the Department of Health and Human Services. By 1990, the Internet connected not only networks—including ARPANET—in the United States, but also included networks in Canada, Mexico, Japan, Europe, New Zealand, and Australia. It is estimated that well over 100,000 computers were accessible through these interconnected networks.[84]

As the development of the network became more visible, interest increased in Congress and the White House. In November 1987, the executive branch's Office of Science and Technology Policy (OSTP) proposed a 5-year R&D strategy on high-performance computing and networking. The proposal would build on NSFNET to extend the Internet into a National Research and Education Network (NREN). The program assumed that the government would continue funding the approximately $500 million combined annual support invested by all federal agencies for computer science R&D.

This interest resulted in the High Performance Computing and Communications initiative, which agencies began discussing in 1989 and which became legislation in 1991. It resulted in a budget that grew eventually to exceed $1 billion, and involved at least twelve agencies.[85] It included support for both infrastructure and research activities in computers and communications. The initiative greatly strengthened understanding of networking, parallel computing, and advanced computer technologies; and it provided the national infrastructure that underlies the leading role of the United States in the Internet today. Albert Gore played a prominent role in promoting this legislation while in Congress. While the emphasis was originally on linking scientific researchers and giving them adequate tools, the network reached out to include many other groups in the educational and library communities. The authorizing legislation ended in 1996, but it has been succeeded by the Next Generation Internet initiative.

Protecting American Business Interests (1990–present)

In the 1990s, the reasons for federal action on IT changed somewhat. IT policy continues to be driven to some degree by a continuing concern about scientific research and education, as well as by national defense needs, but there has been a new emphasis on building an adequate workforce to meet the needs of American business. The continued improvement in price performance of chips and the emergence of the Internet has created a heated demand for IT workers, not just among manufacturers of computer hardware or software, but in all sectors of industry and in the public sector. The Y2K problem has also added a sharp peak in episodic demand, as individual companies spend as much as hundreds of millions of dollars in making their computer systems Y2K-compliant.

In order to meet the concerns of the business community, the federal government would, of course, like to be in a position to regulate the number of IT workers so that supply and demand are equal. If supply is less than demand, wages are driven up (making American companies less competitive) and certain projects cannot be completed or are delayed. If supply is greater than demand, there are unemployed workers to deal with. Unfortunately, in the market economy that the United States practices, the government has only limited ability to act. The government can only provide inducements to individuals to train for a certain occupation, or for companies to hire more workers or accept certain workers who may not have an ideal skill set from the employer's perspective—government cannot regulate any of these issues.

The recent intervention of US government agencies to address the perceived shortages of scientific and technical workers does not provide an encouraging picture. During the late 1980s, senior management at NSF warned of looming "shortfalls" of scientists and engineers. These warnings were based on methodologically weak projection models of supply and demand that were originally misinterpreted as credible forecasts, rather than as simulations dependent upon certain key assumptions. The projections yielded numerical estimates of the shortfalls anticipated, eventually reported to be 675,000 scientists and engineers by the year 2006.

Based in part on these worrisome pronouncements, Congress increased funding for NSF science and engineering education programs. Several years later, in 1990,

again influenced by the shortfall claims, Congress agreed to greatly expand the number of visas available to foreign scientists and engineers, for both permanent and nonpermanent residents. Many educational institutions moved to increase the number of graduate students in science and engineering. By the time these large cohorts of graduate students emerged with their newly earned doctorates, the labor market had deteriorated badly, and many found their career ambitions seriously frustrated. This experience proved embarrassing, leading to congressional hearings in 1992 and harsh criticisms of NSF management from several prominent congressional supporters of science and engineering. This experience has served as a caution throughout the 1990s as Congress has considered acting on other technical labor shortage claims.[86]

In response to labor shortages of nurses reported by hospitals and other US employer groups, Congress passed the Immigration Nursing Relief Act of 1989, which provided nonpermanent (H1A) visas for registered nurses for a 5-year period. Responding in part to NSF's concerns about a shortage of scientists and engineers, Congress authorized a new temporary visa category (H1B) for technical workers and a few other specialty occupations (specialty foreign cook and fashion model among them!). The records are not clear, but approximately 25,000 technical workers, including many computer scientists, were coming to the United States under this visa program in the middle 1990s (out of a total of 65,000 visa certificates provided each year).

In 1997, the Information Technology Association of America (ITAA), a large trade association, reported a shortage of 190,000 IT workers in the United States and a supply system that was unable to come close to meeting that demand. A second study conducted the following year by the ITAA, which involved surveying mid-sized as well as large companies, showed an even larger shortage of 346,000 unfilled information technology positions—approximately 10 percent of all IT jobs in the United States. The Department of Commerce's Office of Technology Policy then issued a report that mirrored the ITAA findings. However, the General Accounting Office criticized the methodology used to gather the data put forward by both ITAA and Commerce, and questioned the existence of a shortage. A heated debate ensued, crystallized around industry's desire to increase the number of H1B visas that could be awarded annually. Compromise legislation was passed and signed into law in late 1998, approximately doubling the number of H1B visas that could be awarded for 3 years, before the cap reverted to the original limit of 65,000 visas per year. However, the newly increased cap on H1B visas was reached after only 8 months into the government's FY, and lobbying began in the summer of 1999 to increase the number of visas once again.

Underrepresented Groups and Affirmative Action (1980s and 1990s)

Several groups of Americans are represented in the IT workforce in percentages that are far lower than their percentage representation in the population as a whole.[87] These include African Americans, Hispanics, Native Americans, and women generally.

Women are heavily underrepresented both in IT occupations and at every educational level in the formal system for educating IT workers. According to the Department of Commerce, only 1.1 percent of undergraduate women choose IT-related disciplines, as compared to 3.3 percent of male undergraduates. Tables 3.1 and 3.2 provide statistics about the percentage of women being educated in IT

Table 3.1. *Number of degrees awarded in computer and information sciences by level and gender*

Academic year	PhDs awarded	% Women	MS awarded	% Women	BA/BS awarded	% Women
1984–1985	240	10.0	6942	28.9	38,589	36.8
1986–1987	374	13.9	8481	29.4	39,590	34.7
1988–1989	551	15.4	9414	28.0	30,454	30.8
1989–1990	627	14.8	9677	28.1	27,257	29.9
1990–1991	676	13.6	9324	29.6	25,083	29.3
1991–1992	776	13.8	9534	27.8	24,578	28.7
1992–1993	808	14.7	10,171	27.1	24,241	28.1
1993–1994	810	15.4	10,416	25.8	24,200	28.4

Source: National Center for Education Statistics, *Digest of Education Statistics*.

Table 3.2. *Degrees awarded in computer science by level and gender*

Academic year	PhDs awarded	% Women	MS awarded	% Women	BA/BS awarded	% Women
1984-1985	326	11.0	—	—	—	—
1985-1986	412	12.1	—	—	—	—
1986-1987	559	9.7	—	—	—	—
1987-1988	744	9.0	5159	—	12,687	—
1988-1989	807	13.3	5457	—	10,606	—
1989-1990	907	12.6	5116	—	9681	—
1990-1991	1074	12.1	4993	—	9353	—
1991-1992	1113	11.3	5121	—	9813	—
1992-1993	997	13.3	4523	—	8218	—
1993-1994	1005	15.6	5179	19.1	8216	17.9
1994-1995	1006	16.2	4425	19.7	7561	18.1
1995-1996	915	11.7	4260	20.0	8411	15.9
1996-1997	894	14.4	4430	22.3	8063	15.7

Source: Computing Research Association, Taulbee Survey. 1984–1986 PhD numbers for CS&CE departments, all other years CS departments only.

fields. Table 3.1 shows the number of women in formal degree programs in computer and information science at all US colleges and universities, whereas Table 3.2 shows the number of women in formal degree programs in computer science and computer engineering at only the PhD-granting institutions.[88]

One of the obvious patterns in these two exhibits is that the percentage of women entering the computer science pipeline and earning the bachelor's degree in these IT fields has been declining steadily since 1984. While the number of computer and information science degrees awarded decreased every year between 1986 and 1994, the decrease is occurring at a faster rate proportionately for women. This is in contrast to general trends in the graduation figures of US colleges and universities for these same years, during which the percentage of bachelor's degree recipients who were women increased from 50.8 to 54.6 percent. It is also in contrast to the trends in scientific and engineering disciplines generally. The decrease in bachelor's degrees awarded to women has also affected the number of women in the graduate degree pipeline, contributing to the decrease in women completing a master's degree in the computer and information sciences area. The percentages at the doctoral level have stayed somewhat flat, with a reduction in the number of US women apparently offset by an increase in the number of female foreign students entering the system at the graduate level. There are no reliable data on the number of women in the IT workforce.

The decline in women engaging in formal IT training since 1984 is in sharp contrast to the pattern of the late 1970s and early 1980s. In that period, concerted efforts were made to recruit women to the field, and these efforts resulted in a rapid increase in the number of women students. Thus the subsequent decline in the percentage of women entering the field has been especially disheartening.

There has been much speculation about the reasons for the decline in women entering the IT training pipeline. Reasons cited include:

(1) lack of opportunity to gain early experience with the technology;
(2) lack of K-12 teachers and guidance counselors who are knowledgeable about the wide variety of career paths and opportunities in IT;
(3) an image of computing as involving a lifestyle that is not well rounded or conducive to family life;
(4) an image of IT work as being carried out in an environment in which one has to deal regularly with more competition than collaboration;
(5) courses in mathematics and science that are requirements for degree programs in computer science and computer engineering, which women have not been encouraged to pursue based on outdated stereotypes of aptitude and interest;
(6) a lack of women role models; and a large percentage of foreign-born teaching assistants and faculty, some of whom have cultural values that are perceived as not being supportive of women being educated or joining the workforce.[89]

Various programs are now under consideration at the national level to increase the participation of women in science and engineering generally, and in the IT community in particular. However, as the discussion below on minorities indicates, the goals and means of these programs have to be framed in an acceptable way in a political climate that has become hostile to the affirmative action programs that have been in effect since the Johnson administration in the 1960s.

The number of persons from most minority groups training or working in information technology occupations is very low. While African Americans, Hispanics, and Native Americans comprise 23 percent of the US population, they make up only 4.5 percent of those holding science doctorates (considering all scientific fields, not just computer science). One probable reason is the small number of minority students moving through the educational pipeline. Considering only those students who graduate from college, the percentages of Native Americans, African Americans, and Hispanics receiving a degree in computer or information science is actually higher than the percentage among non-Hispanic white males. However, this promising statistic is more than offset by the fact that minorities attend college in much lower percentages than whites do. Table 3.3 shows the low percentages of African Americans, Hispanics, and Native Americans training in IT-related disciplines.

Many of the reasons that discourage women from IT careers also apply to minorities. There are very few minority role models in IT. Minority students are less likely to have computers at home or at school on which to gain early exposure

Table 3.3. *PhD degrees awarded in computer science and engineering by minority ethnicity*

Academic year	PhD awarded	African American		Hispanic		Native American		Asian or Pacific Islander		Other	
		#	%	#	%	#	%	#	%	#	%
1984–1985	326	3	1.0	7	2.1	—	—	—	—	92	28.2
1985–1986	412	6	1.5	6	1.5	—	—	—	—	151	36.7
1986–1987	559	3	0.5	9	1.6	—	—	—	—	197	35.2
1987–1988	744	6	0.8	8	1.0	—	—	—	—	281	37.8
1988–1989	807	0	0.0	12	1.5	—	—	—	—	299	37.0
1989–1990	907	4	0.4	11	1.2	—	—	281	31.0	148	16.3
1990–1991	1074	8	0.7	26	2.4	—	—	349	32.5	151	14.0
1991–1992	1113	11	1.0	17	1.5	—	—	412	37.0	131	11.8
1992–1993	997	7	0.7	13	1.3	—	—	319	32.0	118	11.8
1993–1994	1005	14	1.4	9	0.9	0	0	154	15.3	76	7.6
1994–1995	1006	9	0.9	28	2.8	1	0	149	14.8	92	9.1
1995–1996	915	11	1.2	27	3.0	5	0	143	15.6	59	6.4
1996–1997	894	6	0.6	3	0.3	0	0	107	12.0	60	6.7

Source: Computing Research Association, Taulbee Survey.

to IT.[90] Students who attend historically black colleges and universities face limited computing facilities, compared with students at the typical US college or university. But there are other reasons as well. For example, minority students who want to devote their lives to helping their communities do not regard IT as a social-conscience field. Students with that goal are much more likely to train for careers in law, medicine, or politics. Since the 1970s, NSF had reserved a portion—typically 15 percent—of its graduate research fellowships for underrepresented minorities. However, this practice was abandoned in 1999 in the face of a lawsuit from a white student who claimed that the separate competition discriminated against the majority population.[91] This lawsuit is just one instance of a larger assault on affirmative action, which is causing federal agencies, universities, and private foundations to redesign their programs for underrepresented groups of all types.[92] Institutions are turning to other kinds of programs. They are giving financial incentives, without quotas, to "majority" universities to lure and retain faculty and students from underrepresented groups. They are establishing programs targeted at indigent communities, rather than groups defined by ethnicity or gender. They are establishing mentoring programs. They are brokering partnerships between research universities and nearby schools that have historically had large minority populations (e.g. Johns Hopkins University with the historically black Coppin State and Morgan State Universities in Maryland). It is too soon to know whether these programs will be effective or whether they will pass political muster.

A New Seed-Corn Problem? (1990s)

Many educators, industrial laboratory leaders, and government science officials are concerned that the high industrial demand for IT workers will siphon out of the higher educational system many students who would otherwise pursue an advanced degree. This diminishes the pool of people who will join the university faculties that perform basic research and teach the next generation of students.[93] This problem is compounded when industry also successfully recruits current faculty members, including junior faculty who would become the academic leaders of the profession in the coming decades.

There are early signs of another cycle of "eating our seed corn." The conditions are similar in many ways to the situation in 1980, as described in an earlier section. There is aggressive recruiting by industry that is luring high-quality undergraduates away from considering graduate school. Doctoral-caliber graduate students are leaving graduate programs after completing only a master's degree. Faculty members are shying away from high-pressure teaching positions. Burgeoning undergraduate enrollments are creating large class sizes, an inflated faculty-to-student ratio, and an over-committed faculty.[94] Not surprisingly, there has been a downward trend in the number of computer science doctorates awarded annually during the 1990s (1074 awarded in 1990–1991, 894 in 1996–1997).[95] The number of new doctoral graduates

entering academia is slightly more than 40 percent when postdoctoral and academic research positions, as well as faculty positions, are counted. This percentage has not been increasing, so the total number of new doctorates entering the teaching field is lower. Meanwhile, the number of faculty positions being advertised has skyrocketed. Advertisements in *Computing Research News*, for example, have doubled over recent years.

Other signs of a seed-corn problem are appearing. Universities have already experienced severe faculty shortages in several research areas, including networking, databases, and software engineering. Faculty recruiting is becoming much more difficult. There are fewer qualified applicants, positions are taking longer to fill, and multiple positions are going unfilled—even at strong research universities. The general attitude of the computing research community at the moment is to monitor the situation closely, until the data and qualitative evidence make it more apparent that a serious seed-corn problem does indeed exist. If this is determined, then actions similar to those taken in the 1980s by government, industry, and academia working together may be warranted.

The situation today is, however, different in some respects from 1980.[96] Today, computer facilities in universities are more comparable to those in industry than they were in 1980; and a healthy research program in experimental computer science now exists in the universities. However, the focus of university research has become much more short term than it used to be, making it less different from industrial research; this change has removed one incentive for faculty and graduate students to remain in the universities. High-level information technology professionals today are employed across a much larger number of employers, including many outside the IT sector. This makes it more difficult for companies to work together, as they did in the 1980s, to restrain the raiding of faculty and graduate students from universities.

Conclusion

The United States has never had a computer worker policy in the traditional sense of a planned economy in which central authorities dictate supply and demand of workers. Instead, the implicit worker policy has focused on improving the infrastructure for the supply system, providing incentives such as fellowships to individuals to enter the field, and more recently providing incentives such as tax credits to employers to do more in training their workers. The vast majority of federal efforts concerning computer workers fall under its policies for higher education and scientific research. Sometimes the worker issue has been an explicit goal in these policies, but seldom is it the single or defining issue. Often the primary intention of policies or programs that benefit the computer worker situation has been to build strong universities, strengthen the national scientific research effort, or ensure that defense needs are met.

Beginning in the 1960s, national policies that positively affected the computer workforce were tied to social welfare concerns. These included the use of the

computer to enhance educational opportunities for poor, rural, and minority communities as part of President Johnson's Great Society program, and the affirmative action programs that increased opportunities for women and minorities. The computerized education initiative failed, largely because the technology was not up to the task. The affirmative action programs are today being rapidly dismembered, and it is not clear what kinds of programs will replace them.

In the 1980s and 1990s, economic competitiveness increasingly has been a driving force in IT policy in general and in IT worker policy in particular. In this environment, IT worker policy has been more directly addressed using traditional tools of government such as tax incentives and immigration law. However, there still seems to be a reluctance to be heavy handed in the use of these legislative remedies.

Acknowledgments

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Notes

1. Peter Freeman and William Aspray, *The Supply of Information Technology Workers in the United States*, Washington, DC, Computing Research Association, 1999, provides basic information and cites most of the relevant literature.
2. Arvid W. Jacobson, ed., *Proceedings of the First Conference on Training Personnel for the Computing Machine Field* held at Wayne University, Detroit, Michigan, June 22 and 23, 1954, Detroit MI, Wayne University Press, 1955. Quotation is from p. 81.
3. Wayne University Conference, p. 85.
4. Ibid., p. 3.
5. Ibid., p. 17.
6. Ibid., p. 11.
7. Ibid., p. 11.
8. *Manpower Resources in Mathematics*. National Science Foundation and the Department of Labor, Bureau of Labor Statistics.
9. Wayne University Conference, p. 82.
10. Eleanor Babco from the Commission on Professionals in Science and Technology prepared a data report based on data from the US Department of Labor, Bureau of Labor Statistics, Current Population Studies. See Appendix 1.
11. Wayne University Conference, p. 16.
12. Ibid., p. 21.
13. Ibid., p. 79.

14. Wayne University Conference, p. 10.
15. Ibid., p. 10. In this era, Grace Hopper, Saul Gorn, and others talked of "automatic programming," which one might think of as making the programming process relatively human-free. What it actually meant was the building of assemblers, compilers, and diagnostic tools. They did not make any given programming task less time-consuming for the human programmer, but they just opened up the flood gates to doing more programming. See, for example, *Symposium on Automatic Programming for Digital Computers*, US Department of Commerce, Office of Technical Services, May 13–14, 1954, Washington, DC. This was also an era in which there was great concern about automation and the displacement of jobs for workers. See, for example, the testimony of Vannevar Bush, John Diebold, Walter Reuther, and others in "Automation and Technological Change," Hearings, 84th Congress, October 14–28, 1955; also "Automation and Recent Trends," Hearings, Subcommittee on Economic Stabilization, Joint Economics Commission, 85th Congress, Vols 14–15, 1957. These automation issues are also a frequent subject of *Fortune* and *Datamation*.
16. The various speakers from academia and industry discussed their various efforts to provide educational and training programs, but it would take us too far afield to discuss these issues. See, for example, the talk by Harry Huskey (UC Berkeley) on "Status of University Educational Programs Relative to High Speed Computation," pp. 22–25; Kenneth Iverson (Harvard University) on "Graduate Instruction and Research," pp. 25–29; and M. P. Chinitz (Remington Rand) on "Contributions of Industrial Training Courses in Computers," pp. 29–32; but these issues are discussed in many other papers at the conference as well.
17. See the talk by Joseph Fishbach of the Ballistic Research Laboratories, pp. 72–74.
18. Wayne University Conference, p. 10.
19. This material is drawn from Claude Baum, *The Systems Builders: The Story of SDC*, Santa Monica, CA, SDC, 1981. For more on psychological profiling, see Gerald M. Weinberg, *The Psychology of Computer Programming*, New York, Van Nostrand Reinhold, 1971, which includes references to various papers and conference talks. The Association for Computing Machinery sponsored an annual computer personnel research conference, beginning in the early 1960s.
20. The material in this extended paragraph is taken from "Automation and Employment Opportunities for Officeworkers," US Department of Labor, 85th Congress, Bulletin 1241, October 1958.
21. Ibid.
22. Wayne University Conference, p. 11.
23. See William Aspray and Bernard O. Williams, "Arming American Scientists: NSF and the Provision of Scientific Computing Facilities for Universities, 1950–1973," *Annals of the History of Computing*, 16: 60–74, 1994.
24. The history of DARPA's contribution to computer science is told best in Arthur L. Norberg, Judy O'Neill, and Kerry Freedman, *Tranforming Computer Technology: Information Processing for the Pentagon, 1962–1986*, Baltimore, MD, Johns Hopkins University Press, 1996.
25. Harry D. Huskey, "Status of University Educational Programs Relative to High Speed Computation," in Jacobson, op. cit., pp. 22–25.
26. Gerald L. Engle, "A Comparison of ACM/C3S and the IEEE/CSE Model Curriculum Subcommittee Recommendations," *Computer* 12 (December): 121–123, 1977.

27. The six studies were the following:

    - NAS–NRC, Committee on Uses of Computers, J. Barkley Rosser, Chairman, *Digital Computer Needs in Universities and Colleges*, Washington, DC, NAS–NRC Publication 1233, 1966.
    - NSF, Working Group on Computer Needs in Universities and Colleges, "Federal Support of Computing Activities, report presented to Advisory Committee for Mathematical and Physical Sciences, see Summary, Minutes of the Advisory Committee, March 31–April 1, 1966, NSF Historians Files, and the Working Group minutes May 13, 1965, June 17, 1965 and Memo to Beoffrey Keller from Milton Rose June 17, 1965 in Documents cited by the Administrative History of NSF, during the Lyndon Baines Johnson Administration," draft copy in NSF Historian's Files.
    - President's Science Advisory Committee, Panel on Computers in Higher Education, Jolin R. Pierce, Chairman, *Computers in Higher Education*, Washington, DC, Government Printing Office, February 1967.
    - John W. Hamblen, "Computers in Higher Education: Expenditures, Sources of Funds, and Utilization for Research and Instruction 1964–1965, with Projections for 1968–1969," Atlanta, GA, Southern Regional Education Board, 1967.
    - John W. Hamblen, "Inventory of Computers in U.S. Higher Education 1966–1967, Utilization and Related Degree Programs," Atlanta, GA, Southern Regional Education Board, August 1, 1970.
    - John W. Hamblen, "Inventory of Computers in U.S. Higher Education 1969–1970, Utilization and Related Degree Programs," Atlanta, GA, Southern Regional Education Board, March 1, 1972.

28. NAS–NRC committee on Uses of Computers, J. Barkley Rosser, Chairman, *Digital Computer Needs in Universities and Colleges*, Washington, DC, NAS–NRC Publication 1233, 1966.
29. It was estimated that this would require a total federal investment starting at $65 million and rising to $180 million per year, including a $200 million investment over the 4-year period. It was anticipated that American universities would have a need in this period for 20 very large (costing $2–8 million apiece), 30 large-to-medium ($500,000 to $2 million apiece for large systems and $300,000 to $1.5 million apiece for medium systems), and 800 small computing systems ($32,000–$180,000 apiece) to supplement those already in place. The report also proposed funding a regional centers program at the level of $10 million per year.
30. Those eight agencies were NASA, NSF, NIH, AEC, ARPA, AFOSR, US Army Research Office, and ONR. The Rosser Report (p. 29) indicates the contribution of computing to be greatest and in roughly equal amounts from NSF and NIH, approximately 60% as much support from each of AEC and ARPA, and much smaller levels of support from the other four.
31. Thomas Keenan, oral history interview with author, Charles Babbage Institute archives, 1990.
32. Arthur Grad, oral history interview with author, Charles Babbage Institute, 1990.
33. Geoffrey Keller, division director for Mathematical and Physical Sciences, April 20, 1965, letter to Lelard S. Haworth, Director, NSF; subject: National Science Board, Committee I, Meeting, April 14 planning for NSF Support of Computers and associated educational activities at universities; Number 43 in "Documents cited by the Administrative History

of NSF during the Lyndon Baines Johnson Administration," draft copy in NSF Historian's Files.

34. US House of Representatives, "Government and Science, Review of the National Science Foundation," "Hearings before the Subcommittee on Science, Research and Development of the Committee on Science and Astronautics, 89th Congress, 1st Session, June–August, 1965, volume 1, Washington," Government Printing Office, 1965, pp. 651, 660, 667–669.
35. Hearings, June–August 1965.
36. Ibid., p. 747.
37. Ibid., pp. 785–786.
38. President's Science Advisory Committee, Panel on Computers in Higher Education, John R. Pierce, Chairman, *Computers in Higher Education*, Washington, DC, Government Printing Office, February 1967, p. 6.
39. Milton Rose, oral history interview with author, Charles Babbage Institute archives, 1990.
40. President Johnson's message was a direct response to the Pierce Report, orchestrated by Joseph Califano, Special Assistant to President Johnson (Rose, oral history).
41. According to Rose, there was a reluctance in the Bureau of the Budget, and also from Joseph Califano, that there would be "political steam" behind this computers-in-education business and that this would lead to an uncontrolled source of funding for the Department of Education, which would not command the technical aspects well enough to use the funding prudently and effectively. It was therefore decided that the funding should go instead to the NSF to implement the recommendations in the Pierce Report. However, there was concern that the NSF would only address scientific developments in education and that the NSF did not have any well-developed education programs of a general character. (Rose, oral history) Also see Leland Haworth's memo to Joseph Califano, April 17, 1967 in Director's Note Files, NSF Historian's Files.
42. NSF, Advisory Committee for Computing Activities, Background Materials and Agenda of the Third Meeting, April 11–12, 1968, Record Accession No. 307-74-038, Box 1, Washington Federal Records Center.
43. NSF, Daniel Alpert, Chairman, Advisory Committee for Computing Activities, letter to Leland J. Haworth, December 20, 1968, Records Accession No. 307-70A-3621, Box 22, Washington Federal Records Center.
44. Industry forecasts projected an annual-need increase of 50,000 programmers and analysts, rising from 250,000 in 1965 to 750,000 in 1975. In 1965 combined enrollments in data processing and computer science programs were 4300 undergraduates and 1300 graduate students. (Draft of Statement of Dr Milton E. Rose, Head, Office of Computing Activities, before the Subcommittee on Science, Research, and Development of the Committee on Science and Astronautics, US House of Representatives, March, 1969, copy in NSF, Office of the Director, Subject Files, 1969, Record Accession No. 307-75-052, Box 2, Washington Federal Records Center.)
45. NSF, letter to W. D. McElroy from S. D. Conte, Chairman, Computer Sciences Department, Purdue University and Chairman, Advisory Panel for Computer Science, Supporting Documentation, January 16, 1970, Office of the Director, Subject Files—1970, Records Accession No. 307-75-053, Box 2, Washington Federal Records Center.
46. The base for this recommendation was the $1.3 million given in FY 1968 and $1 million in FY 1969 to support graduate (and one undergraduate) computer science programs, with average grant sizes of $150,000–350,000.
47. John R. Pasta, Head, Office of Computing Activities, June 10, 1970, memorandum to David E. Ryer, Special Assistant to the Director, Subject: Comments on the OCA

Committee Annual Report, NSF, Office of the Director, Subject Files—1970, Records Accession No. 307-75-053, Box 2, Washington Federal Records Center, p. 2.

48. Pasta, memorandum to David E. Ryer. See also the Office of Computing Activities Draft of Five Year Plan, April 27, 1970, attached to the Agenda for the Seventh Meeting of Advisory Committee for Computing Activities, June 11–12, 1970, NSF, Office of the Director, Subject Files—1970, Records Accession Number 307-75-053, Box 2, Washington Federal Records Center.
49. Office of Computing Activities Draft of Five Year Plan April 27, 1970.
50. Pasta answered such questions so often that he compiled a list of the most frequent ones: What is computer science? Why do we study it? Why not let industry do it? Does it have societal impact? Is complexity theory worth studying? What will come out of all this basic research? Is it relevant? (John R. Pasta, "Conclusions," Director's Program review: *Computer Research*, May 20, 1975, pp. 45–47.)
51. The companies were IBM, Burroughs, Honeywell, Univac, Digital Equipment, Bell Telephone Laboratories, GE, and Xerox.
52. The prominent example cited was work on computational complexity. Juris Hartmanis was required to leave his employment at GE for Cornell University in order to pursue his interest in this subject. After he and his academic colleagues had developed it, IBM, GE, and Bell Telephone Laboratories became interested in the subject.
53. See Bruce L. R. Smith and Joseph J. Korlesky, *The State of Academic Science*, New York, Change Magazine Press, 1977, pp. 16–19.
54. Agenda, Mathematical and Physical Sciences Division Director's Retreat, November 15–16, 1982, Appendix, "Degrees Awarded in Computer Science," Office of the Director Subject Files, File MPS, Records of the NSF, Accession No. 307-87-219, Box 3, Washington Federal Records Center.
55. The departments identified by Perlis as "strong" were California-Berkeley, Carnegie-Mellon, Harvard, Illinois, MIT, Michigan, New York University, Pennsylvania, Purdue, Stanford, and Wisconsin.
56. NSF, Report of the Meeting of the Advisory Committee for Mathematics and Physical Sciences, March 7–8, 1969, Office of the Director, Subject Files 1969, Records Accession No. 307-75-052, Box 2, Washington Federal Records Center.
57. Statement of Dr Milton E. Rose, Head, Office of Computing Activities, before the Subcommittee on Science, Research, and Development of the Committee on Science and Aeronautics, US House of Representatives, March 1969, attached to Agenda, Fifth Meeting of Advisory Committee for Computing Activities, May 22, 1969, p. H-9.
58. National Science Foundation, letter to W. D. McElroy from S. D. Conte, Chairman, Computer Sciences Department, Purdue University and Chairman, Advisory Panel for Computer Science, 16 January 1970, Office of the Director, Subject Files—1970, Records Accession No. 307-75-053, Box 2, Washington Federal Records Center.
59. In its first year (FY 1968), the OCA made awards to Johns Hopkins, Ohio State, and New York University to improve their graduate programs and to Colgate University to establish an undergraduate program. Grants totalling $1.0 million were made in FY 1969 to graduate programs at California-Berkeley, Purdue, the University of Rhode Island, the University of Southern California, SUNY-Stony Brook, and Washington University, St Louis.
60. NSF, letter to W. D. McElroy from S. D. Conte, Chairman, Computer Sciences Department, Purdue University and Chairman, Advisory panel for Computer Science, 12 January 1970, Office of the Director, Subject Files—12970, Records Accession No. 307-75-053, Box 2, Washington Federal Records Center.

61. Curtis Kent, "University and Industry Research," Computer Science, Directors Program Review, 20 May 1975, NSF.
62. See Harry Hedges, oral history interview, Charles Babbage Institute archives, 1990. Also the Snowbird Report, Peter Denning, ed., "A Discipline in Crisis," *Communications of the ACM*, 24 (June): 370–374, 1981.
63. Agenda, Mathematical and Physical Sciences Division Director's Retreat, 15–16 November 1982, Appendix, "Degrees Awarded in Computer Science," Office of the Director Subject Files, File MPS, Records of the NSF, Accession No. 307-87-219, Box 3, Washington Federal Records Center.
64. The 1978 Snowbird Conference is summarized in J. F. Traub, "*Quo Vadimus*: Computer Science in a Decade," *Communications of the ACM*, 24(June): 351–355, 1981. The 1980 Snowbird conference is reported in Denning 1981.
65. Jerome A. Feldman and William R. Sutherland, eds., "Rejuvenating Experimental Computer Science: A Report to the National Science Foundation and Others," *Communications of the ACM*, 22(September): 497–502, 1979.
66. ACM pointed to other studies that corroborated the findings of the Feldman Report: Daniel P. McCracken, Peter J. Denning, and David H. Brandin, "An ACM Executive Committee Position on the Crisis in Experimental Computer Science," *Communications of the ACM*, 22 (September): 503–504, 1979; The President's Federal ADP Reorganization Study (FADPRS) reported that shortages of computer science personnel may impede technological advance. The Council on Wage and Price Stability (COWPS) has ruled that (in certain instances) computer scientists (but not system analysts or programmers) are an "endangered species" and therefore can be excluded from the President's Wage and Price guidelines.
67. The Research Equipment Program was continued into the 1980s. By 1986 state-of-the-art machines had been provided to eighty universities and colleges. See "LRP material submitted to OBAC," April 25, 1986, in CISE Administrative Records, NSF, p. 4.
68. McCracken, Denning, and Brandin op. cit., p. 504.
69. Ibid.
70. W. Richards Adrion, oral history interview, Charles Babbage Institute archives, 1990.
71. Adrion, oral history.
72. Hedges, oral history.
73. Ibid.
74. In 1983, the computer science bachelor-degree–faculty ratio was twice that in electrical engineering and four times that in any other related discipline. The computer science full-time graduate student to faculty ratio was 50% higher than that in electrical engineering and other engineering fields, and three times as high as in other related disciplines.
75. Kent Curtis, "Computer Manpower—Is there a Crisis?," in Robert F. Cotallessa, ed., *Identifying Research Areas in the Computer Industry to 1995*. Park Ridge, NJ, Noyes, 1984, pp. 12–53.
76. Many different people referred to the case of Larry Smarr, an astrophysicist of the University of Illinois who had to travel to Germany to do his research calculations, and who today directs the national supercomputer center at the University of Illinois. When asked if the Bardon–Curtis recommendations should be implemented, Smarr waxed patriotic:

> America cannot possibly afford not to make this investment. America won't be the leader in basic research and technology if it pulls back from this . . . This investment will completely revitalize

American universities, industries, and American basic research . . . The only barrier to America surpassing other countries in basic research is a lack of leadership and national will, a lack of vision. We make the computers. We have the scientists. We have the money. We need the vision. (As quoted by Gene Dallaire, "American Universities Need Greater Access to Supercomputers," *Communications of the ACM*, 27(4): 292–298, 1984, quoted from p. 294.).

77. NSF, "Prospectus for Computational Physics," Report by the Subcommittee on Computational Facilities for Theoretical Research to the Advisory Committee for Physics, Division of Physics, March 15, 1981.
78. An organizing committee was formed of representatives of NSF, DOE, NASA, ONR, NBS, and AFOSR.
79. "Report of the Panel on Large Scale Computing in Science and Engineering," Peter D. Lax, Chairman, December 26, 1982, NSF. (Agenda for Workshop on Large-Scale Computing for Science and Engineering, June 21, 22, 1982, p. 20.)
80. NSF, "A National Computing Environment for Academic Research," prepared under the direction of Marcel Bardon by the NSF Working Group on Computers for Research, Kent K. Curtis, Chairman, July 1983.
81. Colin Norman, "Supercomputer Restrictions Pose Problems for NSF, Universities," *Science* 229(12): 148, 1985.
82. W. R. Adrion, D. J. Farber, F. F. Ko, L. H. Landweber, and J. B. Wyatt, "A Report of the Evolution of a National Supercomputer Access Network: Sciencenet," NSF, 1984.
83. Eliot Marshall, "NSF Opens High-Speed Computer Network," *Science* 243(6): 22–23, 1989.
84. Tracy La Quey and Jeanne C. Ryer, 'The Internet Companion: A Beginners Guide to Global Networking', Reading, Mass, Addison-Wesley, 1993, pp. 194–195.
85. See Marjory S. Blumenthal, "Federal Government Initiatives and the Foundations of the Information Technology Revolution: Lessons From History," *Clio and the Economic Organization of Science*, AEA Papers and Proceedings, 88(2): 34–39, 1998.
86. This paragraph and the previous one are taken almost directly from Freeman and Aspray, op. cit., p. 46, and are based in part on analysis by Michael Teitelbaum of the Alfred P. Sloan Foundation.
87. Much of the material in this section is taken from Freeman and Aspray (1991), ch. 7. Thanks to Mary Jane Irwin of Pennsylvania State University for her help with the analysis of the women's issue.
88. Table 3.2 works from a smaller sample, but it provides more current information. The percentages of women in bachelor's and master's programs are much lower in Table 3.2, which is attributed not to any methodological problem with either dataset, but rather to the fact that Table 3.1 includes information systems degrees and Table 3.2 does not.
89. Some methodologically rigorous research on this issue is under way. See Allan Fisher and Jane Margolis, Computer Science Department, Carnegie-Mellon University, on "Women in Computer Science: Closing the Gender Gap in Higher Education," www.cs.cmu.edu/~gendergap.
90. Minority students who do have computers in their schools are more likely to use them for repetitive math skills, instead of simulations and real-life applications of mathematics concepts. See Educational Research Service, "Does it Compute? The Relationship between Educational Technology and Student Achievement in Mathematics."
91. David Kerstenbaum, 'DOD Axes Grant Student Program', *Science*, 26 June 1998, issue 5372, p. 2037.

92. Examples of these assaults, in addition to the NSF lawsuit, are a 1996 California referendum (Proposition 209) that prohibits a race-based criterion in admission and hiring at state institutions; and the *Hopwood v. Texas* federal appellate court ruling that sets similar rules for Texas, Louisiana, and Mississippi. For a general discussion of this issue of science programs for minorities, see Jeffrey Mervis, "Wanted: A Better Way to Boost Numbers of Minority Ph.D.s," *Science*, 28 (August): 1268–1270, 1998.
93. This discussion of the seed-corn problem in the 1990s is taken from Freeman and Aspray, op. cit.
94. See the anecdotal account of this situation in Bronwyn Fryer, "College Computer Science Enrollment Skyrockets," *Computerworld*, October 22, 1998.
95. Computing Research Association, Taulbee Surveys.
96. The Presidential Information Technology Advisory Committee has addressed some of these issues in its report to the president. See www.ccic.gov/ac/report.
97. William Aspray, Bernard O. Williams, and Andrew Goldstein, Computer as Servant and Science: The Impact of the National Science Foundation, Report to the NSF 1991.

4

Public Policies, Private Platforms: Antitrust and American Computing

Steven W. Usselman

By any measure, the American computer industry has been a remarkable economic success story in terms of global performance. What is especially striking about the industry is its resilience—its ability to sustain dominance across a series of technical watersheds. American computer firms, led by IBM, moved rapidly to world leadership with the advent of stored-program electronic computing during the two decades following the Second World War. New enterprises—Digital Equipment Company (DEC) in minicomputers, Apple and Intel in personal computers (PCs), SUN in workstations, Cisco in routers—kept the United States at the forefront through successive waves of innovation that drove down the size and cost of computer hardware while dramatically increasing its performance. More recently, American firms such as Microsoft and Oracle have captured an enormous share of the world software market. This sustained performance for the industry as a whole seems all the more impressive given the highly varied performance of individual firms within the computing sector.[1]

How do we explain it? Well, we do not want for hypotheses. Proponents of virtually every theory of economic activity and from every school of political economy have found some basis for support in the experiences of the computer industry. Free marketers celebrate the turnover of industry leadership and the recurrent rise of dynamic start-ups as evidence of the fluidity and flexibility engendered by market mechanisms.[2] Others, in stark contrast, cite the industry as a primary example of the fruits of public investment and of the potential spin-offs (and possible distortions) arising from pursuit of military objectives.[3] Some close observers of the industry's history, such as Alfred Chandler, read it as yet another example of how first-movers gain enduring advantages.[4] Others, interpreting such persistence in terms less celebratory of entrepreneurship, speak of network linkages and bandwagon effects.[5] Still others, such as Annalee Saxenian and the many planners inspired by her work, link American leadership to a distinctive (and elusive) mix of qualities prevailing within specific regions such as Silicon Valley.[6]

This chapter adds one more element to the story: Government competition policy, specifically antitrust, and its close cousin, intellectual property law. Throughout the history of this remarkable industry, government has through these tools (and, to a degree, through its funding and purchasing as well) sought persistently to shape

demand in ways that countered the strong tendencies of network externalities to reinforce first-mover advantages. In particular, government has attempted whenever possible to break the bonds between providers of basic platforms and firms oriented toward tailoring those platforms to meet the varied desires of consumers. Though often obscured by the intense focus on government's role in funding the industry, these policies pertaining to competition have managed to encourage consumer-oriented innovation without sacrificing the social benefits derived from the stability of basic platforms. Working in concert with trends in technology and the forces of competition, they have given shape to the industry and helped foster those qualities that impart such distinctive vitality to American computing.

At heart, this ongoing effort by the regulatory community involved a critical balancing act that has characterized much business regulation in American history. Regulators persistently wrestled with the difficult task of weighing the benefits of efficiency, which typically derived from routine and system, against the potential dynamism of innovation, which was typically aimed at meeting the needs of diverse customers.[7] A key aspect of this struggle involved questions of institutional boundaries and markets. Through a combination of private actions and public policies, computing like many other industries evolved toward a dualistic structure. One group of firms, often highly coordinated and perhaps even dominated by a clear industry leader, provided the basic platforms. Typically, these basic platforms existed not so much in the form of physical artifacts (though in its early years the industry did rely on tight physical coupling of central processors and peripheral devices into a technical system), but as sets of rules governing logical design and programming (the latter known, suggestively, as operating systems).[8] Each type of platform offered ample opportunities for sustained improvement that would yield greater efficiency. Consumers would reap the benefits in the form of greater power at lower cost. Many of those benefits resulted from relentless pursuit of standardization. Uniformity yielded economy, in the true sense of the word.

There was more to the computing industry, however, than sustained achievement along a well-defined trajectory of increased speed at lower cost. Improvements in the basic platforms also opened possibilities to perform entirely novel operations. Such novelties typically have occurred in the readily recognizable form of applications software. All of us who have experienced the steady stream of upgrades in our word processing programs over the past two decades well understand that technical change in computing involves new features rather than a mere increase in speed. The computer software and services industries have long emphasized product differentiation and customized installations.

To the extent that innovation of this sort involves customization, it necessarily exists in some tension with the pursuit of uniformity and routine that generally characterizes the behavior of those responsible for the basic platforms. Not surprisingly, the push for novelty generally comes from outside, in the form of requests from particular consumers who bring distinct needs to bear upon the system. Providers of the basic platforms often attempt to suppress such particular interests and keep demand as homogenized as possible.[9] Dominant suppliers such as IBM

and Microsoft persistently faced accusations that their standards placed unnecessary constraints upon those wishing to perform customized operations. Not coincidentally, both firms reluctantly gravitated toward so-called "open architectures" capable of facilitating a wide variety of specialized applications devised by numerous independent suppliers.

As these brief comments suggest, a key element in the ongoing trade-offs between uniformity and novelty involves the interface between platform providers and firms concerned with accommodating the specialized needs of particular consumers. Seldom has this boundary been sharply drawn. Technological interdependencies draw firms and consumers together in complex ways, and business strategies frequently converge. On many occasions, the critical interface has formed within the platform providers themselves, as their managers made trade-offs between the relative merits of pursuing further standardization versus the possibility of capturing greater returns by offering premium services.

Even in these circumstances, however, the choices have always been made within a larger framework of public policy. Using instruments such as antitrust and intellectual property law, government has functioned as a watchdog, monitoring the critical boundaries that mediate the choices between uniformity-enhancing routine and product-differentiating innovation. Frequently, such monitoring has taken the form of antitrust proceedings in which government called for firms to "unbundle" systems and routines from more specially tailored applications. Though government has hardly been unfailingly consistent or clear in its objectives, its focus has recurrently turned to the same fundamental challenge. Politicians and the regulatory community, like the firms they monitor, have struggled in their thinking and in their policies to conceive of the market not merely as a homogeneous mass seeking standard performance at lower cost, but as a collection of interests wishing to have their individual needs met through innovative service.[10]

Government, IBM, and the Early Computer Industry

Prevailing narratives in the history of early electronic computing typically emphasize the connections between military needs and commercial capabilities. These connections run through IBM, which during the first decade following the Second World War managed to capture the lion's share of the emergent market for stored programmed electronic computers.[11] In many accounts, this story percolates down quite readily to one in which IBM secured key military contracts through which it developed crucial new capabilities that it then used to dominate the emerging commercial market.[12] Elsewhere I have suggested that this scenario obscures or even distorts important elements in the emergence of IBM and the industry. Rather than anointing IBM as the champion, the military through its procurement policies actually fostered a healthy competition among potential suppliers. IBM triumphed in this competition because of its established capabilities, including most importantly its ability to strike compromises in system design, operation, and maintenance.[13] These skills also gave IBM a distinct advantage in its abilities to

transfer knowledge from military programs to commercial objectives. This task proved much more difficult than imagined, however, because each specific product development program required its own distinctive mix of trade-offs between design, manufacture, and software. As IBM negotiated the difficult transition from the world of accounting equipment to that of electronic computing, much of the critical learning took place not under the rubric of "research," but rather in the course of product developments whose budgets included no separate category for research. Data linking a high percentage of computing research to the military is thus highly distorting.[14]

Lost in all the attention given to government funding, moreover, are the important steps taken by the Department of Justice to structure competition in computing during these formative years in the history of the industry. Throughout this period IBM came under intense scrutiny from antitrust investigators. Indeed, antitrust involvement in the industry stretched back some two decades further, to the mid-1930s, when IBM had first entered into a consent decree with the Department of Justice.[15] With this decree IBM agreed to create a separate market for the punched cards customers used to store data for processing with its accounting machines. Government believed the card format tied customers to IBM, preventing them from switching easily to competitive accounting equipment and compelling them to pump large profits into IBM's coffers in the form of inflated prices for cards.[16] The decree marked an early example of government attempting to unbundle components that had historically been closely joined in an integrated data processing system.

In breaking apart these bonds, government hoped to create space for competition involving both price and innovation. By the end of the 1940s, however, this decree had largely failed to accomplish the desired affect. As worldwide demand for accounting equipment soared during the war and after, IBM revenues reached unprecedented levels. The firm actually gained market share.[17] Not surprisingly, Justice began investigating, and the younger Thomas Watson, walking a fine line between his incensed father and government, entered into negotiations that would stretch across several years before resulting in a consent decree. These negotiations occurred at the very time Tom Watson was devising his strategies for computing, and they unquestionably shaped his choices. Watson understood clearly that Justice would not permit him to acquire expertise in electronics and computing by purchasing concerns such as the pioneering firm of Eckert and Mauchly, who had approached him about a sale. IBM would have to develop its own capabilities in the new technology.[18] (Its competitor, Sperry-Rand, was allowed to purchase Eckert and Mauchly.)

The subsequent consent decree of January 1956 went even further. Its principal provisions called for IBM to sell as well as lease its products and to allow consumers to purchase parts of their systems from competitors. To facilitate the integration of components from rival suppliers, government required that IBM license its patents and technology.[19] Government hoped by taking these measures to break open the closed world of IBM and to facilitate competition by giving upstarts clearer targets upon which to concentrate their efforts. In effect, the Justice Department

positioned IBM as a broker or common carrier for component and peripherals manufacturers and for applications programmers, much as the FCC had done with network broadcasters.[20]

To this end, the 1956 consent decree also insisted that IBM set up a new entity, the Service Bureau Corporation (SBC). This wholly owned subsidiary would offer data processing services. While utilizing IBM equipment, the service bureau would operate independently from its parent. The consent decree banned SBC from hiring IBM personnel or using the IBM logo. More importantly, it called for open distribution of all operating manuals and other technical materials flowing between IBM and SBC.[21] At a time when virtually no one had imagined the idea of prepackaged software products, the creation of an entity such as SBC constituted a first step toward unbundling hardware and services and creating separate forums of competition for each.

How well did this experiment in market segmentation work? This is not an easy question to answer. SBC itself underwent a strange odyssey during the next decade and a half. By 1958, it had achieved annual revenue of approximately $40 million. This amounted to just under 3.0 percent of IBM's total revenue for that year and about 4.5 percent of the revenue IBM generated from its activities in data processing. Much of this business likely represented a shift from services previously performed by IBM to the new subsidiary, as the parent reported a drop in the services share of data processing revenue from 5.0 percent in 1955 to 2.8 percent in 1958 to a low of 2.0 percent in 1961. Meanwhile, SBC's share of IBM's data processing revenue held steady at about 3.0 percent into the early 1960s. For 1963, it reported revenue of $65 million. IBM generated more than $2.8 billion in revenue that year, more than double the figure from 1958, with over $2.2 billion coming from data processing.[22]

During the mid-1960s, revenue from both SBC and services spiked upward. In 1964, SBC reported revenues of $111 million, or 4.4 percent of the IBM total from data processing, and the parent reported that services accounted for another 3.4 percent of that total. By 1966, revenues at SBC had crept up to $150 million, or more than 4.6 percent of the IBM total from data processing, while services held steady at roughly 3.5 percent. Together, SBC and services accounted for more than 8 percent of IBM's data processing revenues that year. This ratio does not differ substantially from the estimates of pioneering industry analyst Montgomery Phister for the data processing industry as a whole. Phister reports services with a 10.5 percent share of total industry revenue for 1966 (down from 13 percent during the early 1960s) and one of just under 10 percent in 1967.[23]

These figures, though useful in providing a sense of proportion, do not in themselves offer much insight into whether the separation of services and hardware worked as the government desired. If we probe a bit deeper into activities taking place within IBM and SBC, the picture rapidly grows muddy. A glance through the annual reports of the parent firm from the late 1950s and early 1960s reveals one overriding theme: A concern with developing new applications for computers. During these years, IBM publicists struggled to find ways to educate stockholders

and others about concepts such as "programming" and "software." For several years running, those writing the annual report felt compelled to define these terms. Only by developing such applications tools, they stressed, could IBM open new markets and sustain the remarkable rates of growth in its sales of computer hardware.[24]

This emphasis on programming might well have directed attention toward the newly created SBC, which as an operator of several complex computer hardware installations might conceivably have become a source or at least a testing ground for new applications programming. Given the requirements in the consent decree that IBM and SBC openly publicize their technical communications, such developments might then have diffused through the industry and spawned considerable competition. Perhaps not surprisingly, however, IBM chose not to give SBC a prominent role in its efforts to develop new applications. Instead, IBM marshaled much of its programming talent toward the new Applied Systems Development Division (ASDD), which it created in 1959. Under the leadership of Jerrier Haddad, who had made his mark in system design, this group would explore complex applications.[25] Each of the two established product divisions and the giant marketing division, meanwhile, would likewise renew their focus on developing new applications software for their customers.[26]

IBM made motions toward expanding the capabilities of SBC as well, adding new computers and considerable disk storage to support more work on databases. But even with these enhancements, the facilities of the service bureau and the range of services it offered remained quite modest when compared to many of the installations designed and operated by the regular IBM divisions and those envisioned by ASDD. During the early 1960s, moreover, the parent firm created a new series of Data Centers.[27] Offering services such as real-time database processing, these centers seemingly operated in direct competition with SBC, and at least some observers felt they clearly violated the consent decree.[28] The rise of these centers might explain why SBC revenues had by the early 1970s receded sharply to just over $60 million annually, or less than 1 percent of the revenue IBM derived each year from data processing.[29] In early 1973, IBM agreed to sell the service bureau to Control Data Corporation (CDC) for $16 million. It did so, ironically, in partial settlement of an antitrust action brought by CDC. Though CEO Thomas J. Watson, Jr, considered the price "a fraction of its real worth" and claimed the settlement "cost IBM a small fortune," IBM had clearly not placed much strategic importance upon SBC for some time before the agreement.[30]

The experiences of SBC in many respects point to the difficulties of breaking a firm into separate entities along functional lines. Despite its avowed desire to develop new programming applications, IBM clearly preferred to keep developments in software tightly coupled to those in hardware. Given the state of computer technology at the time, IBM had some compelling technical reasons to keep software and hardware joined in this way. With memory and central processing unit (CPU) capacity severely limited, systems design still involved significant fundamental trade-offs between hardware and software.[31] Machines still aimed at either the commercial or scientific user. Yet even as IBM strove to collapse such

distinctions and to produce general-purpose machines in standard format—a pursuit that resulted in the announcement of the System 360 line of computers in April 1964—it still preferred not to separate hardware so completely from services and programming. For in addition to facilitating technical compromises, the ties between these activities gave IBM enormous flexibility in its business practices. Most importantly, they introduced substantial latitude into its pricing, because sales representatives could as necessary offer customers various amounts of services and programming for no additional charge. Such practices gave IBM an important strategic advantage. (In 1995, new CEO Louis Gerstner would renegotiate the 1956 consent decree with the Justice Department in order to regain absolute freedom for IBM to bundle products and services in any manner it pleased and offer a single comprehensive price.[32]) Precisely how big of an advantage, however, remained a matter of dispute. IBM offered no separate accounting for the contribution of services to its revenue, and the efforts of industry analyst Phister to unearth this data yielded the preposterously low figure for the late 1960s and early 1970s of less than 1 percent, at a time when services accounted for nearly 20 percent of revenue for the data processing industry as a whole.[33] (In 1974, Phister later estimated, services, supplies, and programming together generated some 10.2 percent of IBM's revenue from data processing.[34]) The bundling of services and software with hardware would come under increasing fire during the mid-1960s and eventually become a central contention of the antitrust suit filed by the Justice Department against IBM in January 1969.

Yet if IBM proved resistant to decoupling hardware from services (and their close cousin, programming) and capable of turning the government-created service bureau into a neglected stepchild, the experiment at market segmentation of 1956 was not without effect. SBC and other service bureaus, though largely forgotten today, emerged as important intermediaries between hardware suppliers and computer users.[35] Some of the service bureaus began to focus upon particular sorts of customers with common data processing needs. Ross Perot, a premiere IBM salesman, left the firm in 1962 and found Electronic Data Services (EDS), which grew into a spectacularly successful enterprise by focusing upon the needs of government contractors.[36] In cultivating such niches, pioneering bureaus sometimes developed software tools that could, with some customizing, be used by many customers. In this way, they helped promote the idea of software as a consumer-oriented packaged product, whose development costs could be spread across a large number of customers.

During the mid-1960s, much of the impetus in the service bureau industry turned toward developing time-sharing applications, a field IBM had largely neglected when it introduced System 360. A few firms rose rapidly to the forefront by seizing this opportunity.[37] In the end, however, the turn toward time-sharing proved something of a Faustian bargain. Many providers profited not by offering novel applications, but by using time-sharing to keep their investment in computing hardware deployed more fully and effectively. A shift in pricing policies at IBM, which in 1966 looked to pump cash into its coffers by encouraging sales over

leases, helped further spur the phenomenon, as bureaus leased machines from third parties at favorable terms.[38] By the end of the decade, however, the bubble had burst. Hardware suppliers such as IBM responded with new time-sharing systems that outperformed those leased from third parties. The service bureaus, observed Walter Bauer of Informatics at a conference of software suppliers held at UCLA in1970, had failed to erect barriers to entry by developing their own specialized applications programs.[39]

Bauer's assessment reflected the important lessons the service bureau phenomenon had imparted to the computer industry about the relationship between hardware, software, and consumers. This critical learning process would, perhaps, have occurred without the consent decree of 1956. But in sending a clear signal to entrepreneurs that they could enter the service business without discrimination from the largest supplier (indeed, they could anticipate that supplier making available important technical information), government almost certainly encouraged the evolution in thinking about the nature of the industry. The experience of watching IBM respond to the service bureaus, moreover, helped spur the Justice Department to launch the next round of antitrust action and significantly influenced its thinking about the industry.

The Antitrust Action of 1969

The Justice Department again began taking a hard look at the computer industry in January 1967, when it declared its intent to investigate business practices at IBM. Two years later, on the final day of the Johnson administration, Attorney General Ramsey Clark filed an antitrust suit against the firm. The first item of contention in the suit involved the bundling of hardware with software and services. At the urging of chief counsel Burke Marshall, who had joined IBM after a stint as assistant attorney general in which he had responsibility for antitrust, IBM had already announced during 1968 that it would offer separate pricing on services and applications programs. In pressing forward with the suit, government signaled its intent both to make certain IBM followed through on this shift in policy and to seek restitution for any enduring advantages IBM may have derived from its previous practices. Government would carry this inquiry forward with great persistence. The case stretched over more than a dozen years, until a federal judge with the concurrence of the Reagan Justice Department deemed it without merit in January 1982. In the interim, the Justice Department had lent its support to several private antitrust actions as well, including the suit by Control Data that resulted in the sale of SBC in 1973.[40]

On their surface, these events point to a straightforward interpretation: Antitrust action, though not resulting in an ultimate victory for government in the courts, prompted IBM to alter its business practices in fundamental ways and in the process created a distinct market for computer software. Though IBM fought this interpretation in the courts, arguing that the decision to unbundle resulted from concerns about costs and other economic factors, this view seems rapidly to be

taking hold, both among academics and participants. In his 1993 autobiography, for instance, Tom Watson unequivocally attributed the decision to unbundle to Marshall's advice regarding antitrust.[41] Watts Humphrey, who headed IBM's programming efforts at the time and played an instrumental role on the task force assigned to carry out the new policy, has recently recollected events in much the same fashion.[42] Recent assessments by Martin Campbell-Kelly, Edward Steinmuller, and David Mowery have likewise identified the decision to unbundle as a watershed moment in the history of the software industry and have suggested concerns about antitrust exerted a major influence over IBM as it took this step.[43]

But is the story really quite so straightforward? Does Justice deserve full credit for the shift in policy at IBM? Might the firm, under pressure from competition and trends in technology, have acted independently? And did the decision to unbundle, whatever its roots, really make all that much difference to the software industry? These questions are worth posing, not out of a desire to reject the prevailing interpretation, but rather in an effort to sharpen our thinking about precisely how government intervention altered the competitive structure.

We can gain some insight into these questions by revisiting the situation prevailing in the mid-1960s, when the Justice Department renewed its interest in IBM and the computer industry. One story dominated the industry at that time: System 360. With this new line of computers, IBM had apparently reasserted its dominance over the industry. The value of computer hardware shipped each year by IBM, after increasing steadily from just under half a billion dollars in 1959 to slightly more than $2 billion in 1965, jumped suddenly in 1966 to $3.4 billion. The following year it exceeded $4.5 billion. IBM's share of the industry total, which had slipped from around 80 percent in the early 1960s to less than 63 percent in 1965, surged to over 71 percent in 1967. Those gains came at the expense of firms such as Univac, Honeywell, GE, and upstart Control Data, which had once appeared to offer the stiffest challenge to IBM. Another potential rival, RCA, barely held its ground.[44]

At a time when computer hardware still accounted for nearly three-quarters of all revenue in the data processing industry, these figures could hardly have comforted those concerned about fostering competition in computing. In the eyes of at least some observers, moreover, IBM's resurgence had resulted less from the merits of its new line than from the heavy-handed tactics used to market the new machines. IBM had rushed to announce a comprehensive series of machines all at once in large part because of competition from Honeywell and GE. It had then expanded the line to counter high-end machines produced by Control Data and to meet the unanticipated demand for time-sharing. Many of these products reached customers later than promised, and most did not meet projected standards of performance for long after that. Much of the disappointing performance resulted from difficulties with the common operating system, which IBM had promised would enable machines throughout the line to run the same programs. Many of the private lawsuits against IBM, including that of Control Data, hinged upon accusations that the firm had knowingly announced its products prematurely. The government raised these concerns in its suit as well.[45]

When the Justice Department again focused its gaze upon IBM in 1967, then, it was overwhelmingly concerned about competition among manufacturers of computer hardware. It homed in on the issue of bundling not out of a desire to foster an independent software industry, but rather because it believed such bundling gave IBM an unfair advantage in the market for hardware by enabling it to obscure the true price and performance of its hardware products. IBM could shift unbilled services and technical support across its large customer base as needed, in order to cover itself in quarters where it faced the stiffest competitive challenges. The common operating system and programming associated with System 360 facilitated these sorts of tactical responses. It was in this sense, rather than out of an appreciation for network effects and the possibility of operating systems functioning as "tails wagging dogs," that Burke Marshall characterized bundling as a classic "tie." In the opinion of Marshall and IBM's crack team of lawyers, the strongest evidence against IBM consisted of an immense database assembled by Control Data documenting cases in which IBM deployed these sorts of marketing tactics. As part of its settlement with Control Data, IBM took possession of this database and promptly destroyed it, severely hampering the government's case.[46]

The primacy of hardware in the thinking of Justice Department officials becomes clear when we consider the position they took in the mid-1960s regarding the patenting of computer programs. As entrepreneurs in the nascent software industry pressed Congress and the patent office to extend patent protection to programs, the Justice Department initially came down hard against the idea. Following the arguments of many prominent law professors, including the future Supreme Court Justice Stephen Breyer, officials in the Justice Department argued that programs should exist as free goods in the public domain. They sought to curtail attempts to turn a grassroots endeavor into an organized competition among firms holding broad proprietary rights.[47] (IBM, with no interest in marketing its software independently from hardware and believing free software developed elsewhere encouraged computer sales, concurred heartily with the Justice Department on this point, as did other computer manufacturers. With its decision to unbundle, the firm hastily reversed itself, advocating strong copyright protection and licensing of rights.[48])

In asking IBM to unbundle and charge separately for services such as programming, then, Justice was almost certainly not looking to create a proprietary software industry. Yet the question remains, did Justice through its antitrust action in fact create such an industry, even if inadvertently?

At least one observer at the time, Walter Bauer of Informatics, offered some strong testimony in the affirmative. At the same 1970 conference at which he castigated the service bureaus for not paying sufficient heed to the importance of applications programming, Bauer predicted that "unbundling or separate pricing will be the biggest factor in the growth of software products." Interestingly, however, Bauer attributed this significance not so much to the diminished power of IBM under unbundling, but rather to the sanction the firm would provide to the software industry. "One of the processes which will be acting to accelerate the acceptance of

purchased software is the fact that IBM with its very large sales organization will be promoting this point of view," explained Bauer somewhat cynically. "There is now a fifteen-year history in modern data processing which says that the only technical or marketing approach which is acceptable is the way IBM does it. As a buyer or seller, you conform." Bauer anticipated that IBM "will pursue software products aggressively," noting that "there is probably a general consensus and major agreement on that point." Yet he questioned whether it would ultimately prevail, because IBM management was "basically hardware and hardware sales oriented." Bauer predicted that IBM and other manufacturers would get the jump on the independents in the market for software products during the first half of the 1970s because of their established marketing presence. Independents would gain the upper hand during the last half of the decade, however, because computer manufacturers "have been so long oriented to the computer as hardware only, and to the provision of 'tool' software, that their ability to enter software markets and to provide systems engineering and applications engineering service has weakened over past years, at least relative to market demand or potential." Putting his finger on what he considered the essence of the matter, Bauer concluded, "Systems work is in direct conflict with the basic objective of marketing hardware."[49]

While Bauer clearly believed unbundling to be an important development, the overall thrust of his comments casts some doubt upon the idea that the Justice Department spawned the software and software services enterprises. Bauer seems to suggest that these activities would have emerged in the ordinary course of events and that IBM would have responded to the new situation, though not all that effectively, regardless of the constraints placed upon it by the government. Is this correct?

One can begin by asking whether IBM would have unbundled even without the pressure of the Justice Department. This was certainly the contention of the firm's lawyers who fought the antitrust suit. They argued that bundling of software was an artifact of the days when IBM needed to foster applications programming in order to increase the size of the market for hardware. With the market maturing, this need had disappeared, and programming seemed increasingly like a costly drain on resources.[50] This seemed all the more true because programming accounted for a steadily larger share of IBM's development resources. In the late 1950s, according to Phister's data, the money spent on programming development was a mere 4 percent of that devoted to engineering. By the mid-1960s, this figure had jumped to more than 60 percent. Over that stretch of time, the number of programmers had jumped from less than a 100 to over 2500.[51] Tom Watson later recalled his chagrin in discovering that programming for System 360, particularly its critical operating system, appeared not to yield the economies of scale customarily achieved in manufacturing.[52] The man in charge of developing that system later wrote a famous book, *The Mythical Man-Month*, which attempted to explain the reasons.[53] Given these characteristics of software and the increasing proportion of consumer dollars flowing toward it, the lawyers contended, IBM and other manufacturers would simply have to charge for programming if it hoped to recoup its investments.

The incentives to charge for programming grew all the more intense because of two trends in technology pursued by competitors. The first was the creation of emulators, or programs that enabled a machine of one hardware design to run applications programs written for another. In 1963, Honeywell announced an emulator that enabled its new computers to mimic the workhorse IBM 1401, and soon RCA followed with an emulator of its own. By breaking the close ties between programming and particular hardware, emulators accomplished much of what unbundling might accomplish, as Honeywell's choice of the name "Liberator" for its emulator suggests.[54] In the eyes of IBM, emulators allowed firms to get a free ride on its investment in programming. Initially, IBM had planned to introduce System 360 without an emulator. In effect, it hoped to tie users to a new architecture and operating system, and conceivably compel them to develop new applications programs. In the end, however, IBM could not resist the advancing tide and offered software that enabled most System 360 models to operate as if they were a 1401. User surveys suggest that more than half of the time logged by the new machines during the first 2 years was spent in emulator mode.[55]

At about the same time some competitors began offering emulators capable of running a broad array of applications, others introduced machines with a minimum of software tailored for particular niche operations. Firms aiming at the scientific user, such as SDS and DEC, led the way. But over time, other firms showed how these lean machines, unburdened by extensive software, could undercut IBM's more general purpose machines in particular markets.[56]

Taken together, these developments certainly called into question the strategic wisdom of tightly coupling software and hardware. But whether IBM would have responded in the way its lawyers implied, without added pressure from the Justice Department, nevertheless remains open to question. As Bauer understood, IBM remained tied to the idea that software existed to sell hardware. Much of the impetus behind System 360 had been to perpetuate that mode of operations by at once establishing a new basic configuration and spreading the costs of programming across an ever larger group of machines, thus allowing IBM to leverage its volumes more effectively. Ironically, System 360 had also served to create a large base of installed machines capable of running common programs. That base opened unprecedented opportunities for independent software providers to write standard programs (much as the PC would later do on a much more spectacular scale). IBM appears not to have anticipated that development (just as it and other firms would later fail to grasp the profound implications of the PC for software). When IBM did unbundle its software, moreover, it dropped the price of its hardware a mere 3 percent.[57] This figure, though justifiable on certain grounds, certainly fell on the low end of the range anticipated by observers at the time.[58] IBM also made no moves to unbundle the operating system and other control programs. These remained bundled until Amdahl and other manufacturers, capitalizing on the antitrust provisions pertaining to licensing, had placed significant numbers of cloned IBM CPUs on the market and IBM perceived an opportunity to reclaim some of its losses in hardware by selling operating software to these Original Equipment Manufacturer—OEMs

and their customers.[59] (Pressure from the EU during the early 1970s may also have contributed to the decision to market parts of the operating system separately.[60])

If it seems unlikely that IBM would have moved aggressively toward unbundling without pressure from the Justice Department, the question still remains whether IBM could have stemmed the trends in technology and retarded the rise of the software industry had it not unbundled. For those frustrated software entrepreneurs of the mid-1960s who complained they could not hope to make a go of it in the industry so long as IBM gave away its software, this question may appear preposterous. Yet there are some grounds, both theoretical and in the historical evidence, to doubt whether bundling really erected such an impenetrable barrier to entry.

The theoretical grounds involve the matter of whether bundling in this case largely served to facilitate some sort of cross-subsidy between hardware and software that could not long persist under the ordinary course of competition. Software entrepreneurs frequently asserted that IBM used the bloated prices of its hardware to subsidize software. Yet in the eyes of the Justice Department and many others, the subsidy seemed if anything to flow the other way, with IBM's low programming costs per machine giving it a critical advantage in the competition with hardware providers. The pioneering strategies of firms such as DEC, which hardly came into view at the time Justice launched its inquiry but figured prominently in the decision to drop the case, showed how competitors might root out these cross-subsidies and exploit them. Similarly, pioneering software firms such as ADR and Informatics had by the mid-1960s demonstrated how programs targeted toward input/output control and file management could outperform those developed by IBM, in large part because these pioneers found ways to achieve the same level of performance with less hardware.[61] As Bauer of Informatics understood, firms oriented toward sales of hardware felt little incentive to write such software. Their bundles likely harbored significant inefficiencies.

How prevalent were firms such as ADR and Informatics, which managed to exploit these opportunities and crack the market for software even before IBM's move to unbundle? If we restrict our definition strictly to firms selling or licensing proprietary software, the answer is clearly "not very." Phister's data give no accounting of software sales prior to 1963 and record no significant purchases of software by users for another 4 years after that. They do suggest, though, that between 1963 and 1967 the purchased software sector grew from $5 million in annual revenue to $175 million, or about 3 percent of total revenue in the data processing industry (which, coincidentally or otherwise, was the amount IBM chose to drop its hardware prices with unbundling). Because software at this point was so closely tied to data services, we might get a more accurate read on the situation by considering the services sector as well. Interestingly, the share of industry revenues derived from services between 1963 and 1967 declined by almost precisely 3 percent, from nearly 13 percent to just under 10 percent. The rise of standard packaged software during these years appears possibly to have come at the expense of services (though the absolute amount of revenue from services during these years nearly doubled, from $265 million to $560 million).[62]

Did these trends change noticeably after 1968, the year IBM unbundled? Yes, they did, but not in the way one might expect. The share of revenue from software continued to increase at about the same rate for another 2 years, then stabilized from 1969 through 1973 at approximately 4.5 percent (or $600 million in 1973). The real action occurred in services. After its low of just under 10 percent in 1967, the services sector increased its share to 17.5 percent by 1970. It stayed at that level or slightly above for another half decade, when it rose to just over 20 percent. The share derived from hardware virtually mirrored the trend in services, falling sharply from nearly 74 percent in 1967 to 62 percent in 1970, where it remained until further decline in 1975. It was services, then, not software, that grew rapidly in the immediate wake of unbundling. Software did increase its share in the late 1970s, rising to 7.7 percent in 1978. By then, services accounted for 20.5 percent and hardware 58.4 percent.[63]

The rapid rise of services relative to software takes on added significance, moreover, when we consider that the industry figures include IBM. According to Phister, services actually declined in significance at IBM during the late 1960s and early 1970s. In 1966, IBM earned 3.5 percent of its data processing revenue from services, plus another 5.2 percent from the service bureau. By 1972, services accounted for just 0.7 percent of IBM revenue from data processing, with the service bureau contributing another 1.3 percent in its last year of ownership by IBM.[64] Unfortunately, we have no data on the amount of revenue IBM derived from software during these years. Phister estimates that from 1974 through 1978, however, IBM generated between 10.2 and 12.4 percent of its revenue from services, supplies, and software.[65] (This number corresponds fairly closely to the estimate of Charles Lecht that IBM accounted for roughly 8–10 percent of the total data processing industry pie from these activities in 1976.)[66] Given the paltry level of services 2 years before and the identified share of 1.4 percent for supplies, this would suggest IBM derived something on the order of 7.5 percent or more of its data processing revenue from software during these years.[67] If correct, these estimates suggest that IBM accounted for perhaps three-quarters of total industry revenues generated from purchased software products during the decade after unbundling.

What, then, are we to conclude about the significance of unbundling for the software industry during the first 10 years of the new practices? The most important effect appears to have been to establish a clearer separation between hardware manufacture and computer services, much as the Justice Department had attempted with its consent decree of 1956. Competitive forces and trends in technology may have pushed the industry in this direction even in the absence of antitrust action. Some prime movers in services, such as Perot's EDS, had emerged during the years immediately prior to the antitrust investigation that began in 1967. One source estimates that by 1965 some forty significant service providers had emerged, and that the industry included as many as 2800 firms all told.[68] In pursuing its case, the Justice Department clearly focused more on the concerns of hardware manufacturers such as Control Data than on those of the software and services sector.

To the extent that services constitute a branch of software, we can say that antitrust may well have hastened the emergence of the software industry during the late 1960s and early 1970s, if perhaps a bit inadvertently. The action by government certainly did nothing to impede the forces propelling the emergence of a separate and vibrant services sector, and Justice may well have hastened the process by causing IBM to withdraw from services. That withdrawal, however, was balanced to some degree by increased marketing by IBM of standard programs. This packaged program sector lagged behind services and the projected estimates of observers such as Bauer, who had anticipated that independent software providers would soon overtake IBM in this rapidly expanding field during the late 1970s. That development would eventually come to pass, but only after the emergence of the PC during the early 1980s.

The PC, Packaged Software, and Antitrust

During the course of the long antitrust proceedings against IBM, which stretched from January 1969 well into 1982, the American computer industry experienced sustained rapid change.[69] Continual refinement of solid-state production technology made available processors of much higher speed and also dramatically increased the memory and storage capacities of computing systems. Increased capacities gave programmers much greater latitude. Instead of devoting the lion's share of their energies to conserving processor time, programmers increasingly could focus their efforts on making computers receive data in different forms, manipulate it in various ways, and present the results in more comprehensible fashion.[70] Data processing continued its metamorphosis into information processing. The modular design of System 360, in combination with new systems applications such as time-sharing, opened huge opportunities for equipment manufacturers to concentrate on building lower-cost versions of common components such as printers and terminals that could be used within IBM systems. The 1956 consent decree had at last begun to bear fruit. Additional competition came from dynamic new firms such as DEC and Wang Industries. Taking advantage of the plummeting cost and shrinking size of components, these start-up companies built "minicomputers" tailored to serve particular types of users.[71]

Meanwhile, miniaturization unleashed an alternative path of innovation that fell entirely outside the IBM paradigm and the realm of institutional users it served. Individual enthusiasts began to patch together one-of-a-kind computers of limited capacity. Infused with a strong antiinstitutional ideology and renegade spirit, these hackers brought the vision of a "home computer" into reality. The era of the unshackled amateurs did not last for long, however, as firms such as Apple Computer and IBM soon imposed a degree of order on the PC market. Rather than offer a stripped-down, expandable kit that customers could assemble and refine themselves, Apple sold a standard machine that included its own monitor, disk drive, and keyboard. The company also provided several basic software packages. As Apple's revenues soared from three-quarters of a million dollars in 1977 to just

under a billion dollars in 1983, IBM launched a crash program to develop a microcomputer of its own. Its PC, introduced in 1981, immediately captured 26 percent of the market. The impact of the PC went well beyond IBM's own sales, moreover, because the product's modular design and extensive use of licensed components left other manufacturers free to produce clones that accounted for another 50 percent or more of the market. In effect, IBM with the PC repeated its experience with System 360 in mainframe computing, only in fast forward. Drawing on its market presence and its capacity for technical compromise, IBM provided a platform that helped rapidly transform the desktop computer into a standardized mass-produced commodity, then watched as low-cost competitors undercut it in the marketplace.

By all accounts, the rapid diffusion of the PC has been the most important factor in the growth of the packaged software industry.[72] Though virtually no one anticipated it at the time, the PC revolutionized the industry by providing a mass market of unprecedented proportions for standard software products. Because software is expensive to generate but cheap to reproduce, this mass market fundamentally changed the dynamics of an industry that had always been hampered by severe constraints on productivity. Now, software producers could amortize their development costs across a vast number of machines. Network externalities, particularly the increasing social returns from standardization of basic programs, reinforced the phenomenon.

What role did antitrust play in this stunning development? Certainly, we can find little direct evidence that government anticipated these trends from the start and sought actively to give shape to the industry. It may be, however, that the legacy of the antitrust actions of 1956 and the late 1960s did in fact exert some influence over the course of events. Such an argument hinges largely upon the critical decisions by IBM to license both the operating system on a nonexclusive basis from Microsoft and the chip containing the CPU on a similar basis from Intel. Did these decisions, made during the final stages of the long antitrust suit against it, reflect a concern deep within IBM about tying up the industry with closed, proprietary systems? After years of antitrust surveillance, had IBM adjusted its thinking and strategies to the point that it instinctively unbundled?

Perhaps, but more likely, the firm simply failed to anticipate the future. As one executive close to the situation recalled, the thinking of top management was that the PC was a small market, and one cannot make big mistakes in small markets.[73] Watts Humphrey recalls that some within IBM did in fact question the decision to license the operating system, but that in its frustration at not having moved more quickly into the market for small machines, top management suspended its customary vigilance regarding such exposures.[74] Soon enough, moreover, IBM certainly went to considerable efforts to recover from these blunders and to reestablish proprietary control with its own operating system and input/output channels.[75] Of course, by then it had triumphed in the antitrust case and no longer dominated the industry.

If government appears not to have directly stimulated the transformation associated with the PC, it certainly wasted little time in addressing the state of

competition in the industry that resulted. For that transformation had by no means eliminated the need for the essential balancing acts that had long characterized the computer industry and its leading firms. Computers remained machines of indeterminate purpose. Indeed, as they grew more commonplace and came into the hands of a more diverse population, the possibilities of what they might do continued to expand. Within the separate but parallel realms Apple and IBM had created, designers and programmers thus still needed to strike compromises and achieve a balance between standardization and customization.

By the mid-1980s, that ongoing balancing act had come to focus on two fundamental issues—the design and production of the microprocessor, and the basic operating language. With Apple, both were proprietary; in the case of the PC, they were shaped respectively by Intel and Microsoft, the firms IBM had chosen as its original suppliers. In a move that clearly heralded its prominence in hardware production, Intel in the early 1990s began advertising directly to consumers. It gave its processors catchy names and insisted that machines containing its processors carry an "Intel Inside" sticker.[76] Meanwhile, Microsoft had grown more profitable than IBM. As owner of the MS-DOS and Windows operating programs, it supplied the essential gateways through which most users gained access to their PCs.[77]

Like IBM in the early mainframe computer industry, these powerful firms established a degree of uniformity in the essentials of computing without closing off the potential for further development. They continued to introduce new generations of processors and operating systems that placed greater computing power at the hands of individual consumers. Their influence and market power gave suppliers of memory, printers, and monitors confidence to pursue techniques of mass production. Most importantly, software writers could proceed with some assurance that their work would find a broad market and not be rendered obsolete by subsequent changes in basic hardware or in the basic operating system. As a result, the microcomputer industry sustained a vibrant competition to develop new applications, and computers came to perform a much broader array of functions.

And as with IBM before them, these dominant firms attracted virulent criticism. Competitors and some consumers accused them of wielding their market influence unfairly to close off technical alternatives. Vibrant competition first from the Japanese and then from domestic chip manufacturers kept Intel insulated from antitrust prosecution. But critics of Microsoft achieved considerable inroads. Throughout much of the 1990s, they persuaded the Department of Justice and attorneys general of several states to pursue vigorous antitrust action against the software giant. In their most extreme form, these actions would have forced Microsoft to sever all connections with hardware suppliers and banned it from the applications business, in effect leaving the firm to operate as a common carrier for specialized software programs written by others.[78]

A settlement announced in the summer of 1994 stopped short of either action. As it had in the case of IBM, the Justice Department determined that Microsoft managed to provide a healthy stability without stifling development. When a federal judge overturned the settlement in early 1995, the Justice Department and

Microsoft briefly joined in an unlikely alliance that successfully appealed the decision. The erstwhile combatants renewed their hostilities shortly thereafter, however, as Justice Department officials accused Microsoft of violating the 1994 agreement by bundling its operating system with its internet browser and prohibiting suppliers of PCs from displaying icons for rival browsers on the Windows screen. When the first federal judge to hear the case concurred, it appeared Microsoft might be broken apart and the boundaries of the software industry redrawn in the radical fashion its most ardent critics desired. Rulings in the subsequent appeals, together with a change in administration at the Justice Department, produced an outcome considerably less hostile to Microsoft.[79]

These actions against Microsoft bore a striking resemblance to those taken against IBM during the previous half-century of American computing. Following long traditions in antitrust, Justice sought to separate the operating system, which now plays the role once held by hardware and logical design, from the applications software, which occupies the position once held by services (and, to a much lesser degree, software). Justice appeared to be on its strongest grounds when showing clear evidence that Microsoft used the tie between the operating system and other parts of the PC complex to exploit concessions from hardware manufacturers (evidence provided most unequivocally by IBM, now the proselytizer of nonproprietary open systems[80]) and to suppress the emergence of independent providers of applications software. Its proposed remedy, though a bit more drastic than those of the 1950s and 1960s, shared with those earlier actions a desire to break the ties and establish clearer separations. Market segmentation, it was hoped, would foster competition and innovation. Microsoft and its defenders (including many economists) responded that such alleged ties cannot make economic sense over the long haul and that trends in technology would undermine any apparent advantages the firm derived from its dominance in operating systems. As before, it was difficult to see how the actions by Justice would in any way retard the forces of economic competition or impede those trends in technology. Though the settlement left the dominant firm largely unaltered and free for the moment to compete without significant restriction in the marketplace, it also left little doubt that government would continue monitoring the boundaries of computing, as it had throughout the history of the industry.

Notes

1. Two excellent surveys of the industry are Paul E. Ceruzzi, *A History of Modern Computing*, Cambridge, MA, MIT Press, 1998; and Martin Campbell-Kelly and William Aspray, *Computer: a History of the Information Machine*, New York, Basic Books, 1996. For economic analysis of industry performance, see David C. Mowery and Richard R. Nelson, *Sources of Industrial Leadership: Studies of Seven Industries*, Cambridge, Cambridge University Press, 1999, chs 1–4 and 9; David C. Mowery, ed., *The International Computer Software Industry*, New York, Oxford University Press, 1996.
2. This was the recurrent theme of the scores of popular and journalistic accounts of leading firms and business managers during the 1990s and also of many academic works on American competitiveness.

3. Kenneth Flamm, *Creating the Computer: Government, Industry, and High Technology*, Washington, DC, Brookings Institute Press, 1988; Kenneth Flamm, *Targeting the Computer: Government Support and International Competition*, Washington, DC, The Brookings Institution, 1987; Richard C. Lewin, "The Semiconductor Industry," in Richard R. Nelson, ed., *Government and Technical Progress: A Cross-Industry Analysis*, New York, Pergamon Press, 1982; David C. Mowery, "Innovation, Market Structure, and Government Policy in the American Semiconductor Electronics Industry: A Survey," *Research Policy*, 12: 183–197, 1983; Richard N. Langlois and David C. Mowery, "The Federal Government Role in the Development of the U.S. Software Industry," in Mowery, ed., 1996, op. cit., pp. 53–85; Arthur Norberg and Judy O'Neill, *Transforming Computer Technology: Information Processing for the Pentagon, 1962–1986*, Baltimore, The Johns Hopkins University Press, 1996. For a critical view emphasizing the role of the military, see Paul Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America*, Cambridge, MA, MIT Press, 1996.
4. Alfred D. Chandler, Jr., *Inventing the Electronic Century: The Epic Story of the Consumer Electronics and Computer Industries*, New York, Free Press, 2001.
5. Jonathan Khazam and David C. Mowery, "Tails that Wag Dogs: The Influence of Software-based 'Network Externalities' on the Creation of Dominant Designs in RISC Technologies," in Mowery, ed, 1996, op. cit., pp. 86–103; and David C. Mowery, "The Computer Software Industry" in Mowery and Nelson, eds., 1999, op. cit., pp. 133-68.
6. AnnaLee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Cambridge, MA, Harvard University Press, 1994; Martin Kenney, ed., *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*, Stanford, Stanford University Press, 2000.
7. For an excellent introduction to American political economy that raises precisely this dichotomy, see Louis Galambos and Joseph Pratt, *The Rise of the Corporate Commonwealth: United States Business and Public Policy in the 20th Century*, New York, Basic Books, 1988. On the ways in which computing fits larger patterns of government regulation and political economy, see Steven W. Usselman, "Computer and Communications Technology," in Stanley Kutler, ed., *Encyclopedia of the United States in the Twentieth Century*, New York, Scribner's, 1996, pp. 799–829; Steven W. Usselman, "Trying to Keep the Customers Stratified: Government, Business, and the Paths of Innovation in American Railroading and Computing," *Journal of Industrial History* 2: 1–21, 1999.
8. I have chosen the term "platform" rather than "system" because the systems approach tends to exaggerate the degree of rigidity in the subject being studied. For my thinking on systems analysis, see Steven W. Usselman, "Changing Embedded Systems: The Economics and Politics of Innovation in American Railroad Signaling, 1876–1914," in Jane Summerton, ed., *Changing Large Technical Systems*, Boulder, CO, Westview Press, 1994, pp. 93–116. See also Steven W. Usselman, *Regulating Railroad Innovation: Business, Technology, and Politics in America, 1840–1920*, New York, Cambridge University Press, 2002.
9. JoAnne Yates, "Co-evolution of Information-Processing Technology and Use: Interaction between the Life Insurance and Tabulating Industries," *Business History Review*, 67(Spring): 1–51, 1993.
10. For elaboration on these themes, see Usselman, 1999, op. cit.
11. On IBM during its move into computing, see Emerson Pugh, *Building IBM: Shaping an Industry and Its Technology*, Cambridge, MA, MIT Press, 1995; James W. Cortada, *Before the Computer: IBM, NCR, Burroughs, and Remington Rand and the Industry They Created*, Princeton, Princeton University Press, 1993; Robert Sobel, *IBM: Colossus in Transition*, New York, Bantam, 1981; Charles J. Bashe et al., *IBM's Early Computers*, Cambridge, MA,

MIT Press, 1986; Flamm, 1988, op. cit.; Steven W. Usselman, "IBM and its Imitators: Organizational Capabilities and the Emergence of the International Computer Industry," *Business and Economic History* 22(2, Winter): 1–35, 1993, reprinted in David E. H. Edgerton, *Industrial Research and Innovation in Business*, London, Edward Elgar, 1996*a*, pp. 452–486; David E. H. Edgerton, "Fostering a Capacity for Compromise: Business, Government, and the Stages of Innovation in American Computing," *Annals of the History of Computing*, 18(2, Summer): 30–39, 1996*b*.

12. Often, such accounts emphasize the contract to build the SAGE anti-aircraft defense system, cf. Edwards, op. cit., ch. 3.
13. Usselman, 1993, op. cit.; and Edgerton, 1996*b*, op. cit.
14. The close ties between learning and product development at IBM during this period were evident when the physicist Emmanuel Piore arrived from the Naval Research Laboratory in the mid-1950s to take over the newly created IBM Research organization from long-time IBM engineering director Ralph Palmer. Piore promptly returned virtually all of the programs supported by Palmer to the product development laboratories (where Palmer had wanted them all along). This included much of the work on components, including those that would provide the essential basis for the forthcoming line of computers, System 360. See Bashe et al., op. cit.; Emerson W. Pugh et al., *IBM's 360 and Early 370 Computers*, Cambridge, MA, MIT Press, 1991. For an excellent study of component research at IBM, see Ross Knox Bassett, *To the Digital Age: Research Labs, Start-Up Companies, and the Rise of MOS Technology*, Baltimore, MD, The Johns Hopkins University Press, 2002.
15. Sobel, op. cit., pp. 85–88. The decree came in the form of judgments against IBM issued on December 26, 1935 and January 29, 1936. These were upheld and extended with the decree of January 25, 1956. For copies of these decrees, see Roy N. Freed, *Computers and the Law: A Reference Work*, 5th edn., published by the author, 1976.
16. During the early 1930s, sales of cards accounted for as much as three-quarters of IBM's revenue. Cortada, op. cit., pp. 149–154.
17. Cortada, op. cit., chs 14–17, and Flamm, 1988, op. cit.
18. Thomas J. Watson, Jr., interview with Steven Usselman and Richard Wight, March 27, 1986. See also Thomas J. Watson, Jr. and Peter Petre, *Father, Son & Company: My Life at IBM and Beyond*, New York, Bantam Books, 1990, pp. 198–199.
19. Consent decree of January 25, 1956 (settling a suit filed by the Department of Justice on January 21, 1952), issued by Judge David N. Edelstein, reprinted in Freed, op. cit. In the fall of 1956 IBM also settled a private antitrust suit with Sperry-Rand. The firms entered a cross-licensing agreement for patents, with IBM agreeing to pay its competitor $1.25 million per year for the subsequent 8 years, based on its larger market share. *IBM Annual Reports for 1956*, p. 12. For a decade after the consent decree, competitors made little headway in getting their peripherals attached to IBM systems. This changed dramatically, however, with introduction of the modular System 360 in 1964, as discussed below.
20. On the parallels to broadcasting, see Usselman, 1996, op. cit.
21. These stipulations regarding SBC were spelled out in the consent decree of January 25, 1956, reprinted in Freed, op. cit. In a letter to stockholders, Watson identified the creation of SBC as one of four major items in the decree. The others were sales of machines rather than just leasing, licensing of patents, and sale of card presses. *IBM Annual Report for 1956*, p. 6.
22. Figures in this and the following paragraph come from Montgomery Phister, Jr., *Data Processing Technology and Economics*, 2nd edn., Bedford, MA, Santa Monica Publishing Company and Digital Press, 1979, pp. 291, 293, 313.

23. Phister, op. cit., p. 599.
24. *IBM Annual Reports, 1959–1967*. See especially *IBM Annual Report for 1963*, pp. 8–10.
25. On ASDD, see *IBM Annual Report for 1959*, pp. 11 and 16, and *IBM Annual Report for 1961*, p. 19. See also Bashe, op. cit., pp. 306 and 553–554.
26. *IBM Annual Report for 1960*, p. 8, and *IBM Annual Report for 1961*, pp. 7–8, 16–17.
27. On the creation of Data Centers, see *IBM Annual Report for 1959*, p. 12; *IBM Annual Report for 1960*, p. 11; and *IBM Annual Reports for 1965*, p. 16. By 1965, IBM operated some twenty-six data centers and education centers in the United States.
28. James P. Titus, "Washington Commentary: Computer Inquiries Increase in Washington," *Communications of the Association of Computing Machinery*, 10(4, April): 246, 1967, reprinted in Freed, op. cit.
29. These figures come from *IBM Annual Report for 1972*, pp. 26–27. Similar data for other years can be found in the appropriate annual reports throughout the years IBM operated SBC.
30. Watson and Petre, op. cit., p. 387, and *IBM Annual Report for 1972*, pp. 26–27. IBM also gave CDC a package of cash and contracts, including $15 million in compensation for legal fees, $26 million in fringe benefits for SBC employees, and guarantees that it would purchase $11 million in services and research from SBC and Control Data during each of the next 5 years.
31. This is a recurrent theme of the recollections contained in Robert L. Glass, *In the Beginning: Personal Reflections of Software Pioneers*, Los Alamitos, CA, IEEE Computer Society, 1999. See also Emerson Pugh, *Memories that Shaped an Industry*, Cambridge, MA, MIT Press, 1984; Usselman, 1993, op. cit.
32. Ira Sager and Diane Brady, "Big Blue's blunt Bohemian," *Business Week*, 3633 (June 14): 107–108, 1999.
33. Phister, op. cit., p. 291, 599.
34. Ibid., p. 624. These data are contained in *IBM Annual Reports* from 1974 and several subsequent years.
35. On the rise of service bureaus, see Franklin Fisher et al., *IBM and the U.S. Data Processing Industry*, New York, Praeger, 1983*a*, pp. 87–91, 253–261, 318–320, and p. 426; Detlev J. Hoch et al., *Secrets of Software Success: Management Insights from 100 Software Firms around the World*, Boston, MA, Harvard Business School Press, 2000; W. Edward Steinmuller, "The U.S. Software Industry: An Analysis and Interpretative History," in Mowery, ed., 1996, op. cit., pp. 15–52; Fred Gruenberger, ed., *Expanding Use of Computers in the 70's: Markets, Needs, and Technology*, New York, Prentice-Hall, 1971; Martin Campbell-Kelly, *A History of the Software Industry: From Airline Reservations to Sonic the Hedgehog*, Cambridge, MA, MIT Press, 2003.
36. Hoch, *Secrets of Software Success*, p. 141; Robert Slater, *Portraits in Silicon,* Cambridge, MA, MIT Press, 1992, ch. 12.
37. Fisher et al., 1983*a*, op. cit., pp. 318–320 and 426; and W. Edward Steinmuller, "The U.S. Software Industry: An Analysis and Interpretative History."
38. On the shift in pricing, see Watson and Petre, op. cit., pp. 357–358; Fisher et al., 1983*a*, op. cit., pp. 304–315, p. 407.
39. Walter F. Bauer, "Software Markets in the 70s," in Gruenberger, ed., op. cit., pp. 53–57.
40. Basic sources on the lawsuit include two volumes prepared by consultants to IBM's legal team, Fisher et al., 1983*a*, op. cit.; Franklin Fisher et al., *Folded, Spindled, and Mutilated: Economic Analysis and U.S. v. IBM*, Cambridge, MA, MIT Press, 1983*b*; Gerald W. Brock, *The U.S. Computer Industry: A Study in Market Power*, Cambridge, MA, Ballinger, 1975;

Freed, op. cit.; *IBM Annual Reports, 1967–1982*. The decision to prosecute can only be understood within the context of what was a watershed moment in American political economy, when influential figures in the regulatory establishment embarked on a fundamental reexamination of the brokering agreements that had characterized much of American economic policy. The case against IBM marched in almost exact parallel with that against AT&T, each reaching its denoument on a single afternoon in 1982. See Usselman, 1996, op. cit.; Peter Temin and with Louis Galambos, *The Fall of the Bell System: A Study in Prices and Politics*, New York, Cambridge University Press, 1987.

41. Watson and Petre, op. cit. pp. 380–381.
42. Watt S. Humphrey, "Reflections on a Software Life," in Glass, ed., *In the Beginning*, pp. 29–53.
43. Campbell-Kelly, op. cit.; Martin Campbell-Kelly, "Development and Structure of the International Software Industry, 1950–1990," *Business and Economic History* 24, 2 (Winter 1995): 73–110; Steinmuller, op. cit.; Mowery, op. cit. and 1996, op. cit., ch. 1. "There is little doubt that the historical development of the U.S. software industry has benefited from a tough federal antitrust policy," writes Mowery (op. cit., p. 147), "which may have prevented IBM from cementing a dominant position as a supplier of both hardware and software in the late 1960s."
44. Phister, op cit., p. 300.
45. The importance of early product announcements associated with System 360 to the antitrust cases of the 1960s and 1970s is readily apparent in the extensive product development histories contained in the legal files prepared by IBM lawyers. Copies of these files exist in the IBM Archives and at the Hagley Museum and Library, Wilmington, Delaware. See also Fisher et al., 1983*b*, op. cit., pp. 289–310; documents in Freed, *Computers and the Law*; and comments about the CDC settlement by Watson and Petre, op. cit., p. 389.
46. Watson and Petre, op. cit., pp. 380–389. The phrase "tails wagging dogs" refers to the role of linkages between software and hardware and the resulting bandwagon effects. See Khazam and Mowery, "Tails that Wag Dogs," op. cit.
47. Freed, op. cit., contains numerous documents from the late 1960s and early 1970s pertaining to the copyrighting and patenting of software. These include an undated clipping, probably from the *Washington Post c.*1968, regarding a 2-day symposium held at George Washington University that attracted nearly 400 registrants, including the Commissioner of Patents, many figures from the emergent software supply business, and representatives from hardware suppliers such as IBM and General Electric. Important articles from the period include John F. Banzhaf III, "Copyright Protection for Computer Programs," *Columbia Law Review*, 64: 12–74, 1964; David Bender, "Computer Programs: Should They be Patentable," *Columbia Law Review*, 68: 240–259, 1968; Stephen Breyer, "The Uneasy Case for Copyright: A Study of Copyright in Books, Photocopies, and Computer Programs," *Harvard Law Review*, 84: 281, 1970. For additional perspective, see National Academy, *Intellectual Property Issues in Software*, Washington, DC, National Academy Press, 1991; Robert P. Merges, "A Comparative Look at Property Rights and the Software Industry," in Mowery, ed., 1996, op. cit., pp. 272–303.
48. The change in IBM policy can be seen by comparing attitudes expressed at the conference held at George Washington University in 1968 (see previous note) with those laid out by an IBM patent attorney in *Communications of the Association of Computing Machinery* 14(4): 274, 1971. For additional perspective, see Humphrey, op. cit.; Jonathan Band and Masanobu Katoh, *Interfaces on Trial: Intellectual Property and Interoperability in the Global Software Industry*, Boulder, CO, Westview Press, 1995, pp. 19–25.

49. Bauer, op. cit.
50. Fisher et al., 1983*b*, op. cit., especially pp. 204–218.
51. Phister, op. cit., p. 327.
52. Watson's frustrations with the absence of a learning curve in programming are legendary. He reiterated them in an interview with Usselman and Wight, March 27, 1986.
53. Frederick P. Brooks, Jr., *The Mythical Man-Month: Essays on Software Engineering*, Anniversary Edn., Reading, MA, Addison-Wesley, 1995; original 1975.
54. On emulators, see Fisher et al., 1983*a*, op. cit., p. 89, and Brock, op. cit., p. 15. Their importance in altering IBM strategy associated with System 360 is readily apparent in IBM corporate files pertaining to the launch of the new line.
55. Fisher et al., 1983*a*, op. cit., p. 118.
56. Fisher et al., 1983*a*, op. cit., pp. 264–278. Ceruzzi, op. cit., is especially insightful about the rise of DEC.
57. Humphrey, op. cit., pp. 40–41, and Fisher 1983*a*, op. cit., p. 175.
58. Humphrey, op. cit., recalls that the public anticipated price drops for hardware of 25–40%.
59. Band and Katoh, op. cit., pp. 19 and 25; Charles P. Lecht, *The Waves of Change: A Techo-Economic Analysis of the Data Processing Industry*, Advanced Computer Techniques Corp., 1977, p. 38; and Fisher, *IBM and the U.S. Data Processing Industry*, pp. 175–179. Fisher does not mention Amdahl as a factor in the decision to price operating systems separately in the late 1970s.
60. Band and Katoh, op. cit., p. 22.
61. Hoch, op. cit. p. 31. See also Fisher, et al., 1983*a*, op. cit., pp. 322–326, discussing the 1965 testimony of Lawrence Welke, president of International Computer Programs, Incorporated, in a private antitrust suit. This testimony has become one of the most frequently cited sources on the history of the early software industry.
62. Phister, op. cit., pp. 598–599.
63. Ibid., pp. 598–599.
64. Ibid., pp. 291, 313.
65. Ibid., p. 624.
66. Lecht, op. cit., p. 38.
67. Phister, op. cit., pp. 291, 624.
68. The source is Lawrence Welke, cited in Hoch, et al., *Secrets of Software Success*, p. 28; in Fisher et al., 1983*a*, op. cit., pp. 322–323; and in Steinmuller, op. cit.
69. Ceruzzi, op. cit., chs 6–8.
70. Campbell-Kelly, op. cit.
71. For an excellent history and analysis of the minicomputer and microcomputer industries, see Richard N. Langlois, "External Economies and Economic Progress: The Case of the Microcomputer Industry," *Business History Review*, 66: 1–50, 1992. This and the following paragraph are based largely on his account.
72. See the works of Mowery, Steinmuller, Hoch, and Campbell-Kelly cited above. "Every software guru I have talked with admits to being caught by surprise by the microcomputer revolution and its outgrowth, the shrink-wrapped software industry," wrote Fred Brooks in 1995 in his epilogue to the twentieth anniversary edition of his classic treatise on software. "This is beyond doubt the crucial change of the two decades since [1975]." Brooks, p. 279.
73. Paul Carroll, *Big Blues: The Unmaking of IBM*, New York, Crown, 1993, pp. 22–23.
74. Humphrey, op. cit., p. 50.

75. Carroll, op. cit., documents several efforts to reestablish proprietary control during the 1980s.
76. For two perspectives on Intel, see Andrew S. Grove, *Only the Paranoid Survive*, New York, Doubleday, 1996; Tim Jackson, *Inside Intel: Andy Grove and the Rise of the World's Most Powerful Chip Company*, New York, Dutton, 1997.
77. The literature on Microsoft is voluminous. Good places to start are Ceruzzi, *A History of the Computer*; Randall E. Stross, *The Microsoft Way: The Real Story of How the Company Outsmarts its Competition*, Reading, MA, Addison-Wesley, 1996. For a recent assessment that puts Microsoft in perspective, see Campbell-Kelly, op. cit.
78. The case has been the subject of extraordinary journalistic coverage. Three compilations are: Joel Brinkley and Steve Lohr, *U.S. v. Microsoft: The Inside Story of the Landmark Case*, New York, McGraw-Hill, 2001; Richard B. McKenzie, *Trust on Trial: How the Microsoft Case is Reframing the Rules of Competition*, Cambridge, MA, Perseus, 2001; Ken Auletta, *World War 3.0: Microsoft and Its Enemies*, New York, Random House, 2001. For more academic analyses of issues germane to the case, see Jerry Ellig, ed., *Dynamic Competition and Public Policy: Technology, Innovation, and Antitrust Issues*, Cambridge and New York, Cambridge University Press, 2001.
79. This assessment is based on contemporary news accounts from fall 2002.
80. Elizabeth Wasserman and Patrick Thibodeau, "Microsoft, IBM Face Off," *Info World*, 21 (24, June 4): 30, 1999.

5

"Beat IBM." Entrepreneurial Bureaucracy: A Contradiction in Terms?

Seiichiro Yonekura

Introduction

Today Japan has become the second largest economy in the world with many internationally competitive industries in various fields. When we consider that Japan's gross domestic product (GDP) per capita in 1950 was almost equal to that of Mexico and Brazil and only 16 percent of that of the United States and 44 percent of that of the United Kingdom, its economic success in the post-Second World War is quite remarkable. There seems little doubt that the private sector made enormous efforts after the war and was largely responsible for this development. Numerous outstanding managers and engineers made it possible for Japan to rapidly catch up with other advanced countries, and they created the very foundation of the present-day Japanese economy. On the other hand, one cannot ignore the fact that the government and its ministries also contributed to this unprecedented growth in many ways. Hence, although we strongly adhere to the notion that the main actors in Japan's development were private industries, we should not underestimate the role of bureaucrats, and those of the Ministry of International Trade and Industry (MITI) in particular.[1]

Sometimes MITI has been referred to as "the leader of Japan Inc." or "notorious MITI." In actual fact, however, it has made a catalog of high-profile errors of judgment. Examples include its opposition to Kawasaki Steel's Chiba Plant and Honda's car manufacture; unfair guidance for the petrochemical industry; the creation of a national champion model car; its emphasis on the Fifth Generation Computer Project, and so on.[2] In spite of these errors, there were several successful cases in which MITI's industrial policies were very effective. By and large, though, these were only evident when MITI and private industry exchanged information and created new knowledge, or when MITI's coordination policy facilitated intense competition as well as cooperation. A knowledge creation process can be seen in the promotion policy of the machinery industry by which MITI tried to articulate what the private sector tacitly needed into its own (MITI's) policy, and then the private sector in turn internalized the policy into their business improvement processes.[3] The fact that MITI's coordination process facilitated further

competition can be seen in the case of the steel,[4] petrochemical,[5] computer,[6] and semiconductor industries.[7]

However, we still do not clearly understand how coordination facilitates competition as well as cooperation and what kind of mechanism works for this process. In this chapter, by studying the embryonic stage of the Japanese computer industry, we explore the relationship between cooperation and competition and how this mechanism created a competitive industry. Our tentative conclusion is that the postwar industrial policies of MITI were only effective when they succeeded in achieving a balance between "market coordination" and "planned coordination." In order to achieve this balance, MITI created a "functional division of labor" in business activities by coordinating cooperation and competition. In other words, MITI divided business activities into several functions, allowing the private sectors to compete against each other in some functions, and coordinated cooperative efforts between private firms in other functions.

Before we proceed, an explanation of what we mean by "market coordination" and "planned coordination" is necessary. "Market coordination" permits the market, with its focus on competition, to play the role in allocating resources and coordinating industrial structure, which determines the growth and decline of an industry. "Planned coordination" means carrying out resource distribution and industrial structure coordination through government adjustment mechanisms by means of administrative planning and guidance. As we can see from the collapse of the Soviet Union, market coordination is usually better than planned coordination for resource distribution and wealth increase in the longer term. However, as the market coordination mechanism fails sometimes, governmental interventions are occasionally justified. Market coordination by itself is bereft of ideas and cannot achieve grand goals in the short term.[8] Examples include the construction of national infrastructure; creating regulations on undesirable economic externalities such as pollution and environmental destruction; dealing with increases in unemployment, the presence of monopolies and cartels; and protecting infant industries. If market coordination proceeds without any planning, for example, a newly established industry would be fatally damaged by foreign enterprises with stronger competitive power. On the other hand, excessive planning by the government would unduly preserve inefficient enterprises, which would result in a heavier cost burden on the government as well as consumers. There is also the attendant risk to generate a tendency on the part of enterprises of overdependence on the government. It is for this reason that a national champion policy, that is, creating one large company to be competitive, does not often work well. Managing this conflicting situation has indeed been a major issue of postwar Japanese industrial policy, particularly in the case of promoting new industries.

It is our contention in this chapter that MITI, whether fortuitously or otherwise, seemed to hit upon a strategy for the computer industry, which called for coordination between appropriate administrative guidance and intervention on the one hand, and allowing autonomy and self-determination for private companies on the other. By heeding the advice of industry and cooperating positively with private companies,

MITI adopted either a "planned coordination" approach or a "market coordination" approach according to industry function. Some functions, such as research and development (R&D), were deemed so important as to merit planned coordination, while other functions, such as manufacturing were considered more appropriate to market coordination. This approach, which we can refer to as "intervention by function", was one of several interventionist approaches used by MITI. The intervention by function approach, which we emphasize in this chapter, worked well for the computer industry. We have identified other approaches used by MITI, which we refer to as "intervention by phase" and "intervention by infrastructure." These were considered more relevant to other industries and are not elaborated upon in this chapter.

Background—The Computer Industry

The computer industry, which is the focus of this chapter, was established in the 1950s. What explains the ability of Japanese computer manufacturers to rapidly catch up with the best in the world to such an extent that they came almost to press on the citadel of IBM? Although there are several pioneering works in this topic,[9] there remains much to be clarified in this process. The aforementioned literature emphasizes how, by using large amounts of money, MITI subsidized the industry and how effectively MITI used a public corporation as a competitive weapon. In actual fact, however, MITI did not have any power over the Ministry of Finance (MOF) and private enterprises as the previous literature supposes. Rather, MITI often locked horns with MOF over the budget allocation and had to deal with fiercely independent and competitive manufacturers. Without considering these conflicting factors, it is difficult to understand and appreciate the essential contributions MITI made to the Japanese computer industry.

When we look at the sales of the computer sector in 1991, those of IBM amounted to as much as $87 billion. On the other hand, Fujitsu, the largest manufacturer in Japan, had sales of $18 billion, while the sales of the Japanese manufacturers as a whole reached $54 billion. When looking at the worldwide market share in 1990 of mainframe multipurpose computers on a shipment basis, IBM still accounted for a dominant 53.2 percent. The total global market share of the three major Japanese mainframe manufacturers (Fujitsu, Hitachi, and NEC) occupied only 17.2 percent. Nevertheless, Japan's market share was still higher than that of the major European nations: 4.2 percent for Germany (Siemens and Comparex) and 2.4 percent for France (Bull).[10] This is a remarkable achievement, and hence the computer industry provides a good example for a study on how government industrial policy affects industrial development.

In the 1940s, several individuals or teams at private companies and universities independently started manufacturing computers or electronic calculators. There was no integrated national policy in the early stages of the industry.[11] Being inspired by the computer development efforts of the private enterprises, which started during the first half of 1950s, MITI made up its mind to assist the promotion

of the Japanese computer industry with a national policy. MITI officials began to have a keen recognition of the importance of the computer industry and its expansive influence over other industries. Also the fostering of the computer industry was a matter of national prestige since it helped to define one's credentials as a leading industrial nation.

From the beginning, Japanese computer manufacturers were confronted with foreign enterprises that were clearly superior to them. Competing with foreign competitors, IBM in particular, the Japanese industry had many obstacles such as the requirement for huge R&D investments that no single company could afford. IBM's entry into the Japanese market occurred in the late 1950s and the trade deficit increased.

In order to obtain a budget from the MOF to assist the development of the industry, MITI needed to persuade MOF of the significance of the industry from a long-term perspective. At that time, MOF, carefully watching the balance of international trade, understood the importance of the industry both technologically and financially. MOF, therefore, consistently requested restructuring and consolidation in the industry, that is, the adoption of a national champion policy. MOF thought that it would be more economical and effective for the Japanese computer industry to reduce the number of players to, preferably, one national champion. On the other hand, the private enterprises insisted on their independence and opposed strongly any control by the government. They, thus, requested government assistance only in such areas as technological development and sales subsidies that were related to the adjustment of competition frameworks. While it was easy for MITI and MOF to ban the import of foreign computers, this would damage the rationalization programs and international competitiveness of other industries. MITI, faced with these contradictory requests, was obliged to seek a method to let competition and planning effectively coexist.

Before we scrutinize more closely what MITI and the Japanese computer industry did, it is illuminating to refer to the statistical impact of their efforts. In 1962, IBM's market share in Japan was 27.3 percent, while in 1964 in the former West Germany and France, it accounted for as much as 66.7 and 48.6 percent, respectively. Less than 10 years later, in 1971, IBM's market share in Japan was 33.2 percent, while being 62.3 percent in West Germany, and 56.6 percent in France. After a further 10 years, in 1980, IBM's market share was 28.7 percent in Japan, 63.9 percent in West Germany, and 56.9 percent in France. These figures indicate that a similar proportion was maintained throughout these years. IBM alone continued to dominate the market share for 20 years in West Germany and France, although it could only occupy about one-third of the Japanese market.[12] Furthermore, with the exception of IBM, only Japanese mainframe computer manufacturers had survived by the 1990s.

Mosquitoes versus an Elephant

In 1959 MITI's serious policy involvement in computers started, when Morihiko Hiramatsu, presently the governor of Oita Prefecture in southern Japan, was

appointed as assistant chief (*kacho-hosa*) of the electronic section, Heavy Industry Department of MITI. In April 1960, Morihiko Hiramatsu sat down at a table to negotiate with Jim Bergenschtock, vice president of IBM in a room of the Hotel New Japan. Hiramatsu was MITI's assistant chief of the electronics section, and was accompanying his manager, Minoru Furusawa, the section chief. There were two major concerns on the agenda in this negotiation between MITI and IBM. First, MITI had been strongly requesting IBM to make its basic patent for computers available to Japanese manufacturers. Second, IBM had been requesting MITI to give IBM Japan the status of a corporation under the 'Foreign Capital Law' (the law concerning foreign capital) so as to allow IBM Japan to repatriate its profits. However, neither party conceded and the negotiation was at a stalemate. MITI did not want to give exceptional treatment to IBM, while IBM had a strong no-licensing policy and a 100-percent-owned subsidiary policy. During the course of the negotiation, the Japanese manufacturers, in desperate need for IBM's patent license, repeated their petition to MITI asking for a compromise as soon as possible. The manufacturers had already made huge R&D investments and were ready to start mass production by using the IBM patent. Therefore, they were concerned that the negotiations would irretrievably break down.

The full-scale development of computers began in the late 1950s in Japan, about 10 years behind the completion of ENIAC in the United States in 1946. At the beginning, a parametron device, a product invented by Eiichi Goto, a researcher at the University of Tokyo, was used for vacuum tubes, but was subsequently superseded by the transistor. Toshiba started computer development work in 1950, Fujitsu in 1952, NEC in 1955, and Hitachi in 1956. As a result, the FACOM 100 (Fujitsu) was completed in 1954, the NEAC 2201 (NEC) in 1958, and the HITAC 101 (Hitachi) and TOSBAC 2100 (Toshiba) in 1959. Behind these achievements, there existed strong support from two national science laboratories, MITI's Electrotechnical Laboratory (ETL), led by Hiroshi Wada at that time, and the Electrical Communication Laboratory (ECL) of the Nippon Telegraph & Telephone Public Corporation, where Zen-ichi Kiyasu was a strong leader at that time. These government research institutes tried to transfer their technology to manufacturers by requesting them to join in production trials and disclosing their completed products.[13]

Meanwhile, the import of US-made computers such as IBM and Univac had just begun, which led to a growing sense of crisis within MITI about the overwhelming technological advantage of US computers over the Japanese products. In order to secure a stable foundation for their computer industry policy, MITI enacted the Electronics Industry Promotion Special Measure Law in 1957 and established the Electronics Industry Section under the Heavy Industry Department, where Hiramatsu joined in 1959. Moreover, the Electronics Industry Deliberative Council was established for better communication between the domestic manufacturers and ministries. Likewise, the manufacturers founded the Japan Electronics Industry Development Association in 1958, as an organ to represent the interests of the industry. Later in the 1950s, both the government and the private sector together established a cooperative system in order to implement industrial policy.[14]

By the late 1950s, the Japanese manufacturers were to some extent successful in producing computers. However, there remained an obstacle in selling their products. This was the issue of a patent that IBM possessed, and which was another point that Hiramatsu and Bergenschtock discussed at the above-mentioned negotiation. In 1960, IBM possessed about 5000 patents nationally and internationally related to computer technology. With regard to the main circuit patent, any infringement of which would certainly contravene the law in production and sales of the computers, more than thirty patents had already been granted in Japan and another forty were still on the waiting list for inspection. The Patent Committee of the Japan Electronics Industry Development Association judged that it would be impossible to ignore IBM's basic patent issue in order to proceed with their production and sales, and they requested MITI's Electronic Industry Section to start a negotiation with IBM on the issue.

There were heated arguments at the negotiation table. MITI, including Hiramatsu, implied that IBM might possibly contravene US Antitrust Law if they would not open their patent. On the other hand, Bergenschtock demanded that Japan should grant IBM preferential treatment, using their world policy as their shield that they would not make any joint corporation with foreign country.[15] At the last minute, MITI finally presented IBM with a simultaneous solution for the two agendas, a barter of IBM's basic patent for preferential treatment. After a tough and long negotiation process, Bergenschtock eventually accepted the offer and the negotiation seemed to reach a peaceful conclusion. However, on the day of signing the agreement in late April, Bergenschtock, with an order from the US head office, suddenly insisted that IBM Japan would produce computers in Japan, which certainly broke down the negotiation. Considering the situation, and with advice from Hiramatsu, Shigeru Sabashi, Director of MITI's Heavy Industry Department, had to make the ultimate decision and concluded the agreement by accepting IBM's demand. Hiramatsu writes the story as follows:

> Mr. Sabashi, Director of the Heavy Industry Department, was very furious and said to Bergenschtock: "Japanese manufactures are like mosquitoes while you are an elephant. If you start producing computers in our country, our manufacturers will be trampled underfoot." Our negotiation was on the verge of rupture. However, with the pleas of Japanese manufactures that they would not be able to proceed with their production unless they were given a license from IBM, the negotiation was finally settled by giving the restriction on production.[16]

As a result, IBM was granted production rights in Japan and remittance of its profit in foreign currency in exchange for making the IBM basic patent available to the Japanese manufacturers. Further negotiations between Hiramatsu and Bergenschtock ensued on the details, and the Japanese manufacturers (which included NEC, Hitachi, Fujitsu, Oki, Toshiba, Matsushita Communication Industry) obtained a license under the basic patent of IBM after December 1960. Hiramatsu also succeeded in getting IBM to accept a certain compromise in its domestic production. Bergenschtock accepted the condition whereby IBM Japan would delay the start of its domestic production by 2 years, rather than be placed under a restriction on the number of units to be produced, and that it would

deliberate with MITI thereafter, too.[17] Thus, the domestic production of IBM computers, particularly the compact model IBM 1401, which was very popular at that time, was postponed until 1963. In the meantime, the Japanese manufacturers were given a valuable lead-time to develop comparable models to IBM's.

Most of the Japanese manufacturers took advantage of the restriction period imposed on IBM Japan, and concluded technological alliances with US manufacturers who were competing against IBM, as a means to a faster and less expensive route in development. The other purpose of such alliances was to obtain know-how on the development of peripheral computer equipment and software programs in which the Japanese manufacturers had a disadvantage. NEC, having the top share among the Japanese manufacturers at that time, entered into technological cooperation with Honeywell in April 1962, and in 1964 it announced the launch of NEAC 2200, a domestic version of Honeywell's H-200. In May 1961, Hitachi concluded a technical collaboration agreement with RCA in parallel with its own development project, and in 1962 the RCA-301 was developed domestically as the HITAC 3010. Likewise, Toshiba collaborated with General Electric (GE), Mitsubishi with TRW, and Oki with Sperryland (Oki-Univac was established in 1963), and launched domestic versions of models developed by their respective partners. Only Fujitsu chose not to enter into any technological cooperation with US manufacturers in its belief that it would be meaningless to collaborate with other companies except IBM.[18] Fujitsu thus followed the path of self-development of new models.[19]

Although the basic patent license was granted, there still was an apparent discrepancy between foreign computers and domestically manufactured ones, and the future of the latter did not seem bright. The 1961 statistics show that foreign machines then accounted for 78.9 percent of the total shipment of computers in Japan, while the share of domestic ones was only 21.1 percent.[20] Under these conditions, MITI adopted a much more direct method to protect the infant industry. In its "Basic Policy and Plan for Trade Liberalization" published in June 1960, MITI listed the electronics industry at the bottom of its list of candidates for liberalization. In addition to high tariffs, it started a number of direct protection measures such as import quota under the Export and Import Transaction Law, the individual examination of foreign capital investment in Japan under the Foreign Capital Law, and the individual examination of technological introduction.

Since its launch in October 1959, the IBM 1401 completely dominated the US market because of its excellent performance. It was expected that the IBM 1401 would also come to dominate the Japanese market, when IBM could start exports to Japan. In fact, applications for IBM 1401 import licenses rushed to MITI in 1961. The protection measures imposed by MITI could not do anything about technological superiority. The next step for Hiramatsu to take was only to hinder or obstruct the import of the IBM 1401 as much as possible. At that time, prior to trade liberalization in Japan, MITI approval was required to import foreign-made computers. Taking advantage of his position as Assistant Chief of the Electronics Industry Section, Hiramatsu dared to neglect the import applications for IBM computers filed by users.[21] When enquiries and complaints were made about the

delays in granting approvals, he summoned the applicants to the MITI office and strongly recommended them to introduce domestic computers. Shigeo Yamamoto, who belonged to the Data Processing Department of Matsushita Electric at that time, recalled the following: "I had been using one unit of IBM and went to MITI to try to get another one to deal with increasing business. Mr. Hiramatsu roared at me and said that I should look for those businesses for which a domestic computer can do the job and use the domestic computer for such business."[22]

It is said that because of such a reputation, Hiramatsu's nickname at that time was "Devil Hiramatsu." As a matter of course, domestic computers were delivered with priority to public institutions such as government and municipal offices and national universities. According to data for August 1963, seven units of foreign-made machines were installed at government and municipal offices versus thirteen domestic units; and one foreign machine versus twenty domestic ones were installed at national universities.[23] During the first half of the 1960s, Hiramatsu and other members of the Electronics Industry Section tried to restrict the flooding of IBM machines in Japan by using any and all possible measures. It was like the desperate resistance of a mosquito in the face of the threat from IBM. Sahashi expresses the concept behind the actions of the MITI bureaucrats as follows:

> If we leave this late comer, and, so-to-speak, infant and immature industry alone, it would be smashed by one stroke. We must protect it with the utmost effort. If it were another industry, we might be allowed to close our eyes and be indifferent. Japan cannot be proud of herself as a leading industrial nation if domestic electronic computers were to be completely beaten.[24]

The protection of an infant industry, therefore, justifies government intervention to supplement market failure. However, there is fallout from such a protective policy. One problem is the burden put on the nation and computer users. The import quota and high tariffs made Japanese computer users buy either expensive imported machines or inferior domestic machines, and, consequently, Japanese consumers as a whole would not benefit in a long run. Another concern is that the use of computers with inferior accuracy would adversely impact the competitiveness of other important industries as well. As mentioned above, MITI succeeded to persuade governmental offices and national universities to install domestic computers. In the private sectors, however, the use of high performance computers such as the IBM 1401 was critical to their competitiveness. For example, the steel industry had just started its rationalization program, and it was necessary to be equipped with the most efficient computers to compete in the world market.[25] MITI, emphasizing the promotion of the steel industry, was faced with a serious contradiction. Unless this dilemma was resolved, the government's protection policy could not be deemed economically rational in the long term.

A National Champion Policy and Repercussions for Private Enterprises

In August 1960, the Electronics Industry Section of MITI announced "Countermeasures for Domestic Production of Electronic Computers," and expressed the frustrations MITI had about the computer industry at that time.

In order to cope with the liberalisation of electronic computers, which will occur inevitably in the near future, a rapid improvement in domestic technology is absolutely essential. If we were to accept liberalisation under the current conditions of the development speed of domestic technology, not only would foreign products monopolise our electronic computer market, but also the progress of domestic electronic computer production technology, so far fostered at best, would become stagnant. Consequently, the development of our electronics industry as a whole would become extremely hopeless.[26]

As shown by the above paragraph, the Electronics Industry Section considered the future of the Japanese computer industry to be pessimistic during this period. Thus, the Section suddenly developed a plan for the creation of a national champion company as a direct backup to the industry. In October 1960, it presented a proposal entitled "About Japan's Electronic Computer National Company." This stressed the importance of planned production by the effective utilization of funds and engineers, the sharing of production models, the unification of codes, and to achieve such measures as the introduction of rental systems, the development of mainframe models, and the promotion of programmers and planners. With such a plan, MITI not only recommended that the above-mentioned measures be adopted, but that such a publicly sponsored company should produce its own computers. The plan aimed at consolidating the computer manufacturers into one company and introducing programmed production that would be carried out under governmental control.

There were two major reasons behind such a policy. One was strong pressure from MOF in funding the budget for the domestic manufacture of computers. The second was the imminent prospect of trade liberalization. From the beginning, MOF was reluctant to appropriate a huge amount of budget for the computer industry and particularly expressed objections to its appropriation by a number of enterprises individually.[27] At that time, the trade balance of Japan started showing signs of improvement to get out of deficit. The priority for financial and monetary investments and loans, for which MOF was responsible, was the power, marine transportation, and coal industries that were of a more public nature. Therefore, it was necessary for MITI to present MOF with a justification for the loans by arranging the structure of an official company. To persuade MOF, MITI was extremely careful in its preparation and even made forecasts showing trends for the following decade.[28] It is not difficult to imagine that MITI preferred a form of public corporation to allowing several competing private enterprises to stand in parallel. It was an urgent task for MITI to give extensive assistance measures for the rapid setting up of the computer industry. With the benefit of hindsight, one can see that Japan was on the brink of falling into the trap of fostering a national champion enterprise for the computer industry, a mistake committed by the United Kingdom and France. Hiramatsu recalls,

MOF would not listen to us if the industry did not speak as one voice and it would also be difficult to get a consensus even within MITI. It was necessary to show that the industry was united to seriously think about its future as well as the future of Japan. The predominant view both at MITI and MOF was that it would not be possible to compete against IBM if

the domestic manufacturers maintained their efforts individually, without any co-ordination. Unless they could get together at once, as in the case of the Japan Aeroplane Manufacturing Company, it would be impossible for the government to support a fragmented industry.[29]

The other reason that MITI quickly proposed the public corporation plan was the impending large-scale trade liberalization. At the time, the Japanese government desperately wanted to play a greater part in international society, namely as a member of the Organization for Economic Cooperation and Development (OECD). In order to join the club, Japan had to accept the agreements of the Kennedy Round by which the OECD, and the American government in particular, aimed to realize reductions or the total abolition of tariffs among the advanced countries.[30] Faced with the prospect of a flood of imports, MITI considered it justifiable to intervene into the activities of private enterprise under the pretext that restructuring important industries would be essential to cope with the coming trade liberalization. A symbolic incident of the sense of urgency at MITI was the introduction in vain of the "Law on Extraordinary Measures for the Promotion of Specific Industry (*Tokushinho*)." By 1963, MITI under the strong leadership of Shigeru Sabashi, a very patriotic and heavy-handed deputy vice minister, strove to enact the law to increase Japan's international competitiveness. The aim of this law was to implement industrial organization over the existing framework of legal constraints, such as the anti-monopoly Law, to cope with the capital liberalization that would soon be inevitable. Its major objective was to artificially carry out the restructuring and consolidation of important industries by planning, rather than allowing market mechanisms to make industrial reorganization. Sabashi insisted that "a co-operative method between the government and private sector" should carry out the consolidations.[31] He intended to implement the plan by collaboration between the government and private enterprises, namely, by the creation of semipublic corporations. However, what came across in the minds of private enterprise management was a recurrence of the wartime-controlled economy.

Therefore, not only banks, but also private enterprises opposed this bill, and consequently politicians became negative about its enactment. This "bill without sponsors," supported only by MITI for its enactment, ended up in a void before the parliament proposal on its enactment. The efforts of MITI to give a legal justification for its intervention in industry had thus failed. Later, Sabashi recorded as follows, recollecting what happened at that time:

> The State had absolute power during wartime under the National General Mobilisation Law, and unilaterally and forcefully mobilised everything toward the pursuit of the War. Even today, I believe a kind of National General Mobilisation Law would be necessary to have Japan develop to the rank of a first class country. The law (we proposed at that time) was a completely different law from the one during the wartime: it would provide general mobilisation of the nation in such a way that all the talent in our country should be collectively utilised. The development of Japan can never be realised if everyone is allowed to say anything and do anything at his/her free will.[32]

In his mind, the motor vehicle and computer industries were the most urgent candidates for reorganization. In a famous episode, Sabashi and Soichiro Honda,

the founder of Honda, had to literally fight over MITI's permission of Honda's automobile production. For Sabashi, who thought that every Japanese car manufacturer should produce a national car model by using a common design and common parts, it seemed nothing but insane that Honda wanted to enter car production, since there were already ten car manufacturers in Japan. When we look at the ability of the Japanese car manufacturers in the 1950s, it was very reasonable for government officials to assume that Japan's small manufacturers would not compete with the likes of GM, Ford, and Chrysler. The same logic applied to the computer industry. No one could believe that Japanese mosquitoes could compete with the world computer giant, IBM.

However, it was the private corporations who fiercely opposed MITI's proposal. They strongly appealed that the free initiative of private enterprises should be assured, particularly in manufacturing and sales. Shojiro Kosakabashi, Manager of the Communication Equipment Sales Department at Toshiba's Communication Equipment Division at that time, criticized the public corporation plan as follows:

> It is absolutely troublesome for the industry to have restrictions on our initiative to get subsidies. The public corporation plan was proposed in order to promote the development of large computers which had been lagging behind. However, the joint development proposal would nip in the bud the free development of the industry that was just started . . . When I said to Mr. Hiramatsu that it would be better to think twice about the national corporation plan, he told me the industry would be beaten by IBM if we continued saying such nonsense in our separate ways.[33]

Koji Kobayashi, then managing director and later chairman of NEC, not only opposed the plan but also gave Hiramatsu the hint of a new measure. He insisted that the scope of the public corporation should be restricted to rental alone, and that MITI should be firm in backing up the domestic manufacturers. Hiramatsu stated as follows the objection of Kobayashi: "The manufacturers at that time were proud of their spirit that they would not submit to control by the government. Mr. Kobayashi took every opportunity to ask me to allow private companies to take their respective initiatives. He believed that it would be a better system if each company made their own computers and the government would just buy them."[34] Although this was splendid for private companies, it was difficult for the government to believe. The national corporation plan, however, could not finally be realized as planned owing to strong conflict among the ministries, and sustained objections on the part of manufacturers.

Functional Division of Labor between Public and Private

During the first half of the 1960s, the above-mentioned heavy-handed trends were prevailing among MITI as a whole. However, Hiramatsu had started thinking about an alternative plan with the advice of Koji Kobayashi of NEC. It may be termed a "functional division of labor" between the public and private companies. He tried to apply the idea of the public corporation to a certain function of private industry. Considering his position at MITI and his relationship with MOF,

Hiramatsu, of course, could not change his attitude as earnest promoter of the national corporation plan until it had finally failed in 1960. However, he says that, at the back of his mind, he was already aware at that time of the efficiency of the private sector's initiatives. In retrospect, Hiramatsu states his thinking at that time as follows, though one must be careful to assess its face value because it was his recollection of events:[35]

> The computer industry would grow rapidly and related businesses would be constantly created. The number of employees would also expand. Under this rapid growth, buildings and factories for computer firms would soon become too small to handle the growth and they should move to bigger and bigger buildings and factories. If this were a public company, in which MOF would closely and minutely check every single move, you would never know when approval would be obtained even when you wish to move or employ only one office employee. To get involved in such an agile business as computers, I began to think that private companies were suitable because they are more flexible.[36]

After the failure of the national corporation plan, MITI changed its policy from a direct to an indirect approach. It decided to shore up its policy to support spontaneous management of the private enterprises. The basic guideline at that time was based on Hiramatsu's second plan, namely to divide the computer business into discrete functions, some to which the government would provide administrative guidance while the others were left solely to the private sector's initiative. More concretely, by dividing the business activity into, say, three important functions, such as R&D, manufacturing, and marketing, Hiramatsu left, say, the manufacturing function to the private initiative. For R&D and marketing, he thought some kind of public intervention might be justified. According to Kobayashi's advice, Hiramastu decided to establish a semipublic rental company that bought the computers the private companies produced. As to R&D, he decided that subsidies and technical assistance from ETL and ECL would only be available when the private companies formed a joint venture or alliance for the development of large computers.

In August 1961, the Japan Electronic Computer Corporation (JECC) was established under the guidance of MITI as a semipublic and semiprivate computer rental company. NEC, Toshiba, Hitachi, Fujitsu, Oki, Mitsubishi, and Matsushita participated in the capital formation of JECC together with a special loan from the Japan Development Bank (JDB) and joint loans from the private banks.[37] MITI and the Japanese computer companies realized that a powerful competitive advantage of IBM was not only its technology but also its rental system. At that time, IBM did not sell its computers, but rented them to its customers. The rental system adopted by IBM was very advantageous for the customers, since computers were very expensive and their technologies rapidly progressed and became obsolete. Owing to the rental, customers could install expensive computers for a relatively small amount of initial investment and it was not necessary for them to worry about technological obsoleteness. The rental system, therefore, was a valuable competitive weapon for the salesperson at IBM. Furthermore, only corporations with a large cash flow such as IBM could enjoy the rental system, since they had already accumulated necessary funds for future R&D expenditure. The ordinary computer

manufacturers, and the latecomers in particular, needed to retrieve the development cost as soon as possible, otherwise they experienced cash flow difficulties or were unable to develop the next generation of computers.

For the private Japanese manufacturers who had just started joint development with their American counterparts, the first priority was to establish something equal to IBM's rental system. Thus, Hiramatsu came up with the idea of creating a company that specialized in the rental system. The JDB initially hesitated to make the loan, saying that legally speaking the rental system could not be seen as a physical facility, since the contractual obligation of the JDB was to make loans available only to such physical facilities. Hiramatsu, however, exerted himself to persuade the JDB to make the loan to JECC: "I prepared and brought the explanatory material to the JDB explaining how it would not be necessary to modify the Law on the JDB and how to perceive the rental system as a facility. Eventually, I succeeded in convincing them to loan one billion yen from the budget of fiscal year 1961."[38]

JECC: Coordination and Competition

JECC was thus established to alleviate the monetary burdens on the Japanese manufacturers from the rental system. However, it did not completely relieve them from the pressures of market competition as Anchordorguy has studied assiduously.[39] We would like to show how JECC realized the coexistence of a coordination and a competition mechanism.

Under the original national corporation plan, it was deemed feasible for the national corporation to purchase computers from private firms as a contracted package, and rented computer systems would be taken back. Because each private firm was to be merely a production division, it was not necessary for them to take on after-sales responsibility. Under the JECC system, however, the manufacturers would have to take back the rented computers when the rental contract period expired or the renter returned the computer. At such times, the manufacturers would also have to pay JECC the balance of the price at which JECC purchased the computers in the first place. In other words, even if the manufacturers could sell their computers at marked-up prices to JECC, they would have to buy them back after the rental period. Even though JECC might purchase the computers at higher prices, it was necessary for the manufacturers to pay attention to price and quality, since they would have to buy them back when customers were not satisfied. The real function of JECC, therefore, was just to provide manufacturers with a time lag for fund collection, and JECC never took on the risk of sales by itself. Consequently, the system could just relieve the manufacturers from their cash flow burden at the initial period without depriving them of their incentive to improve price and quality. On the other hand, although the manufacturers had to take on the risk of rental buyback, they were assured to have the liberty to embark on their own technological development and management strategies. JECC was thus designed to handle coordination and competition simultaneously.

FONTAC as Joint R&D

It was the joint project of Fujitsu-Oki-NEC-Triple Allied Computer (FONTAC) in the function of R&D that played a similar role to that of JECC in marketing and sales. In September 1962, MITI incorporated the Research Association for Computer Technology under the 1961 enacted "Law for Research Association for Mining and Manufacturing Technology." Its purpose was to develop much larger electronic computers than those that each manufacturer had been developing, either jointly with an American partner or independently. Because of the large amount of subsidies provided, Fujitsu, Oki, and NEC decided to join the Association. They received a subsidy to the tune of as much as ¥350 million, and engaged, under the auspices of the Agency of Industrial Science & Technology of MITI, in joint R&D for a large-scale computer, targeting the IBM 7040/7044. This jointly developed computer was named FONTAC, taking the initials of the three participant companies, and was completed in 1964. This model itself was not aimed at public sales but rather for the technology accumulation of each company that could then utilize the acquired expertise in their later products.

The FONTAC provided the participants not only with cooperation but also with the spur of competition. Through the cooperative process of FONTAC, the participant companies shared the same technology and know-how, and they could gain some insight into one another's secret methodologies to some extent through the subsequent competitive development programs. These factors brought about strong incentives to try to develop technology superseding that of the other participants and promoted better technological development. This was a good indication that joint development programs not only serve to improve cooperation but also serve to intensify competition.[40]

Thus, the government support measures were implemented in such ways as to divide business activity into functions: Production to the initiative of private enterprises; establishing JECC, a joint rental company, for sales; and organizing FONTAC, a joint development project, for highly advanced R&D. This served to limit the scope of government planning, and not to impede the competitive incentives of domestic manufacturers for production and development. Moreover, such functional division involved cooperation and competition in dual senses. First, the coexistence of cooperation and competition was achieved because not everything was put under national policy. In addition, skilful collaboration and competition were simultaneously promoted under the joint research and joint rental systems.

Thereafter, Hiramatsu moved to the Industrial Environment Protection Section as section chief in 1964, and then to the Petroleum Planning Section in 1965. Thus, he was temporarily withdrawn from the forefront of computer industry policy until he returned as first section manager of the Electronics Policy Section in 1969, after having served as the Information Industry office manager.

While Hiramatsu was away from the computer industry, a major setback affected the Japanese computer manufacturers. In April 1964, IBM announced the introduction of a revolutionary new model, the System 360. This had been developed with huge investment, against objections even within IBM, to resolve problems of

incompatibility between many product lines. The System 360 heralded the integration of all IBM's product lines into one, and was a pioneer of third generation computing by using integrated circuits as the core processors. As its name indicated, the System 360 was characterized by multipurpose applications covering all-round (360°) uses, from office requirements to scientific and technical calculations. With the appearance of this powerful system, all the traditional models of the Japanese manufacturers, as well as foreign manufacturers suddenly became obsolete. In the year when the System 360 appeared, Machine Bull, the biggest computer manufacturer in France, was acquired by GE because it could no longer sustain the excessive burden of rental funds and further development costs.[41] In September 1964, Matsushita, one of the original members of JECC, withdrew altogether from the costly computer business in order to concentrate its resources on electrical appliances. IBM's System 360 achieved such an impact that it served to accelerate the partial restructuring of the computer industry in each country. At that time, the Law on Temporary Measures for the Promotion of the Electronics Industry was about to expire, but MITI, faced with the introduction of the System 360, decided to extend the term of the Law by 6 more years. Under these circumstances, the Electronics Industry Council published its "Report to Enhance the International Competitive Advantage of the Computer Industry" in April 1966. In August of that year, based upon this report, MITI launched the "Development Project for Super Efficient Computers" to defeat the System 360. In October of the same year, the Japan Software Corporation was founded to start joint research on software with the aid of capital and technical assistance from the government.

Japan Software Corporation: A Failure in Policy

In the previous section, we pointed out that the government's promotion policies, such as JECC and FONTAC, enhanced the competitive incentives among the domestic manufacturers as well as helping to foster cooperation. However, when we look at the design of the Japan Software Corporation, we can find certain elements that caused a failure in coordination between cooperation and competition.

The basic concept of the Japan Software Corporation was very similar to that of JECC and FONTAC. Its purpose was to develop a common language for multipurpose machines by creating a corporation in which Fujitsu, Hitachi, and NEC participated. The motive of the creation of the company was MITI's belief that the unorganized and uncoordinated software development of each manufacture was a total waste of precious resources. In addition, MITI was convinced that if the software for multipurpose computers could be made common, it would enable the computer users to save the switching costs from one model to that of another manufacturer, as the IBM 360 had done.

However, the Japan Software Corporation failed to work as MITI had expected, since it did not fully appreciate the nature of competition in the industry at that time. After participating in the FONTAC project, the manufacturers Fujitsu, Oki, and NEC, in particular, considered that software was the key for differentiating themselves from their competitors, since they had already shared much common

technological knowledge. They therefore tried to lock their customers in the line-up of their own products by daring to make their software closed. Under such strategies, although compatibility was important for the industry as a whole, each manufacturer had little incentive to positively promote common software.

Groupings as a Compromise

In July 1969, the Electronics Industry Section was reorganised into the Electronics Policy Section at MITI, and Hiramatu was appointed its first section chief. In the late 1960s, as the heavy industries such as steelmaking, shipbuilding, plant engineering, and car manufacture began to gain in international competitiveness and to earn foreign currencies, the sections in charge of the heavy industries were proud of their achievements. Meanwhile the sections related to the computer industry such as the Electronics Policy Section were considered to be a waste of precious budget.[41] Nevertheless, from 1968 onward, both the numbers of units and sales amounts of the domestic computers surpassed those of the foreign products in the Japanese market. Hiramatsu recognized that MITI's industrial promotion policy had achieved success to a certain extent insofar as hardware was concerned. In fact, in 1970, market share in terms of the amount of money installed showed that IBM Japan accounted for 31.9 percent, by far the largest, while the Japanese manufacturers occupied reasonable positions with Fujitsu at 15 percent, Hitachi at 16 percent, and NEC at 19 percent.

Toward the end of the 1960s, the focus of computer related policy moved to software, as we have examined above, since it was recognized that the industry had fairly well caught up in the field of hardware. MITI clearly recognized that the information age, with implications broader than that of the computers age, had arrived and established a "Committee for the Information Industry" at the Industrial Structure Council. In May 1969, the committee published its "Report Concerning the Policy for Information Processing and Information Industry," which starts with the statement, "The developed countries including Japan are to knock at the door of the information-oriented society." In parallel with this movement, in September 1969, the Liberal Democratic Party (LDP) organized a "Diet Members Association for the Information Industry" with Tomisaburo Hashimoto as Chairman and Taro Nakayama as secretary general. They held a series of breakfast meetings at the headquarter of the LDP and studied the information policies of the relevant government ministries. Hiramatsu, together with several Diet members, visited the United States to observe the information industry there and had the following impression: "At the IBM Watson Laboratory in the U.S.A., I heard from Dr. Reona Ezaki that there were as many as five Nobel Prize winners who had been engaged in computer software development in the Laboratory. I strongly felt that from now on it would be the age of software rather than hardware."[42]

After returning home, Hiramatsu endeavored to enact the bill of the Law on the Promotion of Information Processing (*Joho shiko Shori Shinko ho*) in order to enhance the software industry in Japan. This was finally brought into being as the Law

concerning the Information Technology Promotion Association in May 1970. Until the establishment of the law, Hiramatsu went around the Diet members appealing to them on the importance of the software industry by citing the example of a piano (hardware) and musical notes (software). He also worked hard to establish the Association for Promoting Information-related Enterprises so that loans might be obtained for software development; such loans had been very difficult to obtain since software was nontangible and hard to value accurately. It was also in November 1970 that he started the National Examination for Information Processing Technicians in order to train programmers required for the software industry. As we can see from the above, he did anything he could for the industry at that time.

In June 1970, however, a new crisis emerged among the Japanese computer manufacturers, who had only recently gained confidence by catching up with IBM. This was the announcement of the IBM System 370. IBM launched the System 370, successor to the System 360, earlier than the industry had expected. The System 370 had complete compatibility with the System 360, and therefore, current users could make use of the software assets of the System 360 with the System 370. The System 370 also featured medium-sized integrated circuits for its logical and memory devices and achieved much higher speeds and a larger capacity by means of a virtual memory system.[43] Although it was not as revolutionary a product as to open fourth generation computing, as expected, it was in a sense a third-and-a-half generation product. Nevertheless, there was no doubt that it would threaten the Japanese manufacturers, as had been the case with the System 360. As a matter of fact, even in the United States, the industry shake-out had begun. In 1970, Honeywell acquired the computer department of GE. In the following year, RCA withdrew from the computer business as the result of its failure to develop a model comparable to the System 370.[44]

Recognizing the System 370 as a trigger, Hiramatsu again started working as middleman between MOF and private enterprises to obtain subsidies for development of comparable models to the System 370. Hiramatsu started similar negotiations to those of 10 years previously with MOF to obtain budgets for the development of comparable models. This time, MOF, recognizing the importance of the computer industry, agreed to grant a budget for the industry, but was again reluctant to subsidize several enterprises. MOF made it clear to MITI that without adequate justification for the allocation of the budget, it would be very difficult to subsidize several companies separately. In order to subsidize the industry, MOF wanted to consolidate, or at least coordinate, the number of companies, hopefully to only one company.[45] However, unlike 10 years previously, Hiramatsu firmly believed in the power of competition among private enterprises, and declined the MOF proposals. As a final compromise with MOF, Hiramatsu conjured up the idea of coordinating the industry into three different groups by way of collaboration among the six companies. In accordance with his idea, MITI requested such a grouping to the respective companies in April 1971. It was not only MOF that put pressure on Hiramatsu to restructure the industry. The politicians at LDP became very sceptical about the fragmented efforts of the companies. Hiramatsu said,

In about 1971, Mr. Toyosaburo Hashimoto, Chairman of the Diet Members' Association of Information Technologies, summoned me about the information industry. He gave me a memo. It showed the concept of restructuring the information industry into two organisations: one for communications being Nippon Telegraph & Telephone Public Corporation, and another for computing being a public corporation to be formed by integrating all the Japanese companies into one. I could not agree with this idea. The Japanese companies were strong rivals and they could not be seen to lag behind their Japanese competitors although they might lose against IBM. If they had been integrated into one national policy corporation, there would have been a high possibility that the power of the private sector would be reduced.[46]

Of course, Hiramatsu could not accept Hashimoto's proposal. He asked Hashimoto to withdraw his proposal by explaining the above-mentioned three-group concept. However, Hiramatsu's counterproposal of the three-group plan was not accepted by the respective manufacturers, as there was little incentive for them to form such a grouping. A similar situation to that of the Japan Software Corporation was about to emerge again.

Early in the 1970s, the demand from the United States for Japan to open its computer market was mounting. The economic downturn in the United States and Japan's trade surplus helped to motivate the request for the opening-up of the Japanese market. MITI had already decided upon the sequence of market liberalization by industries, and the computer industry was bottom of the list. Even at that time, MITI thought that it was still necessary to maintain the existing policy to earn time for strengthening the competitiveness of the domestic manufacturers. However, it was increasingly difficult for diplomatic and political reasons to further postpone the demands for liberalization. Manufacturers were opposed to the liberalization and filed petitions against it. However, 50 percent capital liberalization in computer manufacturing, sales and rental businesses, and trade liberalization of peripheral equipment, excluding memories and terminals, were announced in June 1971.[47] In the face of further imminent liberalization, Hiramatsu made serious efforts to coordinate the six Japanese manufacturers into three groups and obtain subsidies, based on such a grouping, to develop comparable machines to the System 370. The Electronics Policy Section had a plan, at the time of the proposal of the 1972 budget, to appropriate development funds for the Japanese manufacturers from the special account using the duties on imported computers. In September 1971, Hiramatsu even visited Kakuei Tanaka, the minister of MITI at that time, to win his support for the idea.

While trying to obtain subsidies, Hiramatsu urged the manufacturers to group together because of the threat of liberalization. The grouping concept was made difficult owing to the different perspectives of each manufacturer. At a restaurant in September 1971, Hiramatsu met Toshio Ikeda, head of Fujitsu's computer division, who told him that Fujitsu wanted to tie up with Hitachi to develop IBM-compatible lines. Fujitsu already had experience of joint development with Oki and NEC on the FONTAC project, and it wanted to explore the technological level of Hitachi, Japan's second largest mainframe producer after Fujitsu at this time.

(Mr. Ikeda said), a loose coupled alliance such as a technological tie-up would be better than a consolidation, because it made it easier to persuade people both inside and outside the companies. It was more than desirable for me that Hitachi and Fujitsu, the industry number one and number two, respectively, should tie up together. I replied, shaking hands with Mr. Ikeda, "Fine. Please proceed accordingly".[48]

Thus, with the tie-up between Fujitsu and Hitachi at the outset, the groupings were completed in November 1971, and MOF and MITI decided to appropriate ¥34.1 billion (about $1.2 billion), not from a special budget account but from a general account, for 3 years starting from 1972. This, in fact, continued until 1976, and about ¥57 billion (about $1.8 billion) were appropriated for the development of new models of the respective groups.

The MITI used to maneuver the manufacturers away from the risks of liberalization by one method or another. However, once liberalization was inevitable, MITI pushed the manufacturers to accelerate their development under the pressure of the liberalization schedule. In the postwar period, MITI used trade liberalization as a means for policy enforcement by which it facilitated industrial rationalization. Thus, each group completed its development of new series in time for the liberalization schedule; Fujitsu and Hitachi, NEC and Toshiba, and Mitsubishi and Oki. After 1974, they successfully announced the launching of competitive models to the System 370: The M Series for Fujitsu/Hitachi, the ACOS Series for NEC/Toshiba, and the COSMO Series for Mitsubishi/Oki.[49]

On April 1, 1976, overall trade and capital liberalization was implemented for the computer industry including software. The development of comparable models to the IBM machine had been completed by that time. The liberalization did not therefore bring about a sharp increase of foreign computers as had been feared. At this stage, therefore, the Japanese industrial policy for the computer industry achieved its planned result, avoiding IBM dominance by fostering domestic producers.

Hiramatsu had left the Electronics Policy Section by then, and followed thereafter a career in the General Affairs Section of the Basic Industries Bureau and then as Councilor in the Regional Development Bureau of the National Land Agency. In July 1975, he resigned from MITI, and started his second life at the age of 51 as vice governor of Oita prefecture in Kyushu Island. In April 1979, he ran for the governor and was successfully elected. Although Oita prefecture had a small local government, his ideas for industrial and regional development bloomed. In order to revitalize the local economy, for instance, he started the so-called "One Village, One Product" movement in November 1979 by which he encouraged each village in Oita to promote a different, specialized (and hopefully competitive) product. The movement became one of the best practices in Japan, and even the Chinese government as well as other Japanese prefectures came to learn from him.[50] While promoting the movement, he was very keen to promote the importance of information networks and proposed the Oita Hyper Network concept by which he has tried to change Oita from a small agriculturally based prefecture to a dynamic, knowledge-intensive prefecture. He is still the governor and remains very active.

Conclusion

Morihiko Hiramatsu assumed responsibilities in MITI at an important phase at the beginning of the Japanese computer industry. Among his achievements, JECC and FONTAC were considered an effective industrial policy for the computer industry. However, the essence of industrial policy for the Japanese computer industry did not lie solely in such isolated individual measures. Rather, it was in avoiding consolidation or nationalization of the industry and in skillfully choosing which industrial activities and functions of the various manufacturers should cooperate with each other and which should be left to compete with each other (Table 5.1). MITI adopted a policy of intervention by function. In other words, a key to the success of Japanese computer industrial policy lay in the coexistence of cooperation and competition policy. Without losing the competitive initiative of private manufacturers, the policy realized a framework of market coordination and planned coordination, according to the individual functions of R&D, manufacturing, software development and sales (in particular, the rental system).

The simultaneous coexistence of market coordination (competition) and planned coordination (cooperation) was the very essence of the relationship between the government and private enterprises in Japan. Hiramatsu, who later became Governor of Oita prefecture, recalls his days when he was engaged in the industrial policy of computers as follows:

> Engineers like Eiichi Goto (at the University of Tokyo) and Yoichi Kiyasu (at the Electric Laboratory of MITI) made their best efforts. In the private sector, people such as Toshio Ikeda of Fujitsu made enormous efforts to create better computers. Bureaucrats also did their best within their power and responsibility. Politicians also backed us up. I happened to play the role of a conductor of an orchestra, as my duty required. They were indeed good days.[51]

As Hiramatsu mentioned, they were "good days" for several reasons. There was a wide economic gap between the United States and Japan, a wide technological gap between IBM and Japanese manufacturers, less globalization of the world economy, the firm consensus that Japan needed to develop a viable computer industry, and no personal computers (PCs) or Internet. It was easier for Japanese bureaucrats to justify their protective and promotional measures for the industry.

Table 5.1. *The relationship between industry function and MITI policy*

	R&D	Manufacturing	Software	Sales (Rental)
Cooperation	Yes	No	Yes and then No	Yes
Competition	No	Yes	Yes	No
Policy methods	Joint R&D (FONTAC)		Japan Software Corp. (Failed)	Joint Sales Corp. (JECC)

Compared with those days, the whole environment of the computer industry today has changed so drastically that it is not only very difficult but also deemed unwise for bureaucrats to intervene in the competition process of the industry. The successful example of the past cannot necessarily be applied to the problems of the present and the future. One thing we can say, however, is that the policy of coordination between cooperation and competition according to function worked in the early stages of the development of the Japanese mainframe computer industry. This policy, and the desire to beat IBM, made it possible for Japanese manufacturers such as Fujitsu, Hitachi, NEC, Oki, and Mitsubishi to remain as competitors of IBM in the world market.

Notes

1. In the 1980s when people praised the role of MITI for the Japanese economic development, we put a greater emphasis on the Japanese private sector. In fact, it was the private companies' efforts to survive in the very difficult postwar environment that proved crucial. Seiichiro Yonekura, *The Japanese Iron and Steel Industry 1850–1990: Continuity and Discontinuity*, London, Macmillan, 1994. In contrast, during the 1990s, people began to accuse the Japanese government and MITI of excessive intervention into industrial and private economic life. Only now can one start to reevaluate what was the essence of Japanese industrial policy and the extent of its success.
2. Yonekura, 1994, op. cit.; Scott Callon, *Divided Sun: MITI and the Breakdown of Japanese High-Tech Industrial Policy, 1975–1993*, Stanford, Ca., Stanford University Press, 1995; David Friedman, *The Misunderstood Miracle: Industrial Development and Political Change in Japan*, Ithaca, NY, Cornell University Press, 1988.
3. Seiichiro Yonekura, "Industrial Associations as Interactive Knowledge Creation: The Emergence of the Japanese Industrial Policy," *Japanese Yearbook on Business History*, Tokyo, 13: 27–52, 1996*a*; According to Nonaka and Takeuchi, new knowledge is created by a conversion process between tacit and explicit knowledge. See Ikujiro Nonaka and Takeuchi Hirotaka, *The Knowledge Creating Company*, Oxford University Press, 1995.
4. Yonekura 1994, op. cit.
5. Tsuneo Suzuki, "Sengo gata sangyo seisaku no seiritu (An Emergence of the Postwar Industrial Policy)," in Hiraoki Yamazaki and Kikkawa Takeo, eds., *Nihon teki keiei no renzoku to danzetsu* (*Continuity and Discontinuity of the Japanese Management Style*), Tokyo, Iwanami Shoten, 1995.
6. Marie Anchordoguy, "The Public Corporation: A Potent Japanese Policy Weapon," *Political Science Quarterly*, 103: 707–724, 1988.
7. Kiyonori Sakakibara, "Kyodo kenkyu-kaihatu no sosiki to menejimento (Organization and Management of a Cooperative R&D)," in Keichi Imai, ed., *Inobeshon to Sosiki* (*Innovation and Organization*), Tokyo, Toyo Keizai Shinpo-sha, 1986.
8. Ryutaro Komiya, et al., eds. *Nihon No Sagyo Seisaku* (*Industrial Policy in Japan*), Tokyo, University of Tokyo Press, 1984.
9. Anchordoguy, 1988, op. cit.; Marie Anchordoguy, *Computers Inc.: Japan's Challenge to IBM*, Cambridge, MA, Harvard University Press, 1989; Kenneth Flamm, *Targeting the Computer: Government Support and International Competition*, Washington DC, The Brookings Institute, 1987; Martin Fransman, *The Market and Beyond: Information Technology in Japan*, New York, Cambridge University Press, 1990.

10. Kazuichi Sakamoto, *Konpyu-ta sangyo* (*The Computer Industry*), Tokyo, Yuhikaku, 1992.
11. Seiichiro Yonekura, "The Beginning of the Japanese Computer Industry." Working Paper No. 97-11, Tokyo, Institute of Innovation Research, Hitotsubashi University, 1996*b*.
12. Sakamoto, op. cit.
13. MITI's ETL and NTT's ECL made a great contribution to technology transfer from public research institutes to private companies in the 1950s. See Fransman, op. cit., ch. 2.
14. For an effective industrial policy implementation, a trinity comprising the policy measure (a law), an industrial association comprised of the major private companies and a neutral council comprised of scholars and users was indispensable. Yonekura, 1996*a*, op. cit.
15. Endo describes the detailed discussion between Hiramatsu and Bergenschtock. See Satoru Endo, *Keisanki-ya kaku tatakaeri* (*How the Japanese Computer Crazes Fought*), Tokyo, Aschi, 1996.
16. Morihiko Hiramatsu, *Watashi no rireki-sho* (*Biography*), Nihon keizai shinbun-sha, June 16, 1992.
17. Kiyoshi Nakamura, "Konpyuta sangyo (The Computer Industry)," in Haruto Takeda, ed., *Nihon kigyo no dainamizumu* (*Dynamism of the Japanese Corporations*), Tokyo, University of Tokyo Press, 1995, p. 246.
18. Michael Lynskey, "The Transfer of Resources and Competencies for Developing Technological Capabilities," *Technology Analysis and Strategic Management*, 11(3), 1999.
19. Toshio Ikeda, a computer genius at Fujitsu, strongly believed that any alliance except with IBM would amount to nothing. He tried to negotiate an alliance with IBM but IBM refused. Seiichiro Yonekura and Clahsen Hans-Urgen, "Gijyutu to keiei no hazama de (Between Technologist and Manager: Toshio Ikeda)," in Hiroyuki Itami, Tadao Kagono, Mataro Miyamoto, and Seiichiro Yonekura, eds., *Nihon kigyo no keiei kodo* (*The Mangerial Activities of Japanese Firms*), Tokyo, Yuhikaku, 1998.
20. Japan Electronic Computer Corporation (JECC), *JECC jyu-nen shi* (*A 10 year history of JECC*), Tokyo, JECC, 1973, p. 82.
21. Yasunori Tateishi, *Hasha no gosan* (*Winner's miscalculation*), Nihon keizai shinbun-sha, Tokyo, 1993, p. 162.
22. JECC, "JECC monogatari (A Story of JECC)," *JECC News*, April 1, 1981.
23. JECC, *Go-nen no ayumi* (*A 5-year history of JECC*), Tokyo, JECC, 1968; Fransman, op. cit.
24. Ito Mitsuharu, ed., *Sengo sangyo-shi heno shogen* (*Eye-witnesses to the Postwar Industrial Development*), Tokyo, Mainichi shinbun-sha, 1977, p. 142.
25. Yonekura, 1994, op. cit.
26. JECC, 1968, op. cit., p. 22.
27. Anchordoguy, 1988, op. cit.
28. JECC, August 16, 1981.
29. JECC, April 1 1981; August 16, 1981, op. cit.
30. In 1964, Japan finally became an official member of the OECD and the protectionist tariffs were dramatically reduced.
31. Shigeru Sabashi, *Ishoku Kanryo* (*A Unique bureaucrat*), Tokyo, Tokuma Bunko, 1967.
32. Ibid., p. 248.
33. JECC, April 1 1981; October 1, 1981, op. cit.
34. JECC, April 1, 1981, op. cit.
35. After reading the Japanese version of this chapter, Mr Hiramatsu wrote a letter to the author, Yonekura, about this sentence. He said it was not in hindsight that he thought of the efficiency of the private sector.

36. JECC, August 16, 1981, op. cit.
37. Fujitsu, NEC, *Hitachi*, Toshiba, Oki, Mitsubishi, and Matsushita paid ¥1.05 billion (¥150 million each). JECC, op. cit.
38. JECC, October 1, 1981, op. cit.
39. Anchordoguy, 1989, op. cit.
40. Ken'ichi Imai describes how the coordination process of MITI facilitates competition through information sharing among the private companies. Ken'ichi Imai, *Gendai sangyo sosiki* (*A Modern Industrial Organization*), Tokyo, Iwanami Shoten, 1979. Kiyonori Sakakibara also put emphasis on the competition aspect of the joint research by examining the VLSI Joint Research Consortium. Kiyonori Sakakibara, "Kyodo kenkyu-kaihatu no sosiki to menejimento (Organization and Management of a Cooperative R&D)," in Keichi Imai, ed., *Inobeshon to Sosiki* (*Innovation and Organization*), Toyko, Toyo Keizai Shinpo-sha, 1986.
41. Pierre E. Mounier-Kuhn, "Un Exporteur Dynamique Mais Vulnerable: La Compagnie Des Machines Bull (1948–1964)," *Histoire, Economie et Societe*, 4, 1995, pp. 658-60.
42. Since the offices of the computer industry related sections were located behind the elevators in MITI's building, the sections in charge of heavy industries contemptuously referred to the computer related sections as "Eremuko Troupe" (troupe across the elevator).
43. Hiramatsu, June 17, 1992, op. cit.
44. Sakamoto, op. cit., p. 103.
45. After the introduction of the IBM 370, a pessimistic feeling that it would be very difficult for the Japanese computer manufactures to compete with IBM emerged in Japan, too. Nakamura, op. cit., pp. 256–257.
46. Tateishi, op. cit., p. 148.
47. Hiramatsu, June 19, 1992, op. cit.
48. Koji Shinjo, "Konpyuta Sangyo (Computer Industry)," in Komiya et al., op. cit., p. 310.
49. Hiramatsu, 1992, op. cit.
50. Shinjo, op. cit.
51. Endo, op. cit., p. 358.
52. Hiramatsu, June 30, 1992, op. cit.

6

Empire and Technology: Information Technology Policy in Postwar Britain and France

Richard Coopey

Technology and Economy in Britain and France: Relative Decline?

The British computer manufacturing industry seems, at first glance, to be a typical example of the relative decline which has been a feature of the British industrial economy for most of the twentieth century. From a position of leadership, for example, in the development of some of the early working, stored-program computers, and in the case of ICL, the establishment of the largest manufacturer outside the United States in the 1960s, domestic capability was, by the 1980s, eclipsed by US and Japanese manufacturers. ICL, initially envisaged as the national champion of British high-technology industry, has been owned by Fujitsu since 1990 and the British market is highly dependent on imported information technology (IT).

Debates about the relative decline of the British economy have been around since at least the last quarter of the nineteenth century.[1] Many culprits have been suggested for the loss of primacy in terms of world manufacturing, including the penalties of being first to industrialize, the inertia or anti-industrial spirit percolating from the political and cultural influence of a vestigial aristocracy, institutional sclerosis, the drag of a London-based global commercial and trading economy, education and management failures, poor industrial relations, limited state intervention at crucial moments, or the costs and effects of empire and the military. Of course, to single out one of the above trends and afford it primacy gets history books noticed in the short term, but does not serve well for understanding what is a complex process (if indeed the relative decline of the British economy is correctly hypothesized in the first place).[2]

A similar picture emerges in the case of France, though with different emphases. The global-finance capital argument cannot be applied as strongly, though the costs of empire do feature in the overall debate over relative decline. Clearly, the two countries also have a different history in terms of specifics, for example, the effects of the Second World War. While British science and industry were affected in terms of both losses (the costs of war in personnel and materials) and gains (scientific and technological advance under the aegis of military imperatives and US sponsorship), occupied France effectively stood still, presenting a very different picture in terms of the reconstruction of both economies after 1945. Arguably, the influence of the military

on high-technology development in France reasserted itself very strongly into the 1950s, however, particularly under the aegis of the nuclear and aerospace sectors. France may also be seen to be different to Britain in terms of state intervention. From the early nineteenth century onward, the French affinity for rationalization and intervention by the state is a notable feature when compared to Britain. Nevertheless when examining the landscape of national technology capabilities, resources, and trajectories from the perspective of the 1960s and 1970s, there is a marked sense of convergence and similarity between both countries.

The history of information technology in Britain and France, and IT-related policies, can be used to test many of the accounts of relative decline. It is also important to note that in order to understand the contours and fate of policies in this area, a range of processes needs to be outlined and assessed. A history of the computer in both countries stretches from the individual scientist and engineer, research establishments, private enterprises, government departments, and user markets. It necessitates an understanding of education and training, the considerable influence of wartime and peacetime military influence, political–economic ideologies, and global economic rivalry. It can also utilize ideas of (or shed light on) the influence of "culture" on economic activity, or refocus the periodization and extent of British or French relative technological and economic decline.

This chapter will delineate the decline process, showing how the foundations and structure of the industry carried long-term inertia and fault-lines within it, but was also subject to short-term strategic mistakes which hastened its eventual relative demise. Some of these mistakes must be laid at the door of the government. As will be seen, the computer industry, certainly in its formative phases, was integrally connected to the government—both in Britain and France. In many respects however the decline of the industry in both countries had its roots in a deeper causality—beyond the influence of any government policy. It is important therefore to outline government links to the industry and to assess their effectiveness or culpability. The essential focus of the chapter will be the developments of the 1960s when a sense of crisis pervaded both countries and the fate of both economies was deemed to hinge on their ability to maintain, or regain, a position of global competitiveness in high-technology industry. The IT sector was singled out as the primary focus of this process. The 1960s was also the high point of economic and social intervention, the period when most optimism surrounded both a positivist technological modernism and the idea that the state should be the agency of its implementation.

Competing for the Future: Intervention in IT

If we begin by examining the British case we can see that intervention does predate the 1960s. In fact we can identify three major episodes in state involvement in the computer industry, which have been fairly well-documented. First there was the attempt by the National Research Development Corporation (NRDC) to foster an early computer industry in the 1950s, through a program of research and development (R&D) funding and advocacy of industry consolidation. Second, there was

a heightened period of government intervention to restructure the industry in the 1960s, through the Industrial Reorganization Corporation (IRC) and the Ministry of Technology (Mintech), one notable result of which was the formation of ICL as a single national champion, provided with government equity capital and R&D funding.[3] Third, the Alvey Program in the 1980s, attempted to promote industry and academic coordination in the development of fifth generation computing.[4]

There are, however, two general omissions—one of scope and one of strategy. First, in terms of scope, some areas of support or influence have scarcely been touched upon. We need to be careful in establishing the boundaries of state involvement. Military and related influences, for example, in shaping technologies and markets in Britain have been generally neglected. A cursory glance at the historiography of the US computer industry immediately reveals a wide interest in the role of the National Security Agency (NSA), Defense Advanced Research Projects Agency (DARPA), the US Air Force and so on through programs such as Semi Automatic Ground Environment (SAGE).[5] Programs such as these were undertaken during the formative years of the IT industry throughout the 1950s and 1960s. In Britain, we need to establish the role played by the Ministry of Supply, the Ministry of Defence, or the Atomic Energy Authority in comparison to the comparatively small-scale effort of nonmilitary initiatives such as the NRDC.

Second, in terms of strategy, we need to fully understand the nature of the interventions in question. General state intervention took many forms ranging from R&D funding, ownership, procurement and regulation policies, etc. These can in turn be taken at face value, or explored at a deeper level. Who, for example, are the constituent members of networks pushing for change, can we detect particular "cultures" at work—socially shaping technological trajectories, or indeed, can we find competing networks, and if so is it possible to measure stronger and weaker influences in these terms?

The structure of the computer manufacturing industry itself forms an essential background to understanding much of government policy in Britain and, as we shall see below, in France. During the 1950s and early 1960s, a number of British manufacturers entered the computer market. These can broadly be divided into two groups. First there were the electronics and control firms, notably Ferranti, English Electric, Elliott Brothers, and EMI. Computers were ideally suited to their existing business, manufacturing high-cost products such as radio communications and power-generation equipment. Second there were office equipment companies, notably BTM and Powers-Samas, with a tradition in punched-card machine manufacture. These two companies had both had noncompetitive agreements with major US manufacturers, BTM with IBM and Powers-Samas with Remington Rand, but these agreements ceased in 1949 and 1950, respectively, following which competition increased in the British market. Nevertheless, punched-card based manufacturers were slower to enter the computer market than electronics manufacturers. In addition to the above, there was the ostensibly rather unorthodox diversification of the J. Lyons company, a nationwide catering firm which had been involved in the early years of computing through its need for rapid, large-scale

transaction processing. This "pioneering" development reflected Lyons' highly evolved culture of rationalization and systems management. The firm initially collaborated with Cambridge University in developing a prototype machine, and began manufacturing LEO computers in their own right in 1955.[6]

Early government involvement in the industry stemmed from the war years. As in the United States developments in computing were accelerated in various ways including the need to enhance cryptanalysis, ballistics calculations, or in the related area of artillery control. Following the war, various agencies and institutions sought to consolidate or build upon wartime advances. These included the universities, notably Manchester and Cambridge, the National Physical Laboratory (NPL), and the Telecommunications Research Establishment (TRE). Each of these produced, directly or indirectly, links to manufacturing companies and paths of development in early computing, the Manchester link to Ferranti, for example.

The first "visible" point of state intervention in the sector appears to be that of the NRDC, which was formed in 1949. Hendry has described the process by which the NRDC, led by Lord Halsbury, was very prescient in targeting the computer industry.[7] NRDC policy was originally aimed at realizing the potential of inventions, usually from the public sector. It enjoyed early success with the Williams cathode ray tube, a storage device licensed to IBM. The NRDC also employed other strategies however, based on Halsbury's broad interpretation of his remit. These ranged from funding well beyond early stages of development, into production, and attempts, unsuccessful in the event, to foster the merging of British manufacturers, not merely to achieve economies of scale, but more importantly to join the electronics manufacturers with the business machine manufacturers. Such a strategy would have resulted in a pooling of both production and marketing expertise—the latter a very crucial part of the success story of companies such as IBM. NRDC policy was proactive in many ways and it showed signs of trying to pick winners. The Corporation supported Ferranti through R&D funding and purchasing guarantees (having switched support from Elliott Automation) in developing the Star Mark I and later Pegasus, the latter built to a design partly specified by the NRDC's Christopher Strachey.

The NRDC effort remained small scale however. Budgets were small—£5 million initially—and hedged around with restrictions. To be sure, Halsbury successfully expanded the envelope of NRDC's activities, nevertheless the Corporation's funding remained cautious—it took 5 years to spend the first £300,000 of its available £5 million capital. The culture of the NRDC, reflected in its operating methods, may also be revealing. Halsbury was appointed on a personal contact basis (he worked with Harold Wilson's wife during the war years—it was Wilson who was President of the Board of Trade when the NRDC was founded in 1949), and this tended to characterize the NRDC modus operandi. As Hendry notes, "If a firm were to be approached by the NRDC, it would very rarely be through a formal letter on NRDC's notepaper. Rather it would be through a luncheon at one of the London clubs, arranged informally either directly by Halsbury or through a mutual friend."[8] Somewhat ironically, the NRDC, in common with other sectors of government,

also had to be careful not to be seen to be bestowing unfair advantage to particular firms, thus avoiding "bad form."[9]

The first major merger among manufacturers was not in fact promoted by government. In 1959 BTM and Powers-Samas joined together to form International Computers and Tabulators (ICT)—at the time the largest data processing machine manufacturer in Europe with over 19,000 employees. This merger was intended to enable ICT to compete more effectively with IBM, not in computer manufacture but rather in the then more important market of punched-card based office machines. The electronics manufacturers continued to produce low-volume, high-cost specialist machines throughout the 1950s. A turning point in the industry occurred in 1959 as IBM redefined data processing with the introduction of its 1401 computer. IBM's new machine offered reliable electronic data processing with good software and peripherals (notably its 600 lines per minute printer).[10] The 1401 greatly extended IBM's existing broad customer base, as it began to sell in unexpectedly high volumes. Partly in response to this redefinition of the market, a wave of mergers took place in Britain between 1960 and 1963. This resulted in consolidation into three manufacturers—ICT, which combined Ferranti electronic data processing interests, and GEC and EMI computer interests; English Electric-Leo-Marconi (EELM); and, still independent, Elliott Automation.

By the late 1950s, the scale of competition from the major US manufacturers—especially IBM—was becoming apparent. Much of this growth had been sponsored in part by military spending. The military had had an influence in the British case too, though in many ways this support was different in nature. Certainly, there were differences in scale of the level of funding devoted to military spending in general, and to computer-related initiatives in particular, reflecting the Cold-War stance of the United States from the 1950s onward. This is not to say that military spending in Britain was not important however, and, as has been noted, Britain continued to devote a disproportionate level of spending to the development and production of weapons during the period.[11] The case of institutions like the Atomic Weapons Research Establishment (AWRE) may be instructive here. In the United States the atomic weapons program features prominently in early support for and use of computing power, from ENIAC onward. The AWRE—a research and production facility—was similarly a heavy user and at the leading edge of computer development in terms of added power, and later computer-aided design and development software and hardware. It also seems clear that the AWRE followed a path of considerable dependency on US machines, certainly into the 1960s, reflecting the compatibility needs of joint weapons development programs—in contrast to the official stance of independent deterrence.

There may also be an early point of divergence here, reflecting commercial cultures. In the United States, for example, the "spin off" of personnel into the private sector was probably greater, backed by an earlier availability of venture capital.[12] In contrast, British scientists and engineers perhaps remained more firmly tied to government institutions. We can also detect the origins of a strong theme of extramural R&D in the United States, funded by government, but carried out in

industry.[13] In Britain, though a significant proportion of government funding went toward R&D in industry, a large and important proportion was undertaken in-house, in government-owned and managed establishments such as the Royal Aircraft Establishment (RAE), the AWRE, and the Royal Radar Establishment (RRE, formerly the TRE).

In summary, a significant proportion of IT spending in Britain throughout the 1950s and after, encompassed defense analytical applications, embedded technologies in defense systems, and more general technologies used in manufacture and administration. Computing technologies were either procured, developed, or customized at a range of government establishments. Atomic Energy Authority (AEA) establishments including Harwell and the AWRE, and Ministry of Aviation establishments including the RRE and RAE, had commissioned and developed a range of computers and components from British industry. However, they also comprised a market for imported computers, notably from the United States. In this respect, the geopolitical context of the 1950s, notably Britain's Cold War stance and alliances, formed an important determinant of national IT efforts. There were compatibility criteria that pushed defense procurement toward US imports, and embroiled it in restrictions, for example, under the COCOM technology embargoes which proscribed British IT export markets, a point to which we shall return below.

The Mintech Years: Meeting the American Challenge

Returning to the civil manufacturing sector, the formal company mergers of the late 1950s did not immediately result in rationalized product lines. ICT, for example, inherited a range of incompatible machines and, perhaps more importantly, software, as a result of their merger. Long-term plans were made for the stabilization and harmonization of production into a single "project set" planned for introduction in 1968. IBM preempted this with the launch of the System 360 in 1964, which had total software compatibility throughout. The announcement of the 360 spurred British manufacturers, ICT and English Electric into accelerating the introduction of a new series of machines. ICT announced the 1900 series in September 1964 (based on the Canadian Ferranti Packard design) and delivered the first production model a mere 4 months later in January 1965, stealing a march on the IBM 360, which was not expected to be available in Europe until the following year. The 1900 rapidly gained market share in both Britain and in export markets, becoming ICT's (and subsequently ICL's) most successful product. ICT's strategy from the outset was to market an *alternative* system to IBM. This was in contrast to English Electric who chose instead to manufacture a range of IBM compatible machines under an agreement with the American manufacturer, RCA.

The mergers within the computer industry, in the context of still rapidly evolving technologies and product lines, were complicated affairs, generating tensions between both product strategies and corporate cultures. The eventual EELM merger, for example, involved significant difficulties in combining the expertise and style of English Electric with the culture and ethos of LEO.[14] The final merger in the

British computer industry came in 1968 with the formation of a single national champion, ICL. ICL was formed in July 1968, through the merger of English Electric computer interests and ICT. The largest computer manufacturer outside the United States, ICL employed over 34,000 workers. The company thus entered the 1970s with a commitment to developing a new range, following the ICT strategy of competing with, rather than seeking compatibility with, the now dominant IBM machines.

The period immediately preceding this eventual emergence of a national champion in the form of ICL was one of the most radical of the postwar era in terms of political economy. The Labour government, headed by Harold Wilson, had been elected in 1964, calling for the modernization of Britain in the "white heat of the scientific revolution." One of Wilson's first tasks was to establish a new Ministry of Technology with progressively wide ranging powers. It is frequently noted that Mintech (as the ministry came to be called) engineered the final consolidation of British manufacturers into the single dominant national champion, ICL, but less well-documented are the ministry's other attempts to boost both the demand and supply of computers, utilizing a wide spectrum of policies.

Mintech's policy was, from the outset, almost obsessed with automation—seen as synonymous with computing development. Wilson's famous Scarborough speech was notable for its vivid imagery of a changing workplace and society, dominated by automated processes. "The essence of modern automation is that it replaces the hitherto unique human functions of memory and of judgement. And now the computers have reached the point where they command facilities of memory and judgement far beyond the capacity of any human being or group of human beings who have ever lived."[15] These concerns, fostered by a growing consensus in the early 1960s of a widening "technology gap,"[16] were reflected in the early activities of Mintech. Advice from a number of quarters stressed both the importance and the urgency of the situation. In advance of his appointment to government Patrick Blackett was receiving portents of doom. "The UK computer industry is now in a very unhappy position. Thirteen years ago, a few million pounds and some imagination could have kept us in the lead. Now, the industry is on the point of eclipse."[17]

When the ministry's Advisory Council on Technology (ACT) first met in November 1964 item A(i) on the agenda was the "urgent problem" of British computer industry.[18] Both Lord Nelson of Stafford from English Electric and Sir Leon Bagrit of Elliott Automation were members of the ACT at this time. Blackett, seen by many as one of the principal architects of the Mintech idea, already had a draft paper on the computer industry to hand, and a working party was set up to examine the industry and make recommendations. The report, when it emerged, reflected the interest shown in automation—linked to a belief that the computer industry was a fundamental, strategic area, valuable in itself but also acting as a foundation technology for an increasing number of manufacturing processes and consumer products. Mintech was particularly interested in manufacturing.[19] The report again echoed Wilson in stressing Britain's role as the "pilot plant" of the world.[20] Exporting advanced-technology based capital goods was to be the primary goal of policy.

Foreign dependency in this field was rejected almost as an act of faith even though there were those counseling alternative strategies for example, modernizing using either imported or licensed production.[21]

The wider geopolitical environment in fact informed policy in a number of ways. Restrictions on exports of technology could come into play if these were imported from elsewhere, for example. Most notable here was the COCOM embargo enforced by the United States on export of advanced technology, including computers and related products, to the Soviet Union and its allies. The COCOM restrictions, so-called after the western allies established the East–West trade coordinating committee on security export controls (COCOM), put a block on the onward sale of technologies incorporated into new systems—a ubiquitous feature of the computer manufacturing industry. As the ACT Report noted, "it is necessary that mechanical, electrical and electronic design (of capital goods) should be based mainly, if not exclusively on British technology. Rights to use foreign know-how or equipment often carry with them limitations on exporting, which experience has shown can hamper British companies in competing for export contracts."[22] This problem was to reemerge later in the 1960s when ICT and English Electric (and later ICL), exports of computers or licensing agreements to countries including the Soviet Union, Romania, Czechoslovakia, and Bulgaria were blocked by US intervention.[23]

Britain continued to view the Soviet Union and Eastern Europe as a trading area in advanced technology, fostered, for example, by a series of Anglo-Soviet Technological Agreements. Such arrangements continued to rankle with US government policy. Permission was granted by the United States for ICL computers to power Gosplan's economic calculations, for example, but a further order for an ICL 4-70 for the Institute of Management Control provoked suspicion. "It was recognized that surveillance of the end use of powerful computers necessarily presented some problems and there had been the additional difficulty in this case posed by the somewhat conflicting role played by this institute in the Soviet economy."[24] US Military Intelligence suspected that the Institute in question was undertaking work in "strategic areas" and continued to veto the export, despite the rather disingenuous attempts by Britain to point out that such export arrangements would give the West valuable intelligence about soviet management methods.[25]

Given that the government was determined to preserve the computer industry in Britain, as a foundation at least for its ambitions to make the British capital goods industry a world leader and the "pioneer" of automation, a series of policies were outlined to Mintech in 1964. Despite the qualms felt in relation to the US challenge, domestic markets for computers were fairly robust in the 1960s in Britain, partly protected behind a 15 percent import surcharge. Britain remained the only European country to avoid total domination by US imports. It was by no means clear that protective tariffs were effective however, since nonprice factors were seen to figure increasingly prominently in purchasing decisions.[26] Software support was seen as crucial. ICT, English Electric, and Elliott Automation all confirmed a high level of lost orders due to relatively poor software support in comparison to IBM in particular. IBM, it was also noted, had superior sales techniques, and had begun to

employ some very effective strategies to tie in customers, ranging from compatibility criteria, leasing facilities, and considerable discounts. The latter were reported to be as high as 60–70 percent to educational establishments leading to the danger, as Mintech saw it, of "the next generation of scientists and engineers being trained on foreign machines" and thus locked in to IBM culture.[27]

A range of recommendations emerged from the Mintech ACT deliberations in 1964. It was noted that companies had asked for taxation policies to be designed to aid rental or leasing arrangements by domestic firms. But ACT proposals went much further, notably on three fronts—public sector procurement, an extension of support services, and additional R&D funding. Procurement was seen to be one of the most effective methods of intervention, if managed effectively. It was noted that although the public sector wielded considerable purchasing power, this tended to be de-centralized. Within central government there was a Treasury Technical Support Unit, advising on purchasing, but individual departments retained autonomy in decisionmaking and the University Grants Committee took its own advice. The Research Councils, Department of Education and Science, AEA, Ministry of Aviation, nationalized industries, post office, local authorities, etc. all acted more or less independently in deciding computer purchases. New proposals included doubling the size of the Treasury Technical Support Unit, transferring it to the Mintech where it would promote the centralization of all public-sector purchasing. Departments, such as Education and Science, could still evaluate requirements independently, but final approval would have to be sought from Mintech.

In addition to the centralization of procurement decisionmaking, criteria for purchasing were also to be fundamentally revised to encompass a proactive role for government. Traditionally the Treasury, for example, had a requirement that computers should be of a proven design. A different approach, it was felt, would "encourage British companies to tender for sophisticated and novel systems" and, if these were purchased by the government initially then commercial and industrial orders would follow. The government sector would thus act as a proving ground for developmental machines—a reverse of the current position.[28] In addition, preference for British machines generally was assumed within the new recommendations. Price criteria were no longer to have primacy and would be assessed in order to judge whether or not imported machines were being unduly discounted. Most importantly policy would be geared to generating a British culture in computing, "ensuring so far as possible that the new generation of scientists and engineers are trained on British machines and in the use of British codes, operating systems and languages."[29]

Centralization was also seen to be the key to solving, or at least reducing, the scale of problems related to software development in Britain, particularly in data processing. At the very least it was hoped that a major advance could be achieved in reducing the levels of duplication of effort. There were a large number different payroll systems alone in the public sector at the time. Proposals thus involved the establishment of a national programming center to act as a center for development and as a bureau and clearing house for programs. ACT proposals were also prescient in suggesting the establishment of a national computer network "in the nature

of a national grid," using telephone (Datel) or telex (five channel paper-tape) transmission lines. This system echoed the ARPANET developments in the United States, and took direct reference from the MIT MAC project, developed with government funding, which was judged to have the goal of "making computing power available on a public utility basis like electric power".[30] Interestingly, Britain had perhaps held an early lead in this area following efforts by the NPL in Britain to develop the potential of teleprocessing with their Mark 1 system.[31] The British initiative was never implemented but would have provided a network for all data processing applications—"commercial, industrial, legal, medical, administrative, and governmental," centered around the AWRE, the largest user of powerful computers in the United Kingdom at the time. The system was envisaged as being operational by 1966.[32]

The third area of government intervention highlighted in 1964 was the level of R&D support for the British computer industry. Companies themselves were seen to be spending between £8 and £9 million a year, but this was seen as a burden in terms of restricted cash flow due to high ratios of capital employed to sales.[33] Dedicated spending by government was in piffling amounts. The NRDC was spending £200,000 per year on the ARCH process control system at Elliott, a magnetic card random access memory (RAM) at ICT, and a magnetic tape at Decca. The Department of Scientific and Industrial Research (DSIR) was spending up to £150,000 on projects including integrated circuits, magnetic stores, and computer-aided design at Plessey, ICT, Elliott, Ferranti, and Leo-Marconi, as part of an Advanced Computer Techniques Project. This project also involved work at the NPL and RRE worth around £100,000 a year.[34] A further £150,000 per year was being spent by the universities and other Government Research Establishments, though this figure did not include "general programmes of the establishments." In total the effort was deemed to be far too meager, which indeed it was in comparison to the level of spending by the US government. Recommendations were that the NRDC effort should be at least doubled, the DSIR project, which was absorbed by Mintech, should be trebled and that the university sector should be vastly expanded—to the tune of £2.5 million per annum.[35]

Implementing the Plan

Thus according to the Labour government, this was a pivotal point for the British economy. A sense of both crisis and opportunity simultaneously drove policy as technology in general, and computer manufacture in particular emerged as the primary targets of a recovery strategy, to be spearheaded by Mintech. The ACT had outlined a multilayered plan to save British IT, indeed to restore it to preeminence in some aspects. Mintech grew progressively between 1964 and 1970, and attempted to put into practice many of the reforms suggested by the ACT, some more successfully than others. As the ministry grew it gained control, directly or indirectly, over the Ministry of Aviation, AEA, DSIR, NRDC, and the Research Associations.

Centralized procurement was instigated with a Computer Advisory Service (CAS) dealing with the system requirements of the public-sector bodies including the

nationalized industries, local authorities, research councils, universities, and other educational establishments. The CAS handled over 500 consultations per year. Here we can see the first general failure of the ACT plan. Advice was, even when sought, not compelling.[36] When faced with software, hardware, and compatibility problems, for example, Her Majesty's Stationary Office (HMSO) preferred IBM over ICT—the former having COBOL up and running, and larger storage capacity. (They expected the LEO system on offer to be obsolete rather rapidly.)[37] A policy statement from the Treasury the following year effectively rejected a strategy of buying British, insisting that computers selected "were those which by ordinary commercial standards were judged to be the best suited for the jobs to be done and the best value for money."[38] In the military sector, establishments such as the AWRE continued to buy IBM, following the principle that in defense expenditure the best technology should be used, rather than compromise over cost or national industrial loyalty (in addition to continued compatibility requirements with the US nuclear weapons program). Some observers thought that some private-sector companies would prefer to "buy British" but this was not, in reality, the case.

> The British Aircraft Corporation whose policy is to purchase from ICL because of the financial interests of the shareholders, concern for the balance of payments and a desire to support technologically sophisticated industries which are of considerable national importance, as well as the fear of being in the hands of a monopoly supplier, has 80 percent IBM equipment.[39]

Another ACT recommendation seemed to fare better. A National Computing Centre (NCC) was set up in Manchester, partly funded by the Mintech, to give advice to computer users outside the public sector, act as a library service for existing software and to develop new software. The NCC also offered training for managers and systems analysts. Research funding was also increased. The Advanced Computer Technology Project was extended, so that by 1970 a total of eighty-one contracts had been placed or completed. Total funding for these projects, which were vetted by the NPL and RRE, exceeded £5 million, of which Mintech provided half. Criteria for projects were that they were novel, engendered long-term commercial prospects and that "the outcome of the work is both in the national interest and in the overall interests of the British computer industry."[40]

Following the pattern of Wilson's interest in automation, computer-aided design and manufacturing projects were extensively funded by the Mintech. Projects related to numerically controlled machine tools included the preproduction order scheme whereby the government sponsored production and trials of new machine tools in return for reports of performance; a trial purchase scheme underwritten by government; the establishment of three Numerical Control Advisory and Demonstration Service centers at the RAE, Production Engineering Research Association (PERA), and at Airmec/AEI; and the establishment of the AWRE Aldermaston Project for the Application of Computers to Engineering (APACE).[41]

The APACE scheme is particularly interesting since it encapsulated some of the most radical aspects of the Mintech project. Not only did it involve the boosting of

automation in British industry, but it also involved the transfer of technology and know-how from the military sector to the civil sector, in response to a perceived imbalance in the national effort toward the former. Housed "outside the wire" at Blacknest, near Aldermaston, the APACE program envisaged using the Stretch and Atlas II computers on site. AWRE interest was however increasingly based around the graphic capabilities of its new IBM 360/40 and was focusing effort on writing FORTRAN programs for this machine.[42] The APACE project involved contract work for industry, but more importantly was designed to familiarize visitors from British industry with the latest CAD/CAM methods. Other problems arose with the project in terms of the constraints imposed by the Treasury over the cost of the program, which was envisaged as operating on a profit-making basis after a trial period—though those in charge at Aldermaston saw their role as "evangelical" and in need of extended subsidy.[43] Other Mintech CAD initiatives were undertaken at the National Engineering Laboratory, the NCC and at various universities, including Cambridge and Imperial College.

Ultimately, the formation of ICL, a single national champion, in 1968 was the most high-profile piece of government intervention of the period. As noted above, the NRDC had attempted mergers from the 1950s onward to no avail. Mintech carried on this policy from 1964, reflecting the dominant belief in both economies of scale and the need to respond to the American/IBM challenge in kind. Despite overtures from Technology ministers Frank Cousins (1964–1966) and Tony Benn (1966–1970), ICT and English Electric remained resistant to merger. In 1967 however, in the face of increasing pressure from IBM, which had now succeeded in capturing over 50 percent of the British market, and in response to the offer of government support for the launch of a new range of machines, the two companies finally entered serious talks. Government support for the new range would be crucial in view of the incompatibility of the existing machines. In the event the merger was delayed and complicated, partly by the intervention of rival electronics manufacturer, Plessey, and involved renegotiation of the level of government aid on offer. As the general economic climate worsened around the devaluation crisis of 1967, the original offer of £25 million was reduced to £13.5 million, with additional equity participation by government amounting to £3.5 million. ICL was eventually formed in July 1968, continuing for the time being as the largest computer manufacturer outside the United States.

The formation of ICL, as noted, represented the culmination of a long-term effort by government to rationalize the industry into a company of world class. There were problems with this strategy, however—which itself may have been based on mistaken premises, or which ran into contextual difficulties. In forming a single national champion the government was not in fact emulating the US environment where there were, in addition to IBM, a number of other large-scale manufacturers, competing in a limited form, but nevertheless competing. The merger also created a significant degree of dissonance within ICL, as attempts to merge managerial cultures and product lines generated increasing friction. Again, compare this to IBM, whose internal organizational cohesion and long-term corporate strategic capacity was one of the

foundations of its success. ICL's attempt to continue its product strategy of competing with IBM in producing a noncompatible range, though fitting well with continued images of national independence, was probably a mistaken one. Similarly, the later continuing emphasis on the larger-scale main frame market, as opposed to the growing minicomputer market may also have been a mistaken strategy.

The company may have also suffered initially due to mistaken assumptions relating to the value of the English Electric component. Maurice Dean at Mintech had commissioned Cooper Brothers to report on the value of English Electric prior to the merger. By December 1968, John Wall and Arthur Humphreys were complaining to Tony Benn. Benn recorded in his diary that "(T)he plain truth is they bought a pup. The English Electric computers were in a complete state of confusion. I think that not only was their order book only half as big as they thought but the valuation of their assets exaggerated." If this was the case it highlighted a further problem for government in formulating policy, that is, its reliance on expert opinion—in this case the independent assessment of the value of English Electric.[44]

Some indication of the realization that the creation of a national champion was perhaps not the best policy option, is revealed in changes in thought toward the end of the 1960s. Benn, for example, was moving rapidly away from an overtly interventionist approach. He now thought that the computer industry, with its seemingly rapid development cycles, underlined the perils of government trying to second-guess the direction of industry. "It kills stone dead the Fabian idea that central Government plans and all else falls into place."[45]

The Mintech was dismantled in the early 1970s by the incoming Conservative government, and the enthusiasm for the "white heat" of technology was dissipated, at least in a rhetorical sense. The Wilson government was replaced by that of Edward Heath, with an initial pledge to roll back the level of state intervention. At this time, the Rothschild report symbolized the government's reorientation of science and technology policy toward the customer–contractor principle. Heath may have made "U-turns" in other policy areas, but the majority of 1960s IT-related policies were not reestablished. R&D funding for ICL was curtailed, and the military–civil transfer of technology was no longer given a programmatic structure. In other sectors of technology there was a shift toward international collaboration, on a European-wide scale, in order to combat the threat of US hegemony. However, the idea of a *national* champion in IT did have a strong legacy. While Britain accepted the need for collaborative initiatives in some areas, notably aerospace, the opportunity to participate in computer initiatives such as the Unidata consortium which combined Siemens in Germany, Philips in Holland, and Compagnie Internationale pour l'Informatique (CII) in France, was resisted by British companies.[46] ICL, then the biggest European manufacturer, took the decision to stand aside from such collaborations, despite some urging from government quarters. ICL did take part in International Data, a joint "study company" which included CII and was based in Belgium, aimed at promoting compatibility.[47]

When the Labour government returned to power in the 1974 the policies of the 1960s were not retried. Perhaps lessons had been learned, but it should also be

noted that by the mid-1970s there was a significant shift in the nature of the technology in the computer industry as minicomputer and semiconductor manufacture began to gain prominence. The central agency of policy during the later 1970s was the National Enterprise Board (NEB), a kind of government venture capital bank. As Campbell-Kelly and Hamilton have found, the NEB, though caricatured as a failure due to its forced diversion into rescuing the "lame ducks" of British industry, also had a considerable impact on the small- and medium-sized sector and undertook investment in some important IT niche sectors. These included chip manufacturer Inmos, the software firm Insac and office automation firm Nexos. These companies experienced mixed fortunes, though the NEB made a good profit on its sale of Inmos, covering all the losses on its other IT investments, in good venture capitalist style.[48]

French Computing and Government Intervention

We can see from the above, then, that a very serious effort went into IT policy in the mid-1960s in Britain, in an attempt to offset the perceived crisis threatening the computer industry. Indeed this was the high point of British postwar technology policy—centered around the computer industry. If we turn our attention to events in France we can see a remarkably similar picture in many respects. The most highly visible phase of government intervention in the French IT industry is that of the Plan Calcul, initiated in 1966. Like the ACT program at Mintech the Plan Calcul was a bold and urgent attempt to rationalize and boost the indigenous IT industry in the face of international, particularly US, competition and the growing dependency on US imports. By the mid-1960s, sales of US manufactured computers in France had captured well over 50 percent of the market and, given the strength of IBM in particular, were expected to continue to increase. By 1967, the total number of IBM computer systems installed in France was calculated at 855, compared to 748 of French manufacture. The situation in Britain—649 IBM, 1303 British—was marginally less alarming.[49]

Mounier-Kuhn identifies four determinants of French policy in implementing the plan.[50] The Commissariat General du Plan, the compact and elite architect of much of postwar French industrial planning, which had pioneered and seemingly successfully imposed the system of indicative planning, had created a specialized committee to deal with the electronics industry as early as 1961. Two specially formed groups, the Commission Permanente de l'Electronique du Plan (COPEP) and the Delegation Generale a la Recherhe Scientifique et Technique (DGRST), utilized expertise drawn from industry, military, government, and universities to generate reports and direct R&D funding. From within this group a "computer lobby" emerged, which pressed strongly for action at a high level of government to support the IT industry.

The remaining three determinants take the form of "shocks" to the French IT industry. The first, and most well-known, is the "affaire Bull." Compagnie Machines Bull had developed into the 1950s as a major multinational business machine

manufacturer, partly with the aid of French government funding and protection, and had also developed a successful leasing strategy—not dissimilar to that successfully employed by IBM. By the early 1960s, the company had major subsidiaries in Germany and Italy and an aggressive marketing strategy aimed at the United States and Britain.[51] The company had been relatively late in moving into electronic computing, however, and when it did so it failed to develop contemporary technologies.[52] During the 1950s, Bull had commercial links to BTM in Britain and Remington-Rand in the United States. In the early 1960s, a combination of unwise overinvestment in punched-card technologies, heightened competition from smaller firms, and the increasing success of the rival, standard-setting IBM 1400 series, allied to financial pressure generated by its leasing strategy, sent Bull into a crisis.

This crisis drew in a range of proposed industrial and political interventions including an attempt to merge the computer interests of Compagnie Generale de Telegraph sans fil (CSF) and Compagnie Generale d'Electricite (CGE) into those of Bull. Bull's problem were eventually resolved only when the company was partially bought out by the US company General Electric (GE).[53] Under the new arrangements two companies were formed: Compagnie Bull (51 percent owned by GE) and Societe Industrielle Bull GE (51 percent owned by Bull). The latter took over Bull's industrial assets, but the overall impression was that the company had fallen into American hands. Such a takeover of the flagship national computer company came as a deep shock and thus became the proof and embodiment of the "defi americaine."

The second shock to hit the French IT industry was the announcement of the IBM 360 series of machines, which Mounier-Kuhn refers to as the "the very incarnation of the American challenge."[54] This system, announced in a great fanfare before it was actually brought to the market, took the international dominance of IBM, already boosted by the success of the 1400 series, to a new and unprecedented level. The third shock was the embargo placed by the US government on the export of Control Data 6600 supercomputers to France.[55] These computers were required by the French Atomic Energy Commission and allegedly blocked because of their capacity to aid the development of the French nuclear deterrent. This move, which virtually placed France under the same regime as the Soviet countries restricted under the COCOM embargo on military technologies, sparked off another wave of indignation and recrimination, in an atmosphere already made difficult by strained US–French geopolitical relations. As Mounier-Kuhn points out the eventual Plan Calcul did not embody the construction of an independent French supercomputer, but rather the Control Data Corporation (CDC) episode was seized upon by the French press and served to generate and reinforce a heightened sense of both commercial and military dependency or frustration at the hands of the US government and large US corporations.

These events set the scene for the emergence of the Plan Calcul between 1966 and 1967. The Plan embraced political, scientific, and industrial aspects at the outset. Robert Galley was appointed as a political representative to head the interministerial Delegation a l'Informatique, established in 1966 and charged with defining the

Plan's strategy, developing teaching and R&D, and generally promoting a "buy French" program. Criticism of the effectiveness of the delegation, which achieved a high media profile (probably to its detriment), revolved around its lack of technical expertise and the strong links of its members, including Galley and his successor Maurice Allegre to state projects, rather than commercial market initiatives. Galley in particular had strong links to the French nuclear weapons program.[56]

The Plan Calcul also established two scientific organizations, the Institut de Recherches en Informatique et Automatique and the Laboratoire d'Electronique et de Technologie de l'Informatique. The former was to undertake basic and applied research, develop educational programs, and disseminate information. The latter was developed around the Center for Nuclear Studies at Grenoble. This initiative bore a strong resemblance to the initiatives emerging around the nuclear research establishments in Britain, at Harwell and Aldermaston, aimed at a combination of disseminating the considerable computing expertise within such institutions and making available to civil–commercial industry the technologies which these centers had accrued or developed.

The major aspect of the Plan Calcul was its goal of industrial restructuring, in particular the formation in 1966 of a national champion manufacturer in the form of the CII.[57] If Bull could not be saved from the Americans then another company would need to take its place to ensure French prestige and independence in IT manufacturing. CII was formed from a merger of Compagnie European d'Automatisme Electronique (CAE), a subsidiary of Thompsom-CGE, and Societe d'Electronique et d'Automatisme (SEA) a subsidiary of Schneider. CAE had a background in process control computers, many manufactured under license from US companies. The company had a strong link to public sector consumers, particularly in the large-scale applications of the nuclear and aerospace sectors. SEA had a longer lineage, being one of the first French computer manufacturers in the 1950s. The company had developed a strong capability in analog computing in the 1950s, heavily influenced by the military market. By the 1960s, it had a wider market presence embracing the public sector and commercial markets and was seen as one of the most innovative IT companies in France at the time. Machines Bull was not included in the new company.[58]

One of the major problems to beset CII was the absence of Bull in the initial configuration. Both SEA and CAE had stronger links with the public-sector historically and the composition of the advisory bodies in the initial setup probably reflected the strong military/public-sector network effect which favored the two "procurement" companies over Bull. With the absence of Bull a great deal of commercial market expertise was unavailable to the new national champion. Another problem to emerge was the antagonism between CII's component parts. As Mounier-Kuhn points out the two constituent companies had opposing corporate strategies: SEA had a bold and innovative plan for product development, aimed at leapfrogging ahead of the competition, whereas CAE's product strategy was built around proven technologies, manufactured under license.[59] Though both companies had a background in supplying the government sector, SEA leant more strongly toward building on its commercial expertise and breaking out of state dependency.

The balance of power at the head of the newly formed CII reflected the legacy of government/military dependency. The company's president, Jacques Maillet, had a background in military supply with the Dassault group, and a central design group was imported from Société Européene de Traitement d l'Information (SETI), a subsidiary of Compagnie des Compteurs, where they had spent a number of years designing computers for the nuclear and space programs. Though the initial announcements of the Plan Calcul called for stress to be placed on business computing markets in particular, in the event the company was dominated by CAE, and the heritage of scientific, military, and public-sector markets which the company bought with it swamped the more business and commercial market strategy which SEA favored.[60]

The chosen strategy of CII to take on IBM was to develop a compatible range of computers—the IRIS system of medium and large commercial and scientific machines. IBM could, and did, respond effectively, however, by cutting its substantial profit margins and restructuring leasing agreements, making this a very difficult sector of the market to compete in. In the event development problems, a constant need to be subsidized by state R&D funding and difficulties in luring customers away from IBM, frustrated the ambitious plans of CII. The company remained tied to a procurement strategy—supplying the "soft" or captive markets in the public sector which it had been guaranteed. The company also looked to markets in developing countries where France retained some influence, and, in a stategy which mirrored that of rival UK national champion, ICL, looked for markets in the communist bloc—the only market IBM could not penetrate, but one which was also guarded by the embargoes of COCOM. These markets were never to prove dynamic enough or of sufficient scale to substitute for the maturing IT markets in the developed industrial economies of the West, and like ICL in Britain, CII was never able to fulfill the overambitious targets envisaged in the initial plans for a national champion.

Other components of the Plan Calcul included the establishment of peripherals and components enterprises. The Societe des Peripheriques Associes aux Calculateurs (SPERAC) was established in 1968 to manufacture tape and disk drives, Visual Display Units (VDUs), and other devices. This company, jointly owned by Thompson and Compagnie des Compteurs, did not fare well and was unable to supply CII with the equipment required. It was taken over by CII after 2 years, when the government finally refused to pour more subsidy into the company, which had already cost over 50 million francs. The Plan's major components initiative was aimed at establishing a domestic semiconductor industry, Societe Europeenne de Semi-conducteurs et de Microelectronique (SESCOSEM). The company was formed from Thompson's semiconductor interests which had been built up through the 1960s through a process of expansion and takeover, with a good deal of government subsidy throughout. The new company received over 90 million francs in subsidy in the first phase of the Plan Calcul, though some of this money may have gone to cover existing losses built up over previous projects, rather than funding new R&D.[61] Again SESCOSEM performance was disappointing in terms of fulfilling the Plan and establishing a major French presence in the world semiconductor market. Mounier-Kuhn notes two contributory events. First, a series of budget cuts in 1968 reduced available spending by the

company's large electronics customers. Second, between 1968 and 1971 the semiconductor market, led by the big US producers Texas Instruments, Motorola, and Fairchild, was going through one of its periodic phases of competition and price-cutting, placing increased pressures on any hopes of profitability for a new entrant.

In reality, the first phase of the Plan Calcul amounted to a Soviet-style 5-year plan, with similar lack of cohesion or an effective, realistic targeting regime. In 1969 there were changes within the Plan's administrative structure. The Delegation a l'Informatique was taken under the responsibility of the Minister for Industrial and Scientific Development, which may have represented an early loss of status. In 1970, the newly merged Thompson CSF became a third partner in CII through the setting up a holding company, Fininfor. In the following year, a second, revised and extended Plan Calcul emerged, essentially a second 5-year plan, agreed between the government and CII. A new emphasis emerged early in this phase to target the emerging minicomputer market or "peri-informatics" as they became known in France. As part of this process a "peri-informatics" club was established, aimed at the grouping together of the interests of French minicomputer manufacturers. In 1975 the government again intervened to partly fund the buy-out of Honeywell's interest in Cie Honeywell Bull, eventually resulting in the formation of CII–Honeywell Bull. "Peri-informatiques" continued to be the emphasis of this new formation, and in the following year the government and Thompson provided funds for CII to set up two subsidiaries: a minicomputer company comprising the Small Computer and Specialized Applications Division and the Military and Aerospace Division of CII, and a new subsidiary combining the Toulouse and Paris manufacturing and design facilities.

Though the Plan Calcul went through further revisions in 1976, the big idea had now had its moment. Indeed, after the first 2 or 3 years it was becoming evident that initial hopes for a managed resurgence of French technological prowess, spearheaded by the IT industry, was based on unrealistic expectations. The emphasis was shifting toward more pragmatic and less ambitious programs, which also began to recognize the shifting and innovatory nature of the IT sector. As semiconductor and minicomputer industries began to attain prominence, generating much more uncertainty and variation in the marketplace, and necessitating interaction with the much more difficult to manage entrepreneurial world of small- and medium-sized companies, policy shifted accordingly. The NEB initiatives in Britain and the later Plan Calcul both withdrew from the big scheme to more measured and piecemeal policies.

The Failure of the National Strategy: Britain and France Compared

In the early 1960s, there was a growing sense that some form of turning point had been reached. In terms of economic, industrial, or technological power, the readjustments following the war had been tackled and what was now emerging was a fundamental long-term realignment of world power. It seemed that center of gravity of military and economic might and geopolitical influence was moving inexorably away from Europe toward the United States. In technological and economic terms

the other superpower, indeed all of the Soviet Bloc remained a military threat, imposing a dead weight on some aspects of technological and economic development, but in terms of economic rivalry the United States emerged as the dominant competitor. In both Britain and France this process was increasingly seen as a point of convergence, as Empire and world political influence receded and a series of new technologies arrived to accelerate the downward spiral. Computers were perhaps the most potent symbol in this process—the technological point at which the past met a new future, and the point at which decisive action needed to be taken. Governments in both countries, in a building atmosphere of media hysteria and technological xenophobia, armed with the ideologies of intervention, needed little persuading when offered radical and bold plans for restructuring their IT industries in a comprehensive form. After all, from a military perspective at the very least, both countries possessed the expertise to innovate—in computing, aerospace, and nuclear technologies both Britain and France had been in at the starting point of many technological breakthroughs and retained significant world class scientific and technological know-how. The key was to harness these assets, indeed to keep them in place,[62] and turn them to commercial and industrial wellsprings for future prosperity.

In both countries, by the mid-1960s there was then considerable will for bold programs, which soon devolved into the idea of creating a national champion. In the formation both of CII and ICL the specter of IBM determined the strategy to be followed. Servan Schreiber's book would perhaps have been better titled *The IBM Challenge*, since the scale and market penetration of this single company dominated the computing world in the 1960s. A response to IBM needed to be of sufficient scale to enable R&D, production, and marketing capabilities to compete. Both national strategies therefore had to look to clustering virtually all available resources into a single company. At this point both encountered one of the fundamental stumbling blocks—the disparate nature of the components of the envisaged national champion. The computer industry in both Britain and France in the early 1960s was composed of a range of firms from different sectors, with different products, different markets, and indeed often radically different corporate cultures. Computer manufacture had come to embrace a range of technologies and systems configurations which had drawn in electronics firms, business machine manufacturers, and the subdivisions of larger, more eclectic manufacturing concerns. In addition, substantial expertise, some of it manufacturing expertise, had developed in state-owned research institutes. The firms which eventually emerged—both ICL and CII—were the result of compromise and power brokerage within these national *melange*. That they had great difficulty reconciling the different traditions, product strategies, and managerial and work environments, which they sought to harmonize, is perhaps unsurprising.

One key question for any government seeking to intervene in a radical fashion in an advanced industry is that of advice—both technical and commercial. In the case of computing, from the outset the industry was one shrouded in specialist knowledge. The situation was made doubly difficult in that the industry was characterized by a great deal of volatility in terms of innovation cycles. Predicting trends

and markets for even the medium term, in hardware initially, but increasingly in applications and software, was extremely difficult; predicting the cost and effectiveness of R&D programs probably more so. An added complication was the continued military influence on decisionmaking. Though less so than in the early years, computing remained at best a "dual use" technology.[63] Military considerations were still brought to bear on planning decisions. Politicians were then faced with a bewildering array of advice from civil servants, military advisors, manufacturers, and users in both public and private sector. During this transitionary period, they were all too ready to listen to Svengali-like promises of independent pathways to modernization.

The idea which resonated most strongly at this time was the idea of independence. This had a number of ramifications for policy and effectively blinkered strategies in a number of crucial ways. First the idea of a national champion—a single large entity—was too uncritically accepted as we have noted. Second the product strategies for such champions were always predicated on establishing and maintaining such independence. Both at CII and ICL proposals for computers, peripherals, and software were designed to take on IBM—to generate their own standards—rather than pursue any degree of compatibility. Given the dominance of IBM and its momentum in the marketplace by the mid-1960s, such ideas were clearly misplaced. Nevertheless the idea of compatibility or worse, licensed technology, smacked of dependency—the very process which these big initiatives were trying to counteract. It must be said that internecine rivalry also played a part. The French were certainly concerned that the British were establishing a lead in Europe with ICL.

Allied to the notion of independence, the most attractive options put forward by the national champions were those which sought to establish a new presence in the market by leapfrogging IBM and getting to market with a new generation of machines. This strategy often appealed to national egos and were seemingly plausibly based on the legacy of pioneering innovations in early computing or on the ideas that advanced science and technology developed in centers of excellence in the academic or military research institutions could be readily translated into marketable and path-breaking commercially viable products. In reality, things were very different. Translating academic or military science and technology into workable and reliable mass-market products is an extraordinarily complex and difficult process involving the technologies themselves and the organizational cultures which generate them at a number of levels. At a fundamental level, the dynamics of supply and demand may well be operating in reverse. A technology produced by the weapons scientists at Aldermaston or Malvern, for example, may have been state of the art, but may well have no immediately recognizable civil application or market. Military research cultures have never operated under the same cost and manufacturing constraints as those in the commercial sector. Another major problem in this respect was time scales. Lead times for new systems had to contend with political and media expectancies which required visible results in the short term. This meant at best that product strategies were compromised as systems were rushed to market, at worst it simply meant that CII and ICL were doomed at the outset given the unrealistic expectations with which they began.

In both France and Britain, the legacy of military involvement in IT development, or of related scientific and technological development may have also had a long-lasting and structural influence on outcomes. The military and big science IT legacy was certainly seen as a positive thing initially. Governments in both countries had invested large amounts in the aerospace and nuclear sectors as part of their geopolitical, great power strategy throughout the 1950s. Both these sectors were heavily dependent on IT as a core technology. That this expertise could be turned around and used to spearhead a new wave of industrial IT capabilities was in many respects too good an opportunity to miss, especially since pressure was now beginning to mount to cut down on expensive military programs, which seemed to have less and less relevance in the bipolar world of the two superpowers. This early "peace dividend" had its drawbacks however. The technologies developed for military applications were frequently just that—they had no straightforward use in the civil sphere and were often too expensive to produce for wider markets.[64]

The military IT sector may also have represented the dead hand of technological history in a deeper sense. In both Britain and France experts and managers from the military or related sectors may have had undue influence within the policy forming groups which emerged. This was clearly because they were seemingly the most knowledgeable and readily available for advice—they were the repository of technical expertise of the highest level. Managers from this sector were also no strangers to the corridors of power. Lobbying for and administering large-scale funding programs was the essence of management in the nuclear and aerospace sectors from their inception in both Britain and France, so it is perhaps no surprise that personnel from these sectors figured prominently in IT regeneration programs from the 1960s onward. The problem here is that these managers had no heritage of commercial operation. Design, production, and marketing environments of the global computer market differed radically from those of the large-scale military or public project.

Similar "market culture" problems also emerged in terms of the customer base which developed for the machines of ICL and CII. As penetration into IBM markets proved difficult, both companies were thrown back onto the "captive" markets of public-sector users. These markets—in national and local government departments and large public enterprises, were meant to provide a secure platform for the new companies in terms of sales volume, while more tricky commercial markets were being tackled. In reality such "soft" markets simply prolonged the transition to fully competitive product strategies. The alternative strategy of moving into the Eastern Bloc markets, or perpetuating imperial dependencies in old colonial markets proved equally futile in the face of a combination of lack of customer power or geopolitical obstruction from the United States. In any case these remained undeveloped and unsophisticated markets at best, unlikely to stimulate innovative product or marketing cultures.

In addition to these structural impediments stemming from the legacy of IT structures in both countries, there were also more fundamental flaws with the strategy of constructing a national champion. The sector was simply too volatile in the 1960s to be amenable to a "big plan." This was true even for the Commissariat du Plan in

France—arguably the most sophisticated planning administration then in existence. Computer manufacture continued to grow and mutate in ways which were very difficult to predict. The world of IT in the 1960s was still characterized by a complex international web of technologies, agreements, and patents.[65] If any institutional form could be found to dominate this market, it was IBM. At the heart of the IT world of the 1950s and 1960s, was the expertise and market power of IBM, imposing the seemingly successful standardization of the IBM 1400 and 360 series and dominating the mainframe world. IBM had used its marketing strategies and technological prowess, constructed with some help from the Pentagon, to outmaneuver rival manufacturers in the United States—the most competitive market in the world at the time, and had exported this success into its global business. IBM's position had been built up from a combination of reliable and innovative technologies allied to an acute awareness of market needs and an extraordinarily successful regime of customer care or "lock-in" depending on who was doing the analysis.

IBM's position had been built up over many years. The hope that a hastily constructed alliance of elite public-sector managers and scientists, and a disparate cluster of manufacturing firms from different sectors of the market could, in the short term, outmaneuver such a company was forlorn at best, folly at worst. National prestige and a sense of national crisis were strong incentives for action at a political level, but the reality of the domestic and international IT market, and the unwillingness of private enterprise or military to sacrifice their functional or economic needs for these ideals meant that such policies were always built on sand.

The idea of intervention in the IT sector did not fade with the failures of these big plans. Future revisions to the French Plan Calcul and successive British initiatives from the NEB to Alvey continued to be predicated on the notion of crisis and state sponsored recovery. These later plans, though problematic in their own ways, were shaped by the salutary experiences of the 1960s. They were more narrowly conceived, targeted at niche sectors, and more pragmatic in application. The high point of state intervention on a grandiose scale had its day, and a grudging acquiescence in the reality of a new post-Imperial order had taken its place. The passage of time put a more realistic, or at least philosophical, perspective on attempts to stave off the inevitability of American challenge. Tom Kilburn, one of the pioneers of the computer in Britain summed up this feeling:

> it was the government which missed the opportunity because only the government could possibly have provided as much money as would have been necessary to keep ahead of the Americans. The Americans have got much larger funds available for development and putting into production and let's face it they're rather better at it than we are anyway . . . I don't really see, in retrospect, how anything could have happened differently.[66]

Acknowledgment

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7

From National Champions to Little Ventures: The NEB and the Second Wave of Information Technology in Britain, 1975–1985

Martin Campbell-Kelly and Ross Hamilton

Introduction

When the Labour Government of Harold Wilson was defeated in 1970, the industrial policy of its 6 years in office had been focused on the large industrial firm, and on grandiose projects that befitted a country which still considered itself a leading industrial nation—albeit in straitened circumstances. For example, the prestigious firm of Rolls Royce had been kept afloat while it developed the troubled RB211 jet engine. And in the information technology (IT) sector, ICL had been formed as the "national champion" computer manufacturer, with government financial support to enable it to develop a new generation of mainframe computers to compete with those of IBM.

While Labour was out of office between 1970 and 1974, it took stock and reformulated its industrial policy. By the early 1970s, "Europe's love affair with bigness" was leading to disenchantment: Rolls Royce had become famous as an industrial lame duck, while ICL had had to go cap in hand to the Conservative government for financial support to maintain development of its mainframe range. While the large industrial firm would remain the mainspring of the economy, Labour's industrial policy was now shifting to embrace the small firm in addition. This shift was in part a populist response to the vogue for the small entrepreneurial firm, but it also reflected a reality in the high-tech sectors. For example, in the IT sector, the oligopoly of IBM and the other mainframe-makers was being challenged by a second wave of IT enterprises. These included the manufacturers of small computers such as the Digital Equipment Corporation (DEC) and Data General in the United States, and by Control Technology Limited (CTL) in the United Kingdom. The 1960s had also created an opportunity for small-scale suppliers of peripheral and office equipment. Finally, in software, IBM's unbundling decision in 1970 created a market for software products where little had previously

existed. This resulted in the formation of several hundred software firms in the United States, and a much smaller number in the United Kingdom.

The National Enterprise Board (NEB) was to be the main instrument for Labour's industrial policy when it returned to power. Foremost, the NEB was to compulsorily nationalize 20 or 25 of the top 100 industrial firms in the country, so that the government would be able to more effectively control industrial development and distribute resources. It was also proposed that the NEB would be a lender of last resort to entrepreneurial firms where there was a market failure in the supply of venture capital. By the time Labour came to power in February 1974, however, the nationalization proposals had already been dropped due to the strong opposition of Harold Wilson. Tony Benn, the Industry Secretary, presided over the drafting of the Industry Act, which gradually accommodated the realities of office.

When the White paper appeared in August 1974, after reportedly twenty-five redrafts, the policy had been considerably diluted. The NEB was to have no compulsory purchase powers, except to prevent foreign take-over. Planning agreements were to be voluntary. There was no list of top firms to be taken over and no mention was made of selective government assistance, which, it had been suggested could be used to reward cooperative firms or punish the unwilling.[1]

The Industry Act became law in November 1975, and the NEB came into existence shortly after. By this time Benn, who had favored much stronger intervention in industry, had been sidelined to the Department of Energy (DOE), leaving the more centrist Eric Varley to take over as Industry Secretary. The NEB's statutory powers and obligations were set out in Section 2 of the 1975 Industry Act. They were: "the development or assistance of the economy of the United Kingdom (or any part of the United Kingdom); the promotion in any part of the United Kingdom of industrial efficiency and international competitiveness; and the provision, maintenance or safeguarding of productive employment in any part of the United Kingdom."[2] The principal means of achieving this was to provide finance either in the form of equity or in loans at commercial rates. The Board was given power to make investments of up to £10 million on its own authority, but required approval from the Secretary of State for Industry for any larger investments. The Board was required to present an annual corporate plan to the Secretary.

The NEB began operation on November 20, 1975, with a head office at 12–18 Grosvenor Gardens, London, and regional offices in Liverpool and Newcastle-upon-Tyne—reflecting its remit to promote industry in the assisted areas. The ten-person Board had the industrialist Sir Donald Ryder as its chairman and the banker Sir Leslie Murphy as his deputy. Both Ryder and Murphy were Labour supporters. The remainder of the Board consisted of three trades union officials, including David Bassnet (GMWU); four industrialists, including Michael Edwardes (Chloride Group) and John Gardiner (Laird Group); and a consultant economist. There were approximately forty full-time staff, typically bright young graduates, recruited from industry or banking, and generally active party supporters.[3]

The NEB was neither autonomous nor free from short-term political interference. The 1975 Industry Act empowered the Secretary of State to give the Board "special

directions" which would define more precisely its operation. The first special directive arrived within months, when, against the Board's wishes, it was saddled with the Department of Industry's portfolio of industrial holdings, mostly in lame duck companies. These included British Leyland, Brown Boveri Kent, Dunford and Elliott, Ferranti, Herbert (machine tools), ICL, and Rolls Royce. By the end of 1976, this portfolio accounted for the vast majority of the NEB's £959 million assets.

Although Ryder made the best of things in public, privately the Board complained to the Secretary of State that the management cost of monitoring the lame ducks would be a huge distraction in executing its proactive role in fostering innovative and profitable firms. But in fact, the Board was in the process of adopting its own lame ducklings—a group of small struggling high-tech firms. In the IT sector these included Systime, a manufacturer of minicomputers, the Data Recording Instrument Company (DRI), a maker of computer storage devices, and Newbury Labs, a maker of visual display unit (VDU) terminals (Table 7.1). The NEB generally maintained a hands-off relationship with these firms, which had the advantage that the Board could deal with a large number of them. Ryder privately acknowledged that by quickly putting its fingers into many different pies the NEB

Table 7.1. *Investments made by the NEB in IT companies, 1976–1981*

	1976	1977	1978	1979	1980	1981
Inmos	—	—	0.59	8.59	29.60	50.09
Insac[a]	—	1.45	2.15	6.10	9.17	(6.86)[b]
Computer Analysts and Programmers Ltd	—	0.55	0.55	1.00	1.00	1.61
Logica[c]	—	—	—	2.30	2.30	2.30
Systems Designers International Ltd	—	—	0.33	0.51	0.51	(+1.00)[d]
Systems Programming Holdings Ltd	—	1.20	1.40	1.55	1.60	1.40
Nexos[e]	—	—	—	4.10	16.80	(34.00)[f]
Logica VTS Ltd	—	—	—	1.80	1.80	1.80
Muirhead Office Systems Ltd	—	—	—	0.21	0.21	0.21
Sinclair Radionics Ltd	0.65	2.60	4.45	7.79	(7.90)[g]	—
Misc						
Systime Ltd	—	0.50	0.89	1.97	2.32	1.97
Newbury Labs Ltd[f]	—	0.62	—	—	—	—

Notes: All figures in £million.

[a] Includes investments in Insac Data Systems Ltd, Insac Group Ltd, and Insac Products Ltd;

[b] Loss on disposal of investment;

[c] Includes investments in Logica Holdings Ltd and Logica Securities Ltd;

[d] Profit on sale of investment;

[e] Includes Nexos Office Systems Ltd and Nexos Office Systems (Holdings) Ltd;

[f] Acquired by DRI in 1978.

was insuring itself against being easily dismantled by an unsupportive future government regime. His policy proved to be very effective—when Thatcher's 1979 Conservative government decided that the NEB should rapidly dispose of its investments the task was found to be very difficult.

By far the most interesting and potentially profitable of the first year's investments was a 43 percent stake taken in Sinclair Radionics, the successful manufacturer of calculators and digital watches founded by Clive Sinclair. Sinclair Radionics was not in any way a lame duck, but the firm needed substantial research and development (R&D) funds to catch what Sinclair perceived as the next wave of consumer electronics—a micro-television set. The normal investment channels had failed him, and his was precisely the type of venture that the NEB was set up to help. Sinclair Radionics was one of the four major IT investments that will be analyzed in detail in this chapter.

In any high-tech venture, there were essentially three issues that had to be addressed: The innovation itself, the development of that innovation into a product, and marketing that product. It was widely accepted that Britain was good at the first of these, but poor at the second and third. The National Research and Development Corporation (NRDC) has explicitly addressed the development task, but had only implicitly considered marketing.[4] As an attempt to focus on the marketing problem, in 1977 the NEB created two organizations to sell existing British high-tech products more effectively. The first of these was Insac, a software sales company, and the second was a medical supplies sales company, the United Medical Company International Ltd (UMC).

The aim of UMC was to market British-made medical supplies overseas, but its development was aborted when it became clear that its role overlapped significantly with that of the Overseas Hospitals division of Allied Investments Ltd. When the extent of overlap between the two organizations was realized, the NEB sponsored a merger between the two companies. In defense of its aborted plan for UMC, the new Chairman, Sir Leslie Murphy, wrote in the 1977 Annual Report that: "The NEB is an entirely new concept—a state-owned body operating in the competitive sectors of the economy and forming a bridge between State ownership and private entrepreneurial activity. It will take several years to prove whether or not this experiment can be successful."[5] Insac lasted a bit longer, but not more successfully.

With some successes and not yet too many failures, by 1978 the NEB was an increasingly confident and productive unit. Its permanent staff numbered about 80, twice the number when it first started. The main Board was now chaired by Sir Leslie Murphy, who had replaced Donald Ryder after the latter retired (harmoniously), and the dozen Board members continued to be a mixture of trades unionists and sympathetic businessmen.

The rising confidence and autonomy of the Board was reflected in two major start-ups in the IT sector, Inmos and Nexos. Inmos was to be a new semiconductor manufacturer that would help restore the UK's position in microchip manufacture, which had been lost in the 1970s to the United States, and increasingly to Japan and the Far East. This was a high-risk, high-cost venture. NEB's up-front investment in Inmos was £25 million, with a further £25 million promised downstream as

innovations flowed into products. In funding Inmos NEB was taking on the mantle of a true venture capitalist.

The Inmos launch was surprisingly well received by Parliament and this emboldened NEB into an even higher risk venture in January 1979. This was Nexos, a firm set up to develop an "office of the future" product line. So far as is known, the Nexos concept was internally generated within the NEB, and was an attempt not merely to pick a winner but also to pick a winning technology. Not surprisingly, this specific proposal encountered great hostility, particularly from the right-wing think-tank the Centre for Policy Studies.[6] In May 1979, when the new Conservative Government came into power, it was only the forces of inertia that allowed Nexos to continue to exist. All subsequent ventures would be regarded with deep suspicion by the new government.

The arrival of the Conservative government was a traumatic shock for the NEB. Guided not least by the Centre for Policy Studies, the new regime in the Department of Industry was intensely negative toward the NEB. Even though all of the Board's original left-wing nationalization plan had long been neutered, its reputation lingered on. The new Secretary of State for Industry, Sir Keith Joseph, presented an industry bill to Parliament in July 1979, which marked out a much less proactive role for the Board. This was further clarified in a statement by Joseph on November 21, in which he stated that the NEB would no longer have a major role in industry, but rather "would have a catalytic investment role, especially in connection with advanced technology and increasingly in partnership with the private sector, as well as its regional and small firms roles." In effect this meant that the NEB would be able to act only when normal investment channels failed, although it would continue to have responsibility for a few lame ducklings. Further, the Board was instructed to sell off its successful investments—its industrial participation would be limited to short-term aid to companies rather than ongoing support. There was no role for the NEB as what Joseph saw as a publicly owned investment trust in Britain's industry.

The same day that Joseph made his speech, the entire Murphy Board resigned. A wily politician, Joseph already had a new chairman, the Conservative industrialist Sir Arthur Knight, waiting in the wings, with a clandestinely assembled Board ready to take over. The trades unions had declined to be involved, so the Board consisted almost entirely of industrialists. With all speed the approximately £1 billion of investments in lame ducks were sold off (although some of the ducks, such as ICL, had recovered sufficiently to yield a handsome return).

The Board's own investment holdings of some £155 million in equity stakes were more difficult to sell. The government initially announced that the NEB would have to reduce its assets by £100 million before April 1980. However, when it became clear that this would force the Board to sell during unfavorable market conditions the directive was amended to urge divestments as soon as economically possible, rather than to a strict deadline.

Nevertheless, some of the Board's investment activities were allowed, or in some cases effectively forced, to continue. For example, Inmos was perceived to be on the

threshold of success and to cut it off from sources of cash would be regarded as perverse. Likewise Nexos, founded only 4 months before the election, had passed the point of no return. Again, a decision taken to reorganize Sinclair Radionics in an attempt to stem a pending cash-flow crisis was allowed to stand. In all these cases, failure to continue supporting the operations could have been arguably as politically damaging as the risk of throwing good money after bad.

Sinclair Radionics and the "Sunrise" Technology

At the time of the NEB's involvement, Sinclair Radionics[7] had become one of the UK's best-known companies and its founder Clive Sinclair one of its most celebrated entrepreneurs. Sinclair Radionics had been trading since the 1950s, originally making self-assembly kits for the electronics hobby market. It struck lucky with the calculator boom of the early 1970s, and had recently pioneered the development of digital watches. The company had just won a Design Council Award for one of its new calculator models, and—very widely reported—another had been displayed in the Museum of Modern Art, New York. The firm's prospects, once golden, had been tarnished by the launch of its digital watch with many design and manufacturing faults. In the 1974–1975 financial year Sinclair Radionics was barely profitable (making just £50,000 on sales of £6.25 million). Sinclair was now seeking funds to bolster the existing calculator and watch businesses, and to aid in the development of a miniature television system, to be called the Microvision (or TV1A), which he expected to launch in 1977. The development of Microvision's technology had already been sponsored by an NRDC grant of around £250,000 during the early 1970s.

Sinclair, advised by Lord Rothschild FRS—the distinguished scientist and author of the Rothschild Report on R&D—had approached without success two venture capital firms (Charterhouse and TDC). He had also applied to Sir Arnold Weinstock, managing director of General Electric Company (GEC), to dip into the company's famous cash mountain, but again without success. Finally, he turned to the NEB, which was never his preferred lender. Although Sinclair's failure to raise private money could be seen as a classic void in the venture capital market which the NEB was set up to fill, the Board was properly cautious, taking a full 3 months to come to a decision. In August 1976, it invested £650,000 in exchange for a 43 percent equity stake.

Unfortunately, just as the NEB investment had been made, the calculator market took a severe downturn due to fierce competition and price-cutting.[8] At the same time, the pre-launch expenses for the Microvision mushroomed. (Clive Sinclair strongly believed in building consumer demand by promoting a product long before it was available.) Radionics was plunged into a 1976–1977 loss of £1.88 million on just £3.95 million sales. The NEB attributed Sinclair Radionics' losses to Sinclair's management style. To protect its investment, the NEB increased its equity holding, taking a controlling interest in the company and with it an active management role. Radionics' status changed from an NEB Associate Company to

a subsidiary. Sinclair was assured that if Radionics returned to profit by 1981, sufficient of the NEB equity would be redeemed so that he could regain control.

The following year, even though the volume of calculators sold by Sinclair Radionics increased significantly, prices fell even faster and the company continued to make a loss. The Microvision was finally launched, but its market appeal turned out to have been seriously overestimated—consumers simply did not see the need for a miniature television. Furthermore, production and quality problems meant that only 200 sets were being manufactured each month, a fraction of the necessary output for the product to be profitable. The problems were attributed to Clive Sinclair's tendency to ignore the need for a development phase between the prototyping and marketing of new products. In practice, at Sinclair Radionics product development tended to be ongoing even as the first units were on the production line, which meant that expensive, skilled technicians were required to complete each unit, rather than production line workers. Without achieving commercial mass production of its products Radionics could not even come close to its predicted profit margin per unit.

To sustain Radionics in this disastrous trading period, in 1978 the NEB increased its investment, adding another £1.65 million to the existing £1.85 million and bringing its shareholding to a 73-percent stake. It also provided a further £1 million loan facility. With its majority holding, the NEB replaced Clive Sinclair as managing director by Norman Hewett. This was a choice that Sinclair found difficult to accept, because Hewett was an ex-GEC manager with experience in heavy electrical engineering—a business both technologically and culturally light-years away from Sinclair Radionics. Hewett immediately made Sinclair the director of research, and took over the company's financial controls. However, Sinclair continued to use informal command lines whenever necessary to retain day-to-day control of the company. After some months of this Hewett resigned and a new, more mutually acceptable, manager was appointed.

Even as Sinclair was feuding with Hewett and the Microvision was fighting for its life, he had another project under development. This was for a home computer, intended to catch the booming hobbyist computing market. Sinclair needed £500,000 to develop the computer. At this point, the NEB finally drew a line and refused: Not only that, but, to Sinclair's dismay, the computer project and its personnel were removed from the firm and sold to an NEB Associate Company, Newbury Laboratories.[9]

Sinclair Radionics' losses continued into 1979. Not least of the problems was one that was again attributed directly to Clive Sinclair's marketing naivety. As sales of the Microvision became sluggish, he announced the imminent availability of the Microvision 2 (or TV1B), which had a simpler design and was better engineered. Sinclair claimed that it would enable Radionics to aim for a £100 price point—half the price of the existing model. Of course, following his announcement, the market for the original model collapsed completely. Sinclair Radionics found it had to dump the stock of TV1As at below the cost of its component parts. The only hope was for the TV1B to be a roaring success, but its reception was as

lukewarm as the TV1A's—even though the price had been halved, there was still no demand for a miniature television set.

Given the proven lack of demand for a miniature television, the imploding calculator market and the digital watch fiasco, the NEB decided to pull the plug and wind up Sinclair Radionics. The only profitable arm, its instruments division, was hived off as Sinclair Electronics. The Microvision and calculator businesses were sold off to Binatone International, in August 1979, and the remaining business was gradually run down.[10] Eventually, the NEB had to write off its £7.8 million investment—the Board's first major failure, and an untimely source of embarrassment as Thatcher's Conservative government came into office.

Clive Sinclair, meanwhile, had adroitly hedged his bets against such an eventuality. He had already begun the development of another microcomputer at Science of Cambridge, a company he had started up, which had no NEB involvement. Reportedly, the Science of Cambridge project was an open secret in Radionics at the time.[11] Two years later, the computer was launched as the ZX80, and the company became Sinclair Research. That computer and its successors were fabulously successful and in June 1983 Margaret Thatcher's "favourite entrepreneur" was honored with a knighthood.[12]

Insac: The Software Titanic

In February 1977, the NEB formed a software sales company Insac that was aimed at exploiting British software skills and products and selling them overseas, particularly to the US market.

The concept of Insac[13] was originally brought to the NEB by John Pearce, a co-founder of the successful John Hoskyns computer services firm. He proposed four main objectives for Insac. First, it would develop an offshore programming capability to capitalize on the relatively low wages of Britain's IT workers (as with the present-day Indian software industry). Pearce argued that "for every New York programmer earning $22,000, there's an equivalent in London earning $10,000."[14] Second, Insac would market British software products in America, which represented two-thirds of the world market. At that time, UK software firms had barely entered the US market because of the high start-up costs of establishing a network of regional sales offices and acquiring sales people. By forming a consortium of UK vendors, the costs would be spread between the member companies. Third, it was intended that UK software firms would collaborate on producing export quality software packages instead of engaging in "destructive competition." Finally, Insac would establish joint ventures with overseas firms to create bridgeheads for the export of British software goods.

Pearce was appointed Managing Director of Insac, and set about recruiting the top dozen or so UK software houses into the consortium (which left the remaining many dozens of small software firms entirely out of the picture). The NEB made it a requirement of membership that it take a minimum one-quarter equity share in each of the members. In the event, only four firms were willing to dilute their equity (or were in need of the cash): Logica, Computer Analysts and Programmers (CAP), Systems Designers Limited (SDL), and Systems Programming Limited (SPL).

The original four companies were later joined by Systime, a "turn-key" systems house and DEC minicomputer reseller. The NEB took equity stakes of around 30 percent in each company, and retained complete ownership of Insac itself. The Insac Board included representatives from each of the member companies, each being a managing director of their own company. The NEB committed £9 million in equity funding to Insac in its first year of operation, and approved a 5-year plan with a peak-funding requirement of £20 million.

Almost from the beginning, Insac proved unworkable. First, the business of offshore software writing simply never materialized, probably because the marketing operations required for "body shopping" and selling software products were completely different. Second, interfirm rivalry consumed most of the collaborative potential. It proved impossible to foster a culture of cooperation within Insac, while the tradition of competition—and even enmity—in the domestic marketplace lived on. There were early accusations that some of the member companies were using Insac solely as a means of funding their own overseas marketing operations, rather than collaborating to produce international software products. By the end of its first year of trading, Insac had an operating loss of £1.3 million, accounted for mainly by staff recruitment and the establishment of offices in London and New York.

Two years later, in 1979, Insac had increased the scale of its operations, with forty staff in seven regional offices, and a portfolio of 500 software products, but still with negligible commercial success. The only product that amounted to a software "hit" was the Viewdata system sold under license from the Post Office (which had originally developed the software for its Prestel information service). This success, however, was purely fortuitous and had no connection with any of the Insac membership. In order to focus on this one patch of success, the Viewdata venture was spun off as Insac Viewdata Ltd.

At the same time, Insac established a marketing agreement with Altergo, the only UK software house with a significant American presence. Described in *Datamation* as an "American Software Dream," the writer noted:

> The pact between Insac and Altergo is fraught with irony. Insac was formed three years ago by the government's National Enterprise Board with the intention of helping to export software. . . . Insac's emphasis was then on the trying to form a consortium of the largest British software and systems houses, such as Logica and CAP. Smaller companies which were showing the entrepreneurial spirit in setting up American sales, were thought too small to be aligned with the Insac set.[15]

Since the refusal of Insac membership, Altergo had grown spectacularly. With a staff of 500 and a turnover of £10 million it was now on a par with any of the Insac consortium. In its most recent year of operation it had grown 60 percent, and was making 20 percent of its turnover in the United States, with significant further export sales in Europe and Japan.

Within the Insac Board, the Viewdata operation and the relationship with Altergo cause major rows. As a result, three of the original Board Members resigned amid accusations of bias, "point-scoring," and harboring uncooperative agendas. CAP announced that it would market its systems in the United States

under the Altergo name, rather than the sullied Insac name. SPL decided to set up its own New York sales office independently of the other companies, announced that it was looking for alternative equity investors, and requested that NEB give up its 80 percent equity holding. (The NEB refused, insisting with condescension that it would not sell its holdings until it had vetted the potential suitors.) Later in the year, SDL also announced that it wanted the NEB to sell its 26 percent equity stake and allow it to make a public stock offering. SDL's chairman publicly accused the NEB-management of Insac of "spending 95 percent of its time on Viewdata" and ignoring Insac's other products.[16]

Overshadowing these events was the early months of the Thatcher Government, when the future of the NEB itself was far from certain. Insac's only real commercial success remained Insac Viewdata Ltd. To avoid further conflict with constituent members, and with the Insac name rapidly becoming tarnished, the Board decided to rename the Insac Viewdata as Aregon. Shortly after, Aregon acquired Global Data Corporation, a West Coast IT company, to enhance its presence in the United States. Somewhat opportunistically John Pearce resigned as Managing Director of Insac to become Managing Director of Aregon, and took with him all but 6 of Insac's 165 US staff.

At this point Insac was almost too small and demoralized to function. A new managing director was appointed, who decided to abandon the consortium concept—a decision partly determined by the fact that only two member firms remained. Instead, Insac would sell UK software products from any source, large or small. However, sales remained poor. Following 5 years of mounting losses, in 1982 the majority of Insac's assets were sold to a US software house, Britton Lee, at a loss to the NEB of £6.86 million (representing about 25 percent of the NEB's net £28.2 million loss on investments during the lifetime of the Board). Although Britton Lee had announced that it would put $300,000 into Insac's US branch, it in fact liquidated the company shortly after the sale.

Insac was a political and commercial disaster for the NEB, but there was a silver lining: Each of the original five member companies was individually profitable throughout the lifetime of Insac, and the NEB's equity investments accordingly increased in value. For example, when in 1981 the Board sold its 26 percent stake in SDL it made a 552 percent profit on its original 1978 investment.

Inmos: A Triumph of National Enterprise?

Inmos[17] was the NEB's attempt to create a British-owned and -based advanced semiconductor manufacturer. It was planned to be a company that built microprocessors and other high-value integrated circuits that would compete directly with the United States' market leaders. Two entrepreneurs, Iann Barron and Richard Petritz, cooked up and presented the proposal to the NEB in March 1978.

Barron was a prominent electronics engineer, promoter, and technology pundit, who had become involved in computer technology while working for Elliott Automation in the early 1960s, and had successfully founded CTL, a British

minicomputer manufacturer, in the late 1960s. He had already acted as a consultant to the NEB, had co-authored an industry analysis with the Science Policy Research Unit at Sussex University,[18] and was well known in political circles, having given evidence to the parliamentary Select Committees on Science and Technology. Petritz was an American electronics engineer turned venture capitalist who had worked in the US semiconductor industry and had been a partner in the setting up of Mostek in 1969, one of the leading manufacturers of high-density memory chips and microprocessors.

Barron and Petritz proposed a company with manufacturing operations in both Britain and the United States, but with design facilities in Britain. They estimated that by the mid-1980s the company would employ around 4000 people in Britain and 1000 in the United States. Their initial proposal for £50 million funding to create Inmos was based on an existing estimate of Petritz. They estimated it would cost £12.5 million to site such an operation in South Korea; they then doubled the amount because of the higher costs of siting the business in Britain, and then doubled it again because "everyone knows such projects always cost twice as much as you expect."[19]

The proposal had its critics, particularly on the Tory right,[20] and in the National Economic Development Office (NEDO), which issued a statement suggesting it was a high-risk venture, that should be more thoroughly investigated.[21] The industrialist Sir Arnold Weinstock, managing Director of GEC, complained of crowding out: His was a British company that was already building semiconductor devices (although not mass-market microprocessors), and the creation of Inmos would deprive it of human resources and domestic market share. Brushing aside the criticism, the NEB agreed in July 1978 to invest £25 million as equity funding, with the assurance that if the company achieved certain milestones a further £25 million would be forthcoming. Because of the large public sums being invested in the company, the NEB maintained a much closer watch on Inmos than with its other investments. The Board generally had two or three nominees on Inmos' board of directors, who typically advised on financial rather than technical matters.

The initial few months of Inmos' existence were fraught. First, it had to defend a lawsuit in the United States from Mostek, which alleged that Inmos had poached some of its key staff in an attempt to obtain trade secrets. The case was dismissed after 2 months but it was a serious distraction. Then, in May 1979 the election of the Tory government put the second £25 million tranche of investment in jeopardy. The new government agreed only to honor the outstanding commitments made by the NEB before the election, and announced that no further investment was to be made—Inmos would have to support itself.[22]

Inmos' progress was further hindered late in 1979, following the company's announcement that it would build its British manufacturing facility in the mellow and prosperous city of Bristol. This decision created a furor because it was widely understood that Inmos had only been given permission to site its headquarters and design team in Bristol provided it built its first factory in an assisted area. Inmos' founders contested that they had never agreed to such a demand, although it was

noted in the NEB's 1978 Annual Report that: "The firm intention is that the UK production facilities will be located in Assisted Areas." However, Barron and Petritz argued that this was the view of the Board, and not the view of Inmos. Although the decision to site production facilities near to the design team made financial and logistical sense, Barron and Petritz had to yield to the political necessity of looking for an assisted area to locate it. In June 1980, they accept a location in Newport, South Wales, which was tolerably close to Bristol. Work on the Newport plant finally began in January 1981, with full production scheduled for 1983. By this time, the company's estimates for construction of the manufacturing facility had increased significantly. Fortunately for Inmos, the new Industry Secretary, Sir Keith Joseph, approved its second £25 million funding in July 1980. This, it was made clear, would be the last government investment in Inmos.

While all of the arguments about the siting of the UK production facilities were raging, Inmos' small prototype plant had been successfully opened in the United States in March 1980, in Colorado Springs. Building on its success, construction of a full-scale plant at the Colorado Springs site was initiated. By 1981, Inmos had there a modern manufacturing facility capable of producing its advanced semiconductor devices, and a design team in Bristol that was quietly and competently working on the integrated circuit designs to be manufactured there.

Inmos' first products in 1981 were relatively simple devices—16 K memory chips—which were chosen because they were in strong demand at the time, but not too technically demanding. They gave the company an opportunity to ascend the learning curve of the manufacturing process, before it advanced to microprocessor production. The 16 K chip was followed in November 1981 by a 64 K version, which proved quite profitable. Inmos' strategy was to produce for the high-specification end of the semiconductor market, selling primarily to the defense markets.

By 1984, Inmos' prospects seemed good enough for the NEB to comply with the government's instruction to divest its investments as soon as economically possible. The government's stake in Inmos was eventually sold to Thorn-EMI for around £95 million. Even though better offers might have been forthcoming from non-UK companies, selling Inmos quickly and retaining British ownership was a political necessity. The NEB reported that it was disappointed with the sale because a better price from an alternative buyer might have been possible within the following few months. In the event, the sale proved to have been made at just the right time: A combination of manufacturing problems in its Colorado Springs plant and a slump in the semiconductor market during 1984 plunged the company into loss. In 1985, it lost £25 million, and it continued to lose money in 1986, precipitating the closure of the entire Colorado Springs operation.

The Nexos Disaster

In the late 1970s office automation (OA) was the hot new application of computing. The visionary basis was the convergence of computing and communications (a vision that has regularly come and gone, before and after). The technological basis

was the use of text processing and communications software to integrate the existing technologies of visual display units, printers, facsimile machines, and computers. The market leader worldwide was the US firm Wang Laboratories, but the big computer manufacturers, such as IBM and DEC, and office machine firms, such as Xerox and Olivetti, were also developing products.

It was in this context that the NEB saw the opportunity to fill a gap in the British OA market; a gap that was not then being met by ICL—which had problems enough maintaining the competitiveness of its mainframes. In January 1979, the NEB created Nexos,[23] a systems integration and sales company to develop OA products that would be significantly in advance of those currently on offer. Nexos was provided with an initial £15 million in equity funding, with the expectation of a further £25 million to be made available later.

The company's early development consisted of opening sales offices in London and Bristol, and undertaking a massive program of headhunting. Sales executives were enticed from other companies by offering generous salaries and benefits packages. By the end of 1979, after a year's operation, Nexos had 144 staff. The recruitment frenzy continued into 1980 with the headcount peaking at 410.

The Nexos office-of-the-future product consisted of a reprographic/facsimile system and a word processor, integrated with a telephone system. The central unit was to be a small computer system that would not only provide the word processing facilities and manage the telecommunications, but also respond to voice commands. NEB now acted as an impresario to bring together the critical technologies. First, facsimile equipment was commissioned from Muirhead Data Communications, a British office equipment company, which formed, with the NEB, a new firm called Muirhead Office Systems, owned 75 percent by Muirhead, and 25 percent by the Board at a cost to the NEB of £210,000 in equity and a further £250,000 loan facility. Second, word processing software was commissioned from Logica (a founding member of Insac). A jointly owned subsidiary company, Logica VTS, was formed, with £5.67 million in equity funding (a 43 percent stake) by the NEB, and loan facilities of a further £1.75 million. Finally, the central control system was commissioned from Delphi Ltd, a computer systems development subsidiary of the oil giant Exxon. Delphi had demonstrated some reasonable success with a voice-operated telephone system in 1977, and appeared to show the most potential of developing a marketable product within a short timescale.

Although the product development plans appeared realizable in a year or two, the rash of hiring in 1979 had led to a situation where there was a sales force crying out for something to sell. Nexos therefore decided to market a simple word processor made by the Ricoh Company of Japan, distributed in the United Kingdom by UDS Ltd. In order to gain access to the Ricoh product line Nexos acquired UDS, adding yet further to its sales force. To make matters worse, Muirhead's facsimile systems were found to be inadequate, and it would be more cost-effective to use equipment from a Japanese manufacturer (Oki Electric). These were intended only as interim solutions until Nexos' own products came on stream. By the summer of 1980, however, Logica VTS had fallen behind schedule

on its word processing software. Although Nexos had been presenting prototypes at trade shows since early 1980, and promising to deliver the full product in the autumn, Logica VTS repeatedly missed its deadlines. Nexos was unable to commission alternative software because of an exclusive license signed with Logica VTS.

Nexos' original cash-flow forecasts had planned for sales of 2000 units by the end of 1981, anticipating that it would be available in the summer, but the final product only appeared in November. Eventually, only 600 units had been sold by the end of that year. Nexos' expensive, high-pedigree sales force had been given very little opportunity to prove its worth, and consequently the company suffered massive losses. Relations between Nexos and Logica VTS became extremely strained. Meanwhile, competition in the office equipment market intensified as companies such as Office Technology Ltd (OTL), a sister company of CTL, began introducing similar products.

Faced with these financial difficulties, Nexos applied to the NEB (by then under Sir Frederick Wood's chairmanship) for further assistance. The NEB commissioned an external report from Arthur Andersen on Nexos' strategy. Meanwhile, the Industry Secretary (Keith Joseph) approved a drip-feed operation which allowed Nexos to meet its immediate cash requirements. The Arthur Andersen report concluded that Nexos' strategy was high-risk, but intrinsically sound, and recommended a further investment, which would bring the government's total to £35 million. However, rather than approve the recommended £19 million, Joseph provided only the £6.3 million needed immediately for Nexos to keep trading.

Joseph agreed that on February 19, 1981 he would announce whether the government would approve the remaining funds for Nexos. In a surprising turn of events, on February 18, the Executive Directors of Nexos sent a letter to Joseph. They urged him not to release the money unless Nexos was also merged with Logica VTS, so that Nexos would be able to put greater pressure on the development of the word processing software. When Wood approached the Industry Secretary for his verdict on the 19th, the investment was approved—Wood did not know about the director's letter before the meeting with Joseph.

However, Nexos' sales performance never improved to the extent required, and by October 1981, it was clear that the company would never become self-supporting. The decision was taken to put Nexos into receivership. The NEB lined up a number of potential companies that would be willing to buy Nexos' remaining assets—which essentially amounted to a strong sales force and potentially valuable technology agreements with Logica VTS, Systime, and Delphi. The prime candidate appeared to be the office equipment manufacturer Gestetner, with whom negotiations were begun. Meanwhile, morale at Nexos plummeted, and Gestetner got cold feet, pulling out altogether in January 1982, by which time the deal with Delphi had also been terminated.

The axe finally fell later in January 1982, when most of the staff was made redundant and sales operations came to a halt. Nexos' assets were soon disposed of. ICL picked up the opportunity to market the 2200 word processor, sharing the rights with Logica. Nexos' service arm, with its 84 remaining staff, was kept alive in

the form of a management buy-out funded by a venture capital organization, Venturelink, and given a new name, Nexel. However, with only a small user base to support it soon faded into obscurity. Finally, the facsimile sales and maintenance operations were picked up by Muirhead, as part of what would prove to be a contentious deal: Muirhead paid £1 for Nexos' existing stock of 875 Oki facsimile machines, and a further £1 for a shipment of 590 machines that was already in transit from Japan. The justification for this deal was that Muirhead would have to assume the costs of a marketing operation to deal with these machines, and the company also agreed to waive its rights to a breach of contract suit against Nexos' assets. However, the Department of Industry, urged in particular by Tory MP Phillip Oppenheim (who also happened to be the co-editor of an office equipment magazine), opened an inquiry into the disposal of Nexos' assets.[24]

Conclusion: Did the NEB Do Any Good?

In its 7 years of existence between 1975 and 1981, the NEB made a modest loss in relation to its £1 billion assets. It would, with a lot of effort, be possible to compute the real cost of the NEB over this period, taking into account the cost of capital, the effects of inflation, etc.[25] However the result would not convey the unquantifiable outcomes of the NEB in creating employment, helping the assisted areas, and changing the business and investment climate toward entrepreneurship. Moreover, the Board's high-tech investments were only at the noise level in terms of its investments in lame ducks.

The NEB made both strategic and tactical investment decisions. At the strategic level it did well. For example, the Board chose IT and biotechnology as being the two growth areas for the future. Admittedly, even without the benefit of hindsight, these were obvious choices, but nonetheless they were the choices the NEB made. Less obviously, it recognized that the engine of growth in these sectors would be small- and medium-sized firms.

At the tactical level, however, most of the NEB's investments turned out badly. This is not unusual in high-tech areas—but the NEB compounded the error by pulling out when things went wrong. For example, in the case of Sinclair Radionics the initial investment in micro-TV was ill judged and caused the NEB to abandon the firm—just as it was on the threshold of becoming a major world supplier of personal computers. If the NEB had stayed with Sinclair Radionics, this one investment would have justified the whole enterprise and transformed its lacklustre image. There was a similar situation with Nexos, the office-of-the-future firm. When Logica failed to deliver its word processing software on time, the NEB lost confidence and broke up the entire enterprise, salvaging as much of its investment as it could. ICL picked up Logica's software and used it as the basis of its successful 2200 word processor.[26] So the Nexos investment had some economic benefit, although it was ICL and not NEB that derived the benefit. This tendency to get cold feet was one of the Board's most disappointing features—unlike the private sector it could reasonably well have afforded to take a long view, throwing bread on the water in the hope that a few sturdy ducks would develop.

In the case of Insac, the whole enterprise was misguided, and was a case of the NEB exceeding its competence. The Board should have been warned by the bloody history of UK firms' attempts to penetrate the US market, almost all of which had been unsuccessful. This was exacerbated by a misunderstanding of the software package market. Even in 1979, it was well known that the software market was not price sensitive. Software was a small part of any data processing budget (typically less than 5 percent), and quality and assurance of supply of mission-critical software were overwhelmingly more important than a factor of two or three in price. In retrospect, Insac would have done much better to focus on a small portfolio of strongly differentiated products and to address the market perceptions of quality and supply.

Inmos was the exception, in that it was a very successful investment. Its sale for £95 million, on an investment of £50 million, covered all the other losses on IT firms. This is exactly how venture capitalism in the high-tech sector is supposed to operate, a fact of which right-wing critics seemed ignorant. Although the sample is too small to make the point too strongly, a success rate of one in four of its major investments (Sinclair Radionics, Insac, Nexos, and Inmos) would be regarded as a model of stability for the venture capital industry, where the norm was for extremely high returns on a tiny fraction of its investments.[27]

Under the incoming Tory regime, the NEB's role as a venture capitalist was terminated, except for the self-contradictory remit to invest in sound ventures where private sources could not be persuaded to invest. But in any case, by the early 1980s, the venture capital gap the NEB had been created to fill was being satisfied by private investment companies such as 3i. Hence the Tory right was arguably correct to call for the curtailment of the NEB's activities, but not for the doctrinaire reasons it advocated. The fact was that the NEB had done itself out of a job. It had successfully filled a venture capital void in the late 1970s, and had helped to change the investment climate to the point where it was no longer needed.

In February 1981, Sir Frederick Wood, who was chairman of the NRDC, became chairman of the NEB. Wood saw the NRDC as a strongly technical organization, while he considered the NEB's greatest strength was its understanding of financial management, and he hoped to marry the capabilities of the two organizations. Urged on by the government, Wood devised a plan that took until 1981 to effect completely, such that the operations of the NEB and NRDC were combined under a new umbrella organization, the British Technology Group (BTG). During 1981, Wood continued to introduce new technologists and financiers to the Board—which notably remained devoid of trade union representatives—and divided the organizational structure three ways: A New Investments section, a Management of Investments section, and a Technology Transfer section. Each section was then subdivided according to three industry sectors: Biological and Chemical Sciences; Electronics and Information Technology; and Engineering. Wood also aimed to improve links with the academic community, by creating a University Coordination division. Ostensibly, the NRDC staff provided technical skills while the NEB provided the financial acumen. However, in essence it appears

that Wood subsumed the financial skills of the NEB within the existing NRDC structure.

In 1992 the BTG was privatized and within a year moved into the FTSE 250. Since privatization its share price has been volatile.

Notes

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2. Industry Act 1975, section 2.
3. Daniel C. Kramer, *State Capital and Private Enterprise: The Case of the UK National Enterprise Board*, New York, Routledge, 1988.
4. John Hendry, *Innovating for Failure*, Cambridge MA, MIT Press, 1989.
5. NEB, *Annual Report*, 1977, p. 7.
6. Michael Grylls and John Redwood, *National Enterprise Board: A Case for Euthanasia*, London, Centre for Policy Studies, 1980.
7. Ian Adamson and Richard Kennedy, *Sinclair and "Sunrise" Technology: The Deconstruction of a Myth*, Harmondsworth, Middlesex, Penguin Books, 1986. The "Sunrise" of the title was ironic. Rodney Dale, *The Sinclair Story*, London, Duckworth, 1985.
8. Ernest Braun and Stuart MacDonald, *Revolution in Miniature: The History and Impact of Semiconductor Electronics*, Cambridge, Cambridge University Press, 1978.
9. Newbury Labs went on to sell the system to Grundy Business Systems, which released it as the NewBrain in 1982. Alongside Sinclair Research and Acorn, Grundy was a key company in the furor surrounding the choice of a home microcomputer for the BBC to endorse. See: Tom Lloyd, *Dinosaur & Co: Studies in Corporate Evolution*, London, Routledge & Kegan Paul, 1984; chapter 6.
10. Binatone planned to re-market Microvision, but never did.
11. Adamson and Kennedy, op. cit., p. 62.
12. Ibid., p. 143.
13. Ralph Emmett, "Insac: Are There Any Survivors?," *Datamation*, March: 226HH–226LL, 1980. The article was accompanied by a cartoon of the *S.S. Insac* sinking beneath the waves.
14. Ralph Emmett, "U.K. Software Group Aims as U.S. Market," *Datamation*, September: 273–275, 1977.
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16. Anon, "SDL Plans to Break Links with the NEB," *Computing*, 28 (August): 3, 1980.
17. Mick McLean and Tom Rowland, *The Inmos Saga: A Triumph of National Enterprise?* London, Frances Pinter, 1985. The authors do not answer the question of the subtitle.
18. Iann Barron and Ray Curnow, *The Future with Microelectronics*, London, Frances Pinter, 1979.
19. Barron, quoted in McLean and Rowland, op. cit., p. 33.
20. Long-standing opponents of the NEB and of Inmos in particular, included MPs Michael Grylls and John Redwood. See John Redwood, *Going for Broke: Gambling with Taxpayers' Money*, Oxford, Blackwell, 1984, p. 75.
21. Kramer, op. cit., p. 131.
22. Incidentally, Michael Grylls MP, speaking in the Commons on 23 July 1979, urged the government to break its contractual agreement with Inmos, and refuse payment of the

second £25m, even at the risk of being sued for the breach. See Kramer, op. cit., p. 132.

23. The description comes from Kramer, op. cit., ch. 10.
24. op. cit., p. 159. Also Public Accounts Committee, *Nexos: minutes of evidence*, London, HMSO, 1985.
25. NEB, *Annual Reports*, 1976–1982.
26. Martin Campbell-Kelly, *ICL: A Business and Technical History*, Oxford, Oxford University Press, 1989, p. 345.
27. Richard Coopey and Donald Clarke, *3i: Fifty Years Investing in Industry*, Oxford, Oxford University Press, 1995, p. 177 ff.

8

The Influence of Dutch and EU Government Policies on Philips' Information Technology Product Strategy

Jan van den Ende, Nachoem Wijnberg, and Albert Meijer

Introduction

This chapter concerns the information technology (IT) policies of the Dutch and European governments in the period from 1960 until the late 1990s. In that period the Dutch and European governments have dedicated considerable efforts to promote the IT sector in the economies under their control. The importance was obvious. It became clear that IT would have an enormous worldwide impact on the economy. Countries or continents that lagged behind, ran the risk of falling behind economically, certainly with heavy social consequences. Moreover, the government of the international frontrunner in the field, the United States, indirectly but heavily supported the IT sector by military procurement and military sponsoring of technology development. It meant that governments in the rest of the world could not stay behind.

In this chapter, we want to evaluate the success of different government policies and instruments against the background of the development of the life cycles of computer technologies. We use a broad definition of technology policy, excluding science policy but including all types of public policy, such as trade policy, that explicitly aim at having an impact on firm's choices and behavior with respect to technological innovation. We do not attempt to assess the overall economic effects of the IT policies. Neither do we want to evaluate the effect on the IT sector as a whole, since it would be very hard to make any definite claim on that point. The main aim of this chapter is to describe the evolution of Dutch and European IT policies and to evaluate the role of one Dutch company, Philips Electronics Ltd, in this context. Philips was the biggest company involved in IT hardware in the Netherlands, and the company that succeeded best in profiting from government policies. We will discuss the effects of government IT policies on the investment decisions of Philips and, thereby, on the performance of the company in the IT business. Particular attention will be paid to the role of Philips, as a company and also as represented by employees and former employees, in the process of framing and implementing government policies.

In the next section, we will sketch a theoretical framework that will allow us to analyze the interrelations of the different policies aimed at the sector, especially focusing attention on the effects of policy on the course of the industrial life cycle. Then we will give a short overview of the history of the computer and component industries. Next, we will discuss the development of EU and Dutch IT policy from the 1960s onward. We will describe the activities of Philips in the field of computers and components. We will attempt to shed light on the relations between Philips and policymaking public authorities. We will attempt to see to what extent these relations help to explain the strategic choices made by Philips as well as the development and effects of specific policies directed toward the IT sector.

Technology Policy, International Trade Policy, and the Industry Life Cycle

To consider technology policy and international trade policy in an integrated way, it has been proposed in Wijnberg[1] to focus on the effects of these policies on the industrial life cycle. This seems a natural choice in so far as the industry is considered to be the locus of competitive advantage,[2] and the industrial life cycle provides a representation of the dynamics of an industry and the characteristics contributing to competitive strength. The main argument of Wijnberg concerns the way in which public policies can, on the one hand, serve to accelerate or decelerate the course of the life cycle in particular industries in particular countries and, on the other hand, to provide these industries with a more challenging or more sheltered or protected environment.

There are a number of different approaches to industry life cycles. A number of authors fused the concept of the product life cycle with Schumpeterian ideas about the dynamics of innovation and imitation.[3] Abernathy and Utterback have proposed an influential model where technology grows from a "fluid" state to a "specific" state.[4] After the rate of product innovation has slowed down, standardization of the product allows greater gains to be made by process innovation and use of scale advantages. This process is accompanied by the growing dominance of the large, integrated enterprise. Thus, life-cycle models propose that, at first, product technology will develop rapidly, especially because of technology-push, and both market and technological uncertainties will be high, while in later phases, the product becomes more standardized, demand-pull forces will become more important than technology-push as causes of innovation, emphasis shifts from product innovation to process innovation, and market behavior will become more easily predictable.[5] Also, while small and recently founded firms will dominate in the first phases of the life cycle, large firms that are able to profit from economies of scale and scope will dominate the later phases.

Duysters has attempted to integrate such a life-cycle model with notions from evolutionary economics and organizational ecology.[6] He tested his hypotheses in a number of industries, including the computer industry. He found that the development of the computer industry did correspond to his version of the life-cycle model, with small and flexible companies dominating the earlier phase until product

standardization opened the way for larger companies with, again in later phases, (new) specialist companies being successful in specific market niches. At the start of the life cycle, government intervention and support, for example, by funding research in institutes and universities, was essential to overcome the high uncertainties present. He also concluded that: "The framework, however, seems to overstate the destructive forces of technological change and to underestimate the various non-technological forces that enable firms to master changing environments."[7] Among these forces must certainly be counted government policy.

In particular, policies can have an impact on the course of the life cycle, causing the industry to develop more or less rapidly and to assume earlier or later the characteristics that belong to mature industries. Stimulating product innovation, lowering barriers to entry, procuring goods and services from small and young firms and strict enforcement of competition laws, can cause industries to remain longer in the early stages of the life cycle, and thus decelerates the life cycle. Stimulating process innovation, early standardization, mergers, etc. can have the opposite effect, accelerating the course of the life cycle.

At the same time, international trade policy can become one of the main factors determining whether an industry develops in a more sheltered environment. A common dichotomy in theories of international trade is between *import-substituting* and *export-promoting* strategies.[8] Highly simplified, this is a distinction between countries that attempt to reserve their home-markets for their own industries and countries that attempt to force their industries to penetrate foreign markets. Import-substitution usually means high tariffs on imports and subsidies to those enterprises that produce the goods for the home-market. An export-promoting strategy means preferential treatment (subsidies, better exchange rates, etc.) for exporting enterprises. The first strategy can lead to creating a sheltered environment; the second can function as a way of forcing a highly competitive environment on home-industries.

These two policy dimensions, acceleration–deceleration of the life cycle and sheltering or challenging the industry, can be employed to construct a matrix of four different types of policy combinations (see Table 8.1). Referring to insights from macroevolutionary biology as well as to empirical studies of the trade policies of various countries, Wijnberg suggested that short-term success could be achieved with acceleration combined with a challenging environment in which the national firms are forced to compete fiercely with each other and with others in the international market-place.[9] Examples can be found in the export-promoting strategy

Table 8.1. *Policy combinations and their most likely outcomes*

	Decelerate life cycle	Accelerate life cycle
Challenging/ export promotion	Long term success	Short term success
Sheltering/import substitution	Unpredictable outcome	Failure

of South Korea and a number of other Southeast Asian countries. In the long term, the most attractive policy combination seems to be deceleration or preservation of youthful features combined with a challenging environment. The innovative capabilities of the industry, including greater capacities for flexible adaptation that come from the conservation of youthful features, such as a focus on product innovation, have to be used fully to survive in highly competitive circumstances. Without such competitive discipline, flexibility may be more likely to lead to a proliferation of varieties of product designs than to cumulative progress, although it is always possible that one of these varieties that can develop in relative security may prove to be uncommonly successful. Therefore, the combination of deceleration and sheltering brings with it the most unpredictable results.

Acceleration combined with creating a sheltering environment seemed the worst possible recipe, especially with regard to industries working with technologies that were themselves still undergoing rapid development and radical changes. Acceleration has the implication that policies are suited to firms acting as if they were part of a ripe industry, focusing on process innovation and large scale, vertically integrated production. Sheltering has the implication that these firms are allowed to escape, at least for a time, from the pressures of world-market competition, with regard to prices and especially with regard to technological performance. The combination resulted, for instance in Brazil in the 1970s and early 1980s, in firms doing well, for a time, in their local markets, failing miserably in the world market. The reason was that at the time they were mass producing a product, competitors were already offering vastly improved products, and finally they failed in their home market too.

We will use this framework when we attempt to draw conclusions from our study of Dutch and EU IT policy. Before that, we will first discuss briefly the development of computers and components, with special attention to the interaction between policy and industrial development in the United States.

The Life Cycles of the Computer and Component Industries

Two industries have to be distinguished in computer hardware, computers and components. At the same time it has to be emphasized that there were significant interactions between the two industries, and their respective life cycles.

The 1950s till the 1970s were the decades of mainframes and minicomputers. In the early 1960s, the main market shifted from scientific computing to data processing. Many companies entered the computer market in the initial period, both new ones and incumbents from other industries (office equipment, electronics). Soon IBM acquired a very important position in this market. The successful IBM 360 line of computers, announced in 1964, was important for the position of IBM. Another American firm, Digital Equipment Corporation (DEC) was the main manufacturer of minicomputers, that were primarily applied in process control and technical scientific applications. It meant that US firms dominated the computer industry. The mainframe computer industry had a high rate of concentration

(mainly due to the position of IBM) but it too had a high level of competition and product innovation, characteristics of a young or decelerated industry. Until the end of the 1960s, when time-sharing was introduced,[10] the mainframe industry can be considered to have been in its fluid phase. In fact the minicomputer market for industrial applications was already in its growth phase since the second half of the 1980s, whereas the minicomputer market for data processing applications remained much longer in its first fluid phase. The mainframe and minicomputer industries profited from the large amounts spent by the US government, almost exclusively on the products of US firms, but that was all the shelter they got.

Young entrepreneurial firms, specialized chip-producers selling to the electronic equipment producers, dominated the semiconductor industry in the United States in the 1960s. According to Flamm, this development owed much,

> first, to the willingness of the military, the leading consumer of leading-edge components, to buy very expensive products from brand-new firms who offered the ultimate in performance in lieu of an established track record, and second, to the rise of a highly competitive computer industry, which was also willing to buy the most advanced component technology from whoever offered it for sale. Other factors included the high degree of labour mobility within American industry . . . , the ready availability of venture capital . . . , huge federal investments in R&D in the underlying technology base . . . , and a first class educational and scientific infrastructure . . .[11]

There were no significant restrictions on imports to the United States, neither for computers nor components, and the main US firms also had to fight it out on the world market while, at the same time, even the shelter of procurement did not provide an easy life to firms who had to be on their toes continually, because of the readiness of the US public authorities to shift their custom to newcomers. Thus, the US IT policy could be pictured, at least in the 1960s and 1970s, in the matrix-segment: Deceleration and no sheltering.

European computer firms played secondary roles. Bull (France), ICL (Great Britain), Compagnie Internationale pour l'informatique (CII) (France), and Siemens (which sold RCA equipment under its own label, Germany) had difficulty in gaining a significant market share and were often mainly active on the domestic market.[12] Some of them had a similar background to IBM (office equipment, particularly punched-card machinery) but they did not manage to develop into IBM-like companies.

The microelectronics industry developed quickly from the 1960s onward. Since the 1970s, Intel has developed into the most important microprocessor company. European firms had problems in this industry too. Only a few of the old vacuum tube and transistor manufacturers successfully made the transition to this new industry (among which figured Philips). Also in this field a more traditional, even hidebound, industrial structure prevailed; there was limited employee mobility among firms, scarce venture capital to fuel start-ups; little (until much later) government disposition to plough huge amounts via public procurement or R&D subsidy into leading edge electronics or computers, and an academic sector with

few links to, or interest in, industrial matters. Established electrical equipment manufacturers were the primary force driving investment in semiconductor electronics as they sought to produce cheaper components for use in their product lines. For the most part, semiconductors were produced within existing, vertically integrated electrical equipment companies.[13]

From about 1980 onward, the microprocessor gave rise to the personal computer (PC) revolution. Both in the United States and in Europe computer firms had difficulties coping with this transition. New companies dominated this sector and older firms, such as IBM and Digital, had to rely on their strength in specific niches (large systems, software, embedded software, consultancy). Some of these older companies made a partial return but competition remained extremely fierce in an industry characterized by a high number of new entrants, from many parts of the world, rapidly changing market shares, and rapidly changing standards of performance, especially when from the 1990s onward computer technology increasingly became linked to telecommunications technology. Competitive conditions in the components industry became more stable, both in comparison with its past and with the computer industry. The market for components was shared by a number of large US, Japanese, Korean, and European firms, among which Philips figured strongly.

Dutch and EU IT policies

Two periods can be distinguished in Dutch and European IT policy: The period from 1960 to 1980 and the period after 1980. From about 1960 to 1980 the Dutch government applied a procurement policy combined with a very restricted IT-funding policy. The European government in that period hardly had any policy related to IT. After 1980 more explicit IT policies started. Although the need to compete with the Americans had already been acknowledged in the 1970s, around 1980 the growing diffusion of mainframe and minicomputers and the increasing penetration of IT in other sectors had led governments to emphasize the strategic importance of IT (especially of microelectronics). Furthermore, Dutch and European governments were afraid that Dutch and European companies would lose the competition with Japanese and American IT firms. Therefore, government support increasingly was considered necessary. Now funding of research and development (R&D) became far more important.

Dutch IT policy in the 1960s and 1970s

The 1960s and 1970s Dutch industry received little government funding for R&D in the field of IT. The IT industry, however, was supported through government procurement. This was part of an explicit government policy. This policy focused on one company that served as a national champion in this field: Philips Electronics Ltd (Philips). In 1971 the Dutch government decided that government institutes always had to request a proposal from Philips in their procurement procedure for

computers. In 1974 this was extended as the government decided to introduce a price preference of 5 percent for Philips equipment (the only Dutch manufacturer of computers).[14] Around 1970 Philips computers were bought or leased by government organizations such as the Dutch Postal Cheque and Giro Services (PCGD), Rijkswaterstaat (The National Public Works Administration), the Municipality of Eindhoven (the seat of Philips Headquarters), and the Dutch Central Statistical Bureau.[15] Support was not restricted to hardware procurement. In the 1970s, the Dutch government also ordered software products from Philips or Philips' subsidiaries. For instance the Dutch Ministry of the Interior acquired a database application (PHOLAS, 60 million guilders). Occasionally, the government supported computer R&D at Philips, in particular a subsidy of 60 million in the early 1970s.

This meant that until the late 1970s the emphasis in Dutch policy was on demand-pull and that there was little support for the development of IT. The government concentrated its policy on buying Dutch IT. Government procurement policy included a partial protection policy for Philips. Whereas in the United States different national computer firms existed that competed for government orders, in the Netherlands only one big company was in position to supply computers, and thus was sheltered. The policy in the 1960s and 1970s can also be characterized as support for "national champions" (i.e. Philips). This aspect did not change much in the 1980s. Although the support shifted then from support for computers and software to support for microelectronics, Philips continued to receive a large part of Dutch government support for IT.

Dutch IT policy in the 1980s and 1990s

At the end of the 1970s it became clear that computers and microelectronics would become pervasive in the economy. In the Netherlands an article in a 1979 issue of a journal of a Dutch government research institute (TNO) under the title "The Netherlands Are Sleeping," written by the space advisor of the government, J. van Boeckel, raised a lot of concern.[16] The author noted that possibly only Philips was not sleeping in the Netherlands. In the same period in left-wing political circles serious doubts were raised about the potential harmful employment consequences of computer applications. The government established a committee "Social Consequences of Microelectronics," headed by the former Philips director of research G. W. Rathenau.[17] The committee attempted to assess the future consequences of microelectronics, for instance for labor quality. The committee advised on the one hand to stimulate the introduction of microelectronics and to support R&D in this area, and on the other hand to start technology assessment research activities. In such research the social consequences of computers would have to be investigated more profoundly. In response, the Dutch government formulated measures to support the national microelectronics sector. Most funds were reserved for a credit program and an advice program. The credit program was mainly aimed at small- and medium-sized enterprises but turned out to be quite unsuccessful: Small- and medium-sized enterprises did not seem ready to invest in microelectronics and

large companies (that could eventually also apply) had no need for credits.[18] The advice program resulted in three Centres for Microelectronics which have played (and still play) an important role in supporting small- and medium-sized enterprises.

Thus far, Dutch government policy did not apply to IT in general but was limited to microelectronics. This changed, however, in 1984 when an ambitious 5-year policy plan for the IT sector was formulated by the Ministers of Education and Science, Economic Affairs and Agriculture: The INSP.[19] The objective of the plan was to give comprehensive support to IT in the Netherlands. It concerned measures in five fields: Information, education, research, private sector, and public sector. Most funds (65 percent) were reserved for support of the private sector. Within this field most money was reserved for the development of IT (both hardware and software). Financially, the largest project of the INSP was the MEGA-project. This was a bilateral project in which the Dutch and German governments supported Philips and Siemens to develop the next generation memory chips technology (chips with more than 1 megabit capacity, see below). The INSP did not exclusively deal with support for technology development. Part of the policy plan for the public sector was a government procurement policy which was implemented in the form of a program with a yearly budget of 30 million guilders (SPIN-OV).[20] The INSP ended in 1988. An independent evaluation committee concluded that the program had been fairly successful: "it's a useful first step."[21] However, there was no comprehensive follow-up to the program. The direct cooperation between the three ministries also stopped. The Ministry of Economic Affairs continued along the same lines for 2 more years between 1989 and 1990.

In the 1990s the Netherlands became aware of the relevance of communications technologies. In the early 1990s this resulted in support for Electronic Data Interchange and Videotext. In 1994 the potential of Internet was acknowledged and the Dutch Minister of Economic Affairs launched a policy plan on "electronic highways." In contrast to the microelectronics policy, this policy mainly aimed at small- and medium-sized enterprises.

Thus, in the 1980s a comprehensive IT policy was implemented. Education, information, research, private sector, and public sector were all dealt with in one program aimed at strengthening IT in the Netherlands.[22] Compared with the previous decade, support shifted from demand-pull to technology-push. Furthermore, there was more attention for small- and medium-sized enterprises. Most actual support, however, was still granted to large companies (most notably Philips). There was also a shift from support for computers and software to support for microelectronics. This trend continued in the 1990s. In that period, communication technologies also became an explicit object of government policy.

European IT Policy in the 1980s and 1990s

Before 1980, there was hardly any European IT policy. In 1982 the European Community started supporting the IT sector through the MELREG-C-program. This program was followed by ESPRIT-0, the preface to the ESPRIT-programs 1–4.

ESPRIT stood for European Strategic Programme for Research in Information Technology and was part of the European Framework Programs. ESPRIT can be regarded as the European answer to the Japanese Fifth Generation Program. ESPRIT aimed at enhancing the competitive situation in Europe and concerned a broad range of technologies (software and microelectronics) and was the most important IT program of the European Union. The number of projects increased from about fifteen in the early 1980s to more than 1000 in the mid-1990s. In the same period the amount of funding involved increased from about 150 million ECU in 1984 to more than 500 million in 1994; see Table 8.2.

Furthermore, in the mid-1980s the European Community started supporting R&D on communications technologies. After a pilot-project in 1986, in 1987 under the Second Framework Program the RACE Program (Research and Development in Advanced Communications Technologies in Europe) was implemented. During the Third Framework Program RACE-1 was followed by RACE-2. Under the Fourth Framework Program (1994–1998) the Advance Communications Technologies and Services (ACTS) was established. ACTS supports R&D in advanced communications. Funding increased to 150 million ECU per year, in the mid-1990s (see Table 8.3). Both in ESPRIT and RACE the importance of cooperation between European companies was emphasized. "National champions"

Table 8.2. *ESPRIT*

Program	Period	Number of projects	Funding per year (millions ECU)	Total funding (millions ECU)
MELREG-C	1982–1985	15	10	40
ESPRIT-0	1983	16	11.5	11.5
ESPRIT-1	1984–1988	241	150	750
ESPRIT-2	1987–1992	435	320	1,600
ESPRIT-3	1991–1994	605	438	1,532
ESPRIT-4	1994–1998	1,341	510	2,084

Source: CORDIS database.

Table 8.3. *RACE and ACTS*

Program	Period	Number of projects	Funding per year (millions ECU)	Total funding (millions ECU)
RACE-0	1985–1986	—	15	22.1
RACE-1	1987–1992	94	110	550
RACE-2	1991–1994	123	154	554
ACTS-1	1994–1998	223	151	671

Source: CORDIS database.

were stimulated more and more to cooperate in their R&D efforts. For the Netherlands, in ESPRIT, Philips was the dominant participant.

Moreover, in the mid-1980s European countries had started to participate in another joint program: EUREKA. The idea behind EUREKA-projects was that national governments coordinated their support for technology development. EUREKA (1986) can be regarded as the European answer to the US Strategic Defense Initiative. The largest project within EUREKA was JESSI (1989).[23] JESSI stood for Joint European Submicron Silicon Initiative. Important proponents of JESSI were the three large European microelectronics companies: Philips, Siemens, and SGS Thomson. It can be regarded as the follow-up to the MEGA-project. JESSI concerned four main categories: Technology, equipment and materials, applications, and basic and long-term research. Compared to ESPRIT and RACE, JESSI also stressed the importance of collaboration between European companies but was more directed to development whereas ESPRIT focused on research. As in ESPRIT, Philips was the dominant Dutch participant.[24] In the 1990s more money was allocated to Philips through JESSI than through the National IT Program. In the late 1980s and in the 1990s, the European government also started supporting communications technologies.

In summary, in the period 1960–1980 government policies were national, and focused on procurement of the products of national computer industries (see Table 8.4). Since in the Netherlands (and in several other European countries) this referred to only one company, this policy involved a situation of sheltering (see Table 8.5). Funding of R&D was marginal in that period, and policies were aimed at computers, not components. In the period from 1980 to the present, the European IT policy became increasingly important. Both EU and Dutch government policies relied more on subsidizing collaborative R&D between

Table 8.4. *EU and Dutch government policies in the computer and components industries*

	1960–1980	1980–
Computer industry	Procurement and small R&D support	Limited R&D support, limited procurement
Components industry	None	Heavy R&D support

Table 8.5. *Dutch and EU policies related to the framework*

	Decelerate life cycle	Accelerate life cycle
Challenging/export promotion		Computer industry, 1980– Components industry, 1980–
Sheltering/import substitution		Computers, 1960–1980

primarily national champions than on procurement. The latter had diminishing effects anyhow in the growing computer market. In ESPRIT and RACE the importance of cooperation between European companies was emphasized. A large part of the both Dutch and European funds still found their way to the former national champions, who now became the champions of supranational collaboration. The collaboration between Philips and Siemens in the MEGA-chip project is a striking example. The focus in that period was on the components industry, particularly microelectronics, although the Dutch national policy also supported the development and application of computer technology to a small extent. Although the 1980s also saw a surge of interest in the technological capabilities of small enterprises, the money spent on these companies were relatively very small in comparison to the monies flowing to the large and integrated firms.[25]

Since the early 1990s the policy instruments remained largely the same, but they were increasingly aimed at the integration of computer and telecommunications technology: The importance of Internet was widely acknowledged. Since at the moment it is still difficult to assess the impact of that policy, it will not be included in the remainder of this chapter.

Philips' Computer Activities

Philips has been active in the field of computers and components for half a century.[26] In the previous section we divided the relevant period in two parts, the period from 1960 to 1980 and the period after 1980. As will become apparent, the half century of Philips' IT activity can also be conveniently split in two halves, with the significant changes occurring in the late 1970s.

Philips was amongst the first organizations building computers in the 1950s in the Netherlands. The company finished the construction of several machines, the poorly functioning PETER in 1956, the PASCAL in 1960 for technical–scientific computing work, and the STEVIN for data processing in the same year. Although these machines were technically advanced and very fast compared to the international state of the art,[27] the company did restrict itself to building single machines for its own use and did not turn them into production. The reason was an agreement with IBM that Philips would produce components (mainly core memory) and that IBM would buy exclusively Philips components to produce their machines.

In 1963 this agreement came to an end and Philips started its own computer development activities, founding Philips Computer Industry (PCI). Philips acquired several other companies in this field:

1. Electrologica, the Dutch computer manufacturer that Nillmij, a big insurance company, had established in 1958 out of the computer development group of the Mathematical Center.[28] Although the computers of this company were also very advanced in the technical sense (particularly the fully transistorized X1 already in 1958), the computer designs of the company were most appropriate for scientific applications, and the company could not compete with IBM in the commercial

market. As a consequence, losses were made and Philips decided to close down the Electrologica Company in 1968. Upon the acquisition of Electrologica PCI was renamed Philips-Electrologica. In 1968, Philips changed the name of the computer division to Philips Data Systems.

2. The French company, Centre Technique et Industrielle (CTI). Philips used this company to produce minicomputers for process control purposes. First Philips marketed a series of minicomputers from Honeywell under the Philips label, later the P800 series of computers was developed and manufactured by CTI. From this latter computer over the years about 10,000 copies were sold. Nevertheless these activities did not become profitable.[29]

3. In 1969 Philips acquired the German Siemag, which produced the P250 desk calculator (stopped before 1970) and the profitable P350 office computers.[30]

4. In 1970 the Swedish company Arenco was acquired to produce bank terminals.[31]

The most important activity was the development of the P1000 series. These were large machines (partially, but not completely complying with IBM-standards). The software was developed in collaboration with Computer Sciences Corporation from the United States. Philips established a joint venture with this company for the production of software for Philips (headquarters in Brussels) which remained in operation until 1975. As we saw above, the Dutch government mainly supported Philips by ordering computers from the P1000-series. For instance, in 1967 J. A. Bakker, the state secretary of transport and public works, on his own initiative personally signed the contract between the PTT-owned PCGD and Philips for a P1100 machine (the PTT was the national Post, Telegraph and Telephone Administration). It took 3 years before the machine was delivered and operating reliably. In these and other cases government agencies were pressed to adopt a Philips machine. They were not always happy with this situation. The report of a consultant, hired by PCGD in 1972, was very critical about the operating system and applications software of the P1100 and recommended loosening the ties with Philips.[32] Even computer users within Philips itself were eagerly looking to machines of competitors.[33] Important problems for users were the incompatibility of the machines with IBM machinery and the lack of reliable software.

In the first half of the 1970s Philips had an unsuccessful attempt to establish the Unidata venture with the German Siemens and the French CII (see Chapter 9 by Eda Kranakis). The contract was signed in 1972, but the project stopped in 1975 when the French government decided to start to collaborate with the American firm Honeywell. After that disastrous event, Philips stopped producing large computer systems. Large parts of Philips Data Systems were discontinued and 2500 employees had to be dismissed or moved to other Philips units.

The remains of Philips Data Systems continued to produce minicomputers and to sell the computers of other manufacturers. Government institutes were still stimulated to adopt Philips' machinery, sometimes leading to problems because of low quality or lacking input–output devices and customer support.[34] Moreover

Philips undertook experiments in other directions. In 1977 the Teleprocessing project was set up, which integrated telecommunications and computer technology, and which aimed at the financial sector, but it was stopped after some years because of software problems. In the beginning of the 1980s also a Teletex system was established but this too became a commercial failure. Furthermore, the company developed printers and documentation systems (Megadoc) in 1981, and interactive programming systems in 1982.

Philips in the 1980s and 1990s

In the 1980s Philips continued its computer activities. The P800 remained in use, particularly in the industrial systems of Philips itself and in bank terminals of the former Arenco.[35] The successor of the P350 became the P4000 and the P9000. Philips sold the P7000, a product of Motorola, particularly for data entry systems. Philips also developed personal computers (YES, again semi-IBM-compatible and the P3000, at first non-IBM compatible, later IBM-compatible) but with no commercial success. Sometimes governments of other countries supported Philips, for instance the Canadian subsidiary Micom that produced the P3000 personal computers was funded by the Canadian government, which also applied a preferential procurement policy for these computers. In spite of all these efforts Philips computer activities did not become profitable and in 1991 Philips sold them to DEC. In total, losses from the company's computer activities over the years are estimated to amount to 4.5–6 billion guilders.[36]

The performance of Philips was different with respect to components. In the 1980s, at a point in time when the components industry had outgrown the turbulent youth of the 1960s and 1970s, Philips heavily increased its R&D activities in components. Philips had been producing integrated circuits since the mid-1960s but at the same time had continued to produce its successful germanium-transistors. Soon developments in the integrated circuits market became very fast (microprocessors and memory chips) and Philips fell behind the United States and Japan in this field. The acquisition of the US company Signetics in 1975 did not yield satisfactory commercial results.[37] As mentioned above, in the beginning of the 1980s, and with Dutch and EU government support, Philips started integrated circuits research in collaboration with Siemens. Philips' R&D in chip technology was concentrated in the MEGA-project, focusing on production technology under the agreement that as far as product technology was concerned Philips would dedicate itself to static memory chips (SRAM) and Siemens to dynamic memory chips (DRAM). Moreover the Dutch government established a contract with Philips to support the company with a maximum amount of 100 million guilders ($50 million) per year.[38] The reason for the Dutch government to enter into this covenant was the fact that Philips could otherwise benefit from different government technology support programs, sometimes even split over a single project. Government considered a contract more appropriate to streamline its support. For Philips the covenant provided a high degree of certainty of government support.

In spite of its late entry on this market in 1987 for a short period Philips was seventh in the world amongst chips producers, but it soon appeared that DRAMs, not SRAMs provided the largest market. As a consequence Philips had to close one factory for chips before it started production, and another factory (in Nijmegen) had to convert its production activities to other types of chips. W. Dekker, Philips president at the time, estimates in retrospect that the project cost two to three billion guilders.[39] In spite of these problems, in the 1990s Philips became the leading firm in the world in specific types of dedicated chips. Moreover, partly as a consequence of chips development research at Philips, Philips' subsidiary Advance Semiconductor Materials Lithography (ASML) became very successful in chips production technology. Circumstances, including public policy, as we will discuss further in the final section, allowed the firm to focus on activities, especially process-orientated, which helped it to be successful in the components industry.

The Effects of IT Policies on Philips' IT Strategy

To what extent did governments policies affect decisions of Philips' management to undertake or to omit specific R&D or production activities? In other words, did government policy contribute, positively or negatively, to Philips' problems in entering this field? In retrospect the Philips' managers involved deny that government influence was very important in entering the computer business. According to several former Philips' managers, government policy did not affect directly the decisions of Philips to enter into specific lines of computers as such. For instance, as far as the IC projects are concerned, Research Director Pannenborg states that Philips only accepted money for activities that it was already planning. However, according to him the support did shift the R&D portfolio slightly to riskier activities. Apparently specific very risky projects would not have been undertaken without government support. Most probably the MEGA-project would have been one of these projects; see Table 8.6.

Although the influence of government policy on Philips' activities is not quite clear, obviously government did not attain its objective of creating a healthy national computer industry. We can understand this based on our framework. Before 1980 government policy in the Netherlands in fact included a partial protection policy for Philips. Whereas in the United States different national computer firms existed that competed for government orders, in the Netherlands only one big company was in a position to supply computers. The instrument of procurement preference in government institutes created a protected space for companies, which sheltered them from real competition. The companies learned to apply their technology but they did not acquire the capabilities required in the market. Although government policy was only one factor in Philips' behavior, we may say that the situation at Philips conforms reasonably well to our framework. In addition, Koutrakou argues that the resources of firms are not applied efficiently in such a case: "Such nationalistic purchasing policies often end up absorbing 50 percent of the products of particular electronics sectors, effectively

Table 8.6. *Influence of government support on Philips' computer and component activities*

	Product line/ research project	Government influence	Degree of success
1967–1975	P1000 series—mainframe computers	After introduction, procurement, extending life cycle of product line	Negative
1967–1990	P350/P4000/P5000/ P9000/P7000—office minicomputers	Marginal, procurement	Positive
1967–1990	P800—process control/ office minicomputers	None	Neutral
1980–1990	YES/P3000—personal computers	None	Negative
1984–1989	MEGA-chip project	Large, considerable financial support	Negative, but spin-off strongly positive

removing half the production from international competition. As a result, companies are often driven to concentrate on the national niche-markets to such an extent that they lose contact with international technological progress."[40] This aspect was particularly important in the tight labor situation in the computer market.

The support of the EU and Dutch government of collaborative R&D in component development may have had some success, in spite of the fact that again this technology had already passed the first phase. The important MEGA-project did not attain its primary aim, although Philips is still successful in the chip industry. Moreover the Netherlands has a successful producer of chip-manufacturing technology (ASML). Indeed the aim of the MEGA-project was process technology. However, the design chosen (SRAM-chips) appeared not to be appropriate in the market. In fact Siemens chose the "right" design, since DRAM-chips became the main memory technology. This aspect does not conform to our framework. The reason seems to be that the choice for SRAM was induced by the need to collaborate and this may explain the fast failure of this product line. To a certain extent short-term success does apply to the activities of Siemens, since this company discontinued its DRAM-production in 1995.[41]

As far as the computer industry was concerned, government support in the 1980s did not focus on a specific type of computer. Under the covenant, government marginally supported the different development activities of Philips in computers.[42] However, in this period the PC was emerging and this offered interesting possibilities for more focused support. At least the Dutch government, but probably also other European governments did not grasp those chances.

In view of their limited success, the question is: Why did EU and Dutch governments develop these policies aimed at national champions and large, established firms, and which, as far as the Dutch government policy was concerned, for a long period included a procurement policy? Several alternatives were available, one of which was supporting small new companies in these fields. A lack of experience seems to form part of the answer. IT was one of the first fields of technology in which Dutch and EU governments conducted an explicit technology policy at all. Knowledge on the effects of policy instruments was limited. However, it seems that Philips–public authority relations also contributed to this situation.

Philips–Public Authorities Relations

To what extent did Philips–public authority relations in this period frame government policies? It is clear that Dutch and EU government attitude toward Philips changed considerably around 1980, together with their policies. According to former Philips research director, A. E. Pannenborg, until the 1980s the Dutch government was not open to consultation with industry on its technology policy. According to him informal contacts between government officials and entrepreneurs were considered inappropriate in that period. Nevertheless Philips was rather successful in acquiring government funds. For instance, the above-mentioned L. E. Groosman remembers that around 1973 two cabinet ministers, R. Lubbers, Minister of Economic Affairs who was later to become prime minister, and T. Westerterp, Minister of Transport and Public Works, were invited to visit Philips Data Systems in Apeldoorn to discuss government support. Several members of the Board of Management (Raad van Bestuur) of Philips were present.[43] After the meeting and after several additional visits by officials of Philips Data Systems to officials of the Ministry of Economic Affairs, the government decided to support Philips Data Systems with about 60 million guilders ($30 million). Moreover these contacts contributed to strengthening the government preferential procurement policy.

Around 1980, the contacts between Philips and the government became more open. In 1979 former Philips research manager, G. W. Rathenau, became chairman of the advisory committee on IT policy. And Pannenborg, vice-president of Philips for R&D until 1984, was invited to chair a committee that reported in 1985 on the introduction of computers in government agencies.

On the European level Philips' influence was also considerable. European IT policy was influenced by an interest-group of twelve large European companies (three English ones, three French, three German, two Italian, and the Dutch Philips), which was established in the beginning of the 1980s by E. Davignon, a member of the European Committee, and which met about four times a year. Important issues discussed were infrastructure and IT policy. Pannenborg, who represented Philips in these meetings, recounts that in framing IT policy the government share in project financing was negotiated first—at 50 percent. Subsequently, to the astonishment of industrial representatives, who were used to

strict prescriptive government criteria (particularly in France where the government decided on the technology on which government programs focused), the European official organizing the events, Davignon, asked them to formulate the program criteria. The initiative resulted in ESPRIT, the European support program in IT.

The reason that Philips was quite active in promoting the establishment of a European policy may have been the limited possibilities of the Netherlands, as a small country, to effectively provide shelter for a national IT industry. According to former Philips executives, other European governments were supporting industry with larger amounts of money than the Dutch did (and could do). These promotional activities were quite successful. This seems to be a general phenomenon. In general, old and large firms have better skills and assets, such as long-standing friendships, to enable them to lobby efficiently. New and successful companies usually will have fewer means, including time, available to meddle in political processes. Also, as Weidenbaum suggests, especially weak or even "sick" firms will have the strongest incentives to lobby hard for policies that will help or protect them.[44] Before 1980 the lobbying activities of Philips may have stimulated the government to apply a policy that was not optimal in the circumstances of a youthful technology. After 1980, in view of the maturing technology, the interests of large firms and an optimal government policy coincided better, although then government missed the opportunity to conduct a policy specifically aimed at the new PC market. Thus it seems that public authorities have to be especially careful not to let industrial lobbying play too great a role in the formation of policy where these policies are intended to serve objects such as a faster pace of technological change with which the old companies do not feel too comfortable, even if they regularly publicly subscribe to these same objectives.

In summary, in spite of the distance created by the Dutch public authorities before 1980, Philips has been quite active and successful in framing the Dutch and EU government policies in IT. As far as the Dutch government is concerned, the lack of experience in conducting a technology policy, combined with the feel of urgency and uncertainty, improved the position of Philips as a large and experienced company. Although less striking, the situation at the European level was similar. The success of Philips in framing the policies was clearly greatest after 1980, when considerable direct government support was acquired. The results of government policies then were slightly better than in the period before; they did not lead to the stated goal of starting a memory chip industry, but they caused significant positive spin-offs to the dedicated chips industry.

Conclusion

Our description of Dutch and European IT policies has shown that Dutch policies did not differ much, with regard to intentions, to the policies of the main EU countries and of the EU itself. Two periods can be distinguished: the period from 1960 to 1980 and after 1980.

In the period 1960 to 1980 government policy was mainly directed toward computers, not toward components or software. One can hardly speak about European policy in this area before 1980. Public authorities in various EU countries, and certainly in the Netherlands, felt an urgent need to assist their own IT industries and firms to compete against the successful US firms. Trade agreements, such as in the framework of General Agreement on Tariff and Trade (GATT), made it impossible or at least inopportune to restrict imports directly or to raise tariffs but European national governments did attempt to protect their industries and firms, mainly by using the instruments of public procurement. The potential effectiveness of public procurement as a policy instrument was still relatively strong because the share of demand by governmental and semipublic organs was still fairly high.[45] At the same time, efforts were clearly almost exclusively directed toward the largest existing firms in the field of electronics. In the 1960s and 1970s "national champion" ideas dominated. The Netherlands supported Philips, France supported CII, the United Kingdom supported ICL, the Federal Republic of Germany supported Siemens and AEG. The idea was that, with the assistance of public authorities, these large firms would quickly start mass producing state-of-the-art computers and effectively compete with IBM. There was almost no attention paid to small and new firms.

In terms of our theoretical framework, the European governments and the Dutch government in particular chose a strategy that combined sheltering and import substitution (as far as that was politically and pragmatically possible) with an industry (and technology) policy that clearly aimed at accelerating the development of the industry life cycle and bringing about as soon as possible a situation in which large mature and integrated firms would dominate a market in which the technology would evolve in an orderly fashion. These policy choices have not been successful. Neither CII, ICL, Siemens nor Philips managed to obtain a significant share of the world market for computers. In terms of our framework, the combination of sheltering and accelerating may stimulate firms to make fast choices with respect to product development, which may appear to mature too early. We gave some examples in the Philips case.

After the early 1980s the European and Dutch governments did not attempt to protect their home industries anymore against outside competitors. In fact, after the early 1980s, EU and Dutch policy did not affect the computer industry very much. European firms are not among the significant competitors in the world market of computers. Philips stopped production completely. Many successful software companies have emerged, but with hardly any governmental support.

After the early 1980s, a number of changes took place. The attention of policymakers shifted away from computers and toward components. The European Community developed its own policies in the field of IT. Protecting European firms and industries by using the instrument of public procurement became less popular and, moreover, lost most of its significance because, especially after the PC revolution, public authorities represented only a small part of the market. Instead, policy shifted strongly toward the use of technology push instruments such as

R&D subsidies. Policy, especially EU policy, also increasingly targeted collaborative efforts. However, both Dutch and European funds still found their way almost exclusively to the former national champions, who now became the champions of supranational collaboration. The collaboration between Philips and Siemens in the MEGA-chip project is a striking example.

The results of the policies are not as clear as for the pre-1980 period. European firms are still not significant competitors in the world market for computers. Philips stopped production completely. Many successful software companies have emerged, but with hardly any governmental support. The great projects of the 1980s that aimed to make Philips and Siemens frontrunners in microchip-production were unsuccessful in their own terms. Nevertheless, Philips has become a very successful chip producer in the 1990s and the Dutch company ASML is one of the world's leading producers of chip-making equipment.

Although the 1980s also saw a surge of interest in the technological capabilities of small enterprises, the money spent on these companies were extremely small in comparison to the monies flowing to the large and integrated firms. The information presented in this chapter tends to strongly support the hypothesis that the influence of Philips, and the other national champions, has been a very significant factor in shaping policy in such a way that the large integrated firms would benefit most from governmental intervention.

It could be suggested that the success of Philips, and, possibly and indirectly of Dutch and EU policy, in the field of components could be due to the fact that that industry had effectively become a more mature industry all over the world. It would mean that the technology had matured to such an extent that large integrated mass-producing firms now had the competitive edge and a policy directed toward young and small firms, focused on product innovation, aimed at providing Europe with a young industry, would now have been as much a waste of money as the accelerating policies were in the 1960s and 1970s. This means that the accelerating government policy was in fact suitable for the maturing components market. It supported the development of process technology in a period when these were appropriate. In that way government policy has added to the success of ASML, as a chips producing company. One can ask, however, how far the right choice of policy in this case should be ascribed to superior insight of policymakers or to a fortuitous lucky draw after a series of failures.

The question is highly relevant because policymakers are currently focusing on another type of IT activity, that pertaining to the new communication technologies that integrate telecommunications and computers. This technology is still immature and the firms that are active in this area compete in an arena that has most of the characteristics of a young industry. On the basis of our framework, public authorities should be advised to refrain from policy, and actions, intended to accelerate the development of the industry or to stimulate firms to act as if they were mature firms in a mature industry. Instead, even large firms, such as Philips, should be made to act as young firms in a young industry and build up their innovative capabilities accordingly. Initiatives such as the new Dutch program

"Twinning" to support new small enterprises and having large enterprises, such as Philips, "adopt" them as partners may be helpful in this respect.

Notes

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22. This does not mean that all relevant policy domains were included. Important exceptions were labor policy and telecommunication policy.
23. Total funding for JESSI amounted to 3800 million ECU in 8 years (July 1989–June 1997). The participation of different countries in JESSI in terms of budgets were as follows: France 27%, Germany 26%, EU 17.2%, Italy 13%, the Netherlands 10%, Rest 6.8% (source: www.eureka.be).
24. Apart from Philips, the other Dutch participants in JESSI were two companies, Advance Semiconductors Materials Lithography (ASML, development and production of photo-lithographic systems for the production of chips, "wafersteppers," in the 1980s 50% owned by Philips) and ASM-International (equipment to produce semiconductors); and two institutes DIMES (Delft Institute for Micro-Electronics and Submicron-Technology: part of Delft Technical University) and SCME (Centers for Micro-Electronics: Government subsidized centers for information and demonstration to small- and medium-sized enterprises) (source: www.eureka.be).
25. Wijnberg, op. cit.
26. Much of the information in this section is based on several interviews with A. E. Pannenborg (May–July, 1999). Pannenborg was senior director of Philips Research from 1963 until 1968, member of the board of management since 1969, and responsible for Philips Research and Development from 1977 to 1984. Information on Philips' computer industry is based on a number of interviews with L. E. Groosman (June–October, 1999). Groosman was manager of Market Development for Philips-Electrologica/Philips Data Systems from 1966 to 1976, director of the Industry Group Minicomputers from 1969–1976, member of the negotiation team of Unidata from 1971 to 1975, and senior director external relations of Philips Electronics from 1976 to 1988.
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29. De Boer, op. cit. (De Boer's paper is largely based on interviews with Groosman, see note 26.)
30. Metze, Marcel, *Kortsluiting*, Nijmegen, SUN, 1991, p. 75.
31. De Boer, op. cit.; Metze, op. cit., p. 77.
32. Dirk De Wit, *The Shaping of Automation*, Verloren, Hilversum, 1994, pp. 222–223.
33. De Boer, op. cit., p. 11.
34. Personal communication with J. Roos, former director of National Computer Center, May 21, 1999.

35. For this section use was made of the above-mentioned interviews with former Philips' directors Pannenborg (see note 8) and Groosman (see note 10). Moreover interviews were held with J. Balder, Product Manager at Philips Data Systems in the 1980s, and with K. van Steensel, Manager Research and Development of Philips Data Systems in the 1980s (June–July 1999).
36. De Boer, op. cit.
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38. Philips received 196 million Dutch guilders for the MEGA-project. This was 16% of the whole budget for the INSP. The amount of money that the company received under the covenant was 899 million guilders between 1987 and 1997.
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9

Politics, Business, and European Information Technology Policy: From the Treaty of Rome to Unidata, 1958–1975

Eda Kranakis

Introduction

An important dimension of European integration since the 1950s has been the development of industrial policies at the European level. But how and to what extent have these policies shaped the actions of European businesses? In order to begin answering this question, this chapter traces the history of European information technology (IT) policy in the decade 1963–1973 and its role in the establishment of Unidata, the first European-level consortium in data processing. Unidata was a joint venture of Siemens (Germany), Philips (The Netherlands), and CII (France), the three leading "native" computer manufacturers in the Common Market. Established in 1973, Unidata's aim was to develop a line of IBM-compatible computers analogous to IBM's 370 series.

Industrial policy is an enormous and complex topic. At the very least, it comprises trade and tariff policy, competition policy, labor policy, taxation policy, problems of standardization, intellectual property policy, technical education policy, the fiscal and legal structures for business, sectoral policy, and research and innovation policy. Moreover, these areas of industrial policy interact in various ways. Systems of standardization affect trade and competition; legal structures for business shape trade, innovation, and sectoral performance, etc. The present chapter does not attempt to cover all areas of the topic but rather focuses on the evolution of SRI policies—sectoral and research and innovation policies—specifically within the domain of computers and data processing (CDP), which was most relevant to Unidata. These SRI policies include issues related to state subsidies for companies in CDP, state and public purchasing, research and development (R&D), market development, and business law.

Apart from the complexity and breadth of industrial policy, two concerns might be raised about any attempt to link the history of Unidata with the history of European technology policy. The first concern has to do with the factors that drive corporate decisionmaking, while the second has to do with the immature state of European technology policy in the period preceding Unidata. It is important to explain the argument put forth in this chapter as it relates to these two concerns.

Corporate decisionmaking responds to a range of factors, including short-term economic and market conditions. In analyzing the role of European industrial policy in the formation of Unidata, I am not suggesting that these short-term factors were irrelevant. Each company's decision to participate in the consortium was based partly on criteria like access to government funding (CII), the opportunity to stem financial losses (Philips), or the sudden need to replace a previous cooperative agreement (Siemens). Yet I will show that these pragmatic, short-term factors cannot provide a full explanation for the establishment of Unidata. In particular, they cannot explain why this option was chosen above all others or why it seemed like a reasonable solution at all. For Unidata was an unusually complex and unwieldy cooperation with a tripartite management structure and three official headquarters, one in the home country of each member company. Meetings of Unidata's many committees rotated among the three countries. One of the middle managers involved in the enterprise suggested, only half-jokingly, that airline companies profited more than anyone else from the venture.

Why would these three companies want to commit considerable money, manpower, and organizational effort to such an undertaking? Why would they want to engage in what appeared to many to be an obviously unworkable cooperation? These questions can only be answered through an understanding of how the Unidata venture was linked with the broader development of European technology policy. This development served to promote, structure, and legitimize the Unidata cooperation.

My second concern is to address the limitations posed by the existing historiography of European industrial policy in the 1960s. Because this historiography emphasizes the *lack* of any coherent European policy, it provides little evidence to suggest that it might have been an important foundation for Unidata.[1] On one level, this interpretation is correct. In comparison with the profound changes that have occurred since 1980, the period of the 1960s was a "dark age" for European industrial policy. It is usually referred to as the era of the "national champions," a designation which highlights not only the efforts of European states in this period to create and support large firms in key sectors, but also the predominantly nationalistic framework of industrial policy. On another level, however, this designation is profoundly misleading because it neglects important changes in the conceptual, organizational, informational, and commercial environments that were taking place at the European level, and which laid the groundwork for the more visible industrial policy changes of the 1980s. These hitherto neglected factors include the development of more detailed statistical and market information, specific efforts to develop sectoral and research policies for data processing at the European level, evolving relationships among the principal actors in the European industrial policy arena, and the impact of the extended process of British entry into the Common Market.

An examination of these factors reveals that the direction and pace of European SRI policy development were intimately bound up with the broader political history of European integration in the 1960s. The political history structured the path of SRI development. In this sense, the apparent lack of a strong, coherent European policy during this period was not due to a lack of initiative but was rather due to positive

choices and decisions, which ensured that certain kinds of policy choices would prevail. Although obvious in retrospect, the importance of this relationship between Common Market politics and technology policy has so far been largely ignored.

To establish the context in which these political and industrial policy changes occurred, the first section of the chapter provides an overview of European institutions, particularly the Common Market, known formally as the European Economic Community (EEC). This review highlights the legal foundations on which European industrial policy was built, and the institutional dynamics that shaped its path of development. The section titled "The Emergence of SRI Policy within the EEC, 1960–1965" surveys the emergence of European industrial policy in the period from 1960 through 1965; the section on "Years of Revolution" looks at the period 1966–1967, when a political crisis rocked the Community and fundamental conceptual changes occurred in the realm of technology policy; the next section looks at the period 1968–1970, which witnessed a further Community crisis and a "relaunch" of European technology policy in CDP; and the section on "Unidata, 1971–1975" traces the emergence of Unidata, its structure, and its ultimate demise in the period 1971–1975. The conclusion summarizes the relationship between European technology policy in CDP and the history of Unidata.

The European Community and SRI Policy

In 1960, the European community comprised five main treaty structures: The Council of Europe, the Western European Union (WEU), the European Coal and Steel Community (ECSC), Euratom, and the "Common Market," officially known as the EEC. In 1967, when the EEC merged with Euratom and the European Coal and Steel Community, its name officially became the European Communities (EC). In 1965 three of these legal structures—the ESCS, Euratom, and the EEC—merged. The Council of Europe, the WEU, and the merged European Communities differed in their mandates, their institutional makeup, and their membership, but all became interested in the creation of European SRI policy, and each devoted some effort to its development. The most important institution in this regard was the EEC, however. My analysis will therefore concentrate on its role.

Two key factors influenced the development and implementation of SRI policies within the EEC. The first factor was the organizational structure of the EEC and the "balance of power" among its institutions, particularly the Council and the Commission. The other factor was the character of the treaty and the legal bases it provided for the development of SRI policy. Each of these factors shaped the context in which European SRI policy emerged.

The Treaty of Rome by which the EEC was created in 1957 says nothing directly about industrial policy. Its basic goal was to establish a customs union among the six signatories: France, Germany, Italy, and the Benelux countries. It guaranteed a common market among the six, and the free movement not only of goods, but also of capital, labor, and business enterprise. Because of the treaty's breadth, however, it left considerable scope for the development of industrial policy

goals. These could arise in relation to economic policy or to issues of trade and competition. We will return later to a detailed examination of the treaty articles pertaining to industrial policy. At this point it is necessary only to emphasize the treaty's general scope and character.

One of the remarkable features of the Treaty of Rome was its *dirigisme*: It sought not merely to regulate trade but to control and coordinate the economic development of its members. This *dirigisme* can be seen clearly in Article 2 of the treaty, which emphasized the need for *coordination* of the economic policies of the member states, *harmonious* development, *balanced* expansion, and *closer relations* between the Member States. "It shall be the aim of the Community, by establishing a Common Market and progressively approximating the economic policies of Member States, to promote throughout the Community a harmonious development of economic activities, a continuous and balanced expansion, an increased stability, an accelerated raising of the standard of living and closer relations between its Member States."[2] The Treaty of Rome's *dirigisme* meant that, as industrial policy concerns emerged, there would be a tendency to focus on coordination, control, and the framing of common policies.

In order to understand how policymaking actually worked under the Treaty of Rome, however, it is necessary to review the administrative structure created by the treaty. It consisted of five bodies: The Council, the Commission, the Assembly, the Court of Justice, and the Economic and Social Committee. (The Council and the Commission were the most important with respect to SRI policy, although the Assembly also played a supporting role.) The Council was the principal law-making body of the EEC; it consisted of the ministers of each Member State. Depending on the issues at stake, these might include either the Foreign Ministers, or the Ministers of Agriculture, or the Trade Ministers, or the Ministers of Science and Research. Any new entity or activity or rule to be laid down within the framework of the Treaty of Rome—relating, for example, to industrial policy issues—had to be mandated by the Council either by unanimous consent or, in specified cases, by a qualified majority vote. In practice, the Council functioned until the 1980s as a purely intergovernmental body: New legislation was enacted only on the basis of the unanimous consent of Council members. Council deliberations were moreover secret, which meant that Member States could easily avoid responding to public or interest-group pressure. Needless to say, these circumstances hindered possibilities for the development of a unified industrial policy at the European level, because any significant disagreement among Member States led to stalemate.[3]

The Commission was the treaty watchdog. Its nine members, who served renewable 4-year terms, were appointed by the governments of the Member States, with the common consent of all the Member States. Once chosen, the commissioners were no longer accountable to national interests and indeed were explicitly forbidden to ask or take instruction from their home governments. They were obliged to work for "the general interest of the Community" and "with complete independence." The Commission was thus intended to be a counterweight to

national power. It could exercise this countervailing power in five ways, all of which have relevance for the development of SRI policy. First, the Commission had the right and obligation to investigate compliance with the treaty, and to refer cases of noncompliance to the European Court of Justice. This power obliged the Commission to monitor a range of developments on an on-going basis, such as firm mergers and state aids to business. Second, it had the right to formulate recommendations and opinions relevant to treaty matters. Third, the Commission alone had the power to propose new laws (regulations and directives) within the treaty framework, on which the Council then voted. Fourth, the Commission was responsible for conducting EEC trade negotiations with non-Member States as well as all multilateral negotiations within international organizations like GATT. Finally, the Commission had the explicit right to collect all information relevant to its mandates, with the proviso that the limits and conditions of its information gathering would be "laid down by the Council in accordance with the provisions of this Treaty." The Council or Assembly, in specified circumstances, could also ask the Commission to undertake studies relevant to treaty issues.[4]

The Treaty of Rome locked the Council and the Commission into a close working relationship but did not specify the precise balance of power between the two. The result has been a continual power struggle in which each side has attempted to establish preeminence in the integration process. The Council (and hence the Member State governments, especially the large ones) wanted the Commission to function as a bureaucracy on call. According to this conception of the relationship, the Council was to lead the way forward. It would indicate how policies were to be framed, interpreted, implemented, or altered, and the Commission, following Council directions, would carry out necessary studies or draw up necessary regulations, on which the Council would then vote. This conception of the relationship minimized the Commission's effective power because it implied that the Commission would only propose legislation requested by the Council.[5] In contrast, the Commission often sought to be the vanguard of the integration process. Although it was clearly willing to take cues from the Council, its reports, memoranda, and other documents make clear that it also wanted to lead the Council in new directions, and particularly toward a broad interpretation of the treaty that would significantly enhance the integration process.[6]

In practice, the relationship between Council and Commission was mediated by a series of "expert groups" established by the Council. The Treaty of Rome, Article 151, gave the Council the right to "establish a committee" and to determine its "task and competence." From this provision grew COREPER, the Committee of Permanent Representatives, which consisted of ambassadors from each Member State, who were posted in Brussels so as to keep abreast of Commission activities and mediate the interactions between Commission and Council. (COREPER was formally institutionalized in an amendment to the Treaty of Rome in 1965, when the ESCS, Euratom, and the EEC were merged.) As new issues began to arise within the treaty framework, including industrial policy concerns, the Council established additional committees of experts, which included representatives from

the Member States as well as from the Commission. The existence of these committees further complicated the relationship between Commission and Council. In the case of SRI policy, as we shall see, they linked the Commission to the SRI bureaucracies of the Member States, and enhanced the power of the Council in relation to the Commission.[7]

The Assembly of the EEC (now known as the European Parliament) was a debating chamber whose only real power was to demand the resignation of the entire Commission if circumstances warranted. It had to be kept informed of Commission activities and of proposed legislation, however, and by debating and making formal recommendations on specific issues it could raise consciousness and exert moral pressure on the Council and the Commission. The Assembly was situated in Strasbourg where it shared the quarters of the Assembly of the Council of Europe. The two assemblies met periodically in joint sessions, which ensured a constant flow of ideas and issues between the two groups. Both assemblies were strongly in favor of the development of an European technology policy and held numerous debates on the problem during the 1960s.

The second key factor that shaped the development of SRI policy in the EC was the structure of the treaty itself. As already noted, the treaty contained no provisions relating specifically to SRI policy, but its very breadth provided a framework for its development. In addition to Article 2 (cited above), which called for "progressively approximating the economic policies of Member States," several other articles dealing with economic policy (Article 103), commercial policy (Articles 111–116), harmonization of Member State legislation (Article 100), and competition and state subsidies to industry (Articles 85, 92, 93) provided additional foundations on which to structure SRI policy.

Article 103 specified that policy relating to economic trends was to be "a matter of common interest" among the Member States and that they were to "consult with each other and with the Commission on measures to be taken in response to current circumstances." Subsequent articles of this section of the treaty make clear that the economic trends in the framers' minds primarily involved currency, balance of payments, and economic cycles rather than research and development (R&D) or sectoral development issues, but the broad wording of Article 103 left the door open to include sectoral trends and R&D trends within the scope of "economic trends."

Articles 111–116 specified that the Member States had to establish a common commercial policy with respect to third countries. Both Council and Commission had a stake in GATT negotiations, and in commercial negotiations with non-EEC countries. These were to be carried out, not by the Member States acting alone, but by the Commission on behalf of the Community, in consultation with the Council. Because of these provisions, both the Commission (who conducted the trade negotiations) and the Council had to develop an intimate knowledge of sectoral performance at the community level, because only in this way could tariff negotiations be carried out to the community's overall advantage. The Commission's annual report of 1967 specifically indicated that its growing concern with industrial policy was necessitated by "the consequences of" its ongoing tariff negotiations in GATT.[8]

Article 100 provided for the harmonization of the laws and administrative provisions of the Member States if these were necessary for the Common Market to function. This very broad article opened the door to a closer coordination of industrial policy on many fronts, including taxation policy, business law, public purchasing rules, and levels of R&D expenditure. The treaty specified that harmonization of laws required the unanimous approval of the Council members, and as a result, this approach to the development of European industrial policy was largely unsuccessful. To give one example, there was great interest in the 1960s in creating a harmonized legal framework for European companies. The project was considered to be a crucial element in the creation of a common policy in CDP. Over a decade later, however, the project was still on the drawing board, seemingly no closer to success. A little reflection on what was at stake makes it easy to see why. A European company law would have required harmonization of taxation, fiscal, and accounting requirements among all the Member States. Equally contentious was the legal framework for industrial relations. In Germany, workers had to be represented on company boards of management, a provision that was not acceptable to all Member States but that could not easily be discarded by Germany. Finally, a harmonized European company law would have made it much simpler for companies to cross borders, and not all the Member States welcomed such a change. Only in 2001 did the Member States finally agree on a European Company Statute.[9]

Articles 85, 92, and 93, part of a package of rules governing competition, constituted yet another route to an interest in SRI policy in CDP. Article 85 forbade any agreements or associations among companies that distorted competition, but allowed agreements that contributed "to the improvement of the production or distribution of goods or to the promotion of technical or economic progress." Article 85 placed the Commission on the horns of a dilemma. Although it had to *oppose* company mergers or associations when they threatened to distort competition, it could *encourage* mergers or inter-firm cooperation that promised to enhance European sectoral development. The ambiguous position of the Commission was not lost on contemporaries, and was a source of many complaints. The issue was prominent in the case of CDP, because of the widespread view that the development of the sector demanded both company mergers and interfirm associations.[10]

Articles 92 and 93 forbade state subsidies when they distorted competition, and specifically required the Commission to keep a close and continual watch on all state aid programs. Article 92 stipulated, however, that "aids intended to promote the execution of important projects of common European interest" were allowable as were "aids intended to facilitate the development of certain activities," provided that they did "not change trading conditions to such a degree as would be contrary to the common interest." The significance of these articles with respect to SRI policy was twofold. First, they ensured that the Commission would take a close interest in Member State efforts to build up their CDP sectors, for example, through the French "Plan Calcul." Second, they led the Commission to an interest in *coordinating* state aids so as to achieve sectoral progress at the European level, for example, by preventing duplication of research among the Member States.[11]

This overview of the Treaty of Rome and the EEC's organizational structure has shown that, although the treaty did not specifically mandate a concern for SRI policy, it did open several avenues for the emergence of this concern. These avenues (notably Articles 2, 85, 92–93, 100, 103, and 111–116), together with the organizational structures created by the treaty, made it inevitable that if and when a concern for SRI policy did emerge, both the Council and the Commission would be involved. What the treaty did not spell out was which of these groups would take the lead in establishing SRI policy for the EC or how such a policy might actually evolve. The following section will explain the historical circumstances in which this interest did in fact emerge and how it was linked to the integration process.

The Emergence of SRI Policy within the EEC, 1960–1965

The Commission's Annual Reports provide a useful basis for tracking the emergence of SRI policy concerns. They show that sectoral development issues were already being given considerable attention by 1960 because of the need to establish community tariffs, but that research and innovation became a topic of specific concern only in 1963.[12] In July of that year, the Commission proposed to the Council the creation of a medium-term economic policy committee. Legitimizing its request partly on the basis of article 103 (coordination of economic policy), the Commission explicitly contemplated that the proposed committee should include a subgroup to study science and research policy issues. The Commission's report cited the growing importance of scientific and technical research for economic progress and productivity improvement, and the growing tendency for national governments to intervene in this domain. The report further emphasized the need to compare the efforts being made by EEC Member States, and to coordinate them in order to ensure that "the efforts made in each country complement and reinforce one another."[13] The Council approved this proposal, and the medium-term economic policy committee was established at the beginning of 1964. At the request of the Commission, the committee was structured to include representatives from the European Coal and Steel Community and Euratom.

It was not until over a year later, however, on March 5, 1965, that the new committee established a subcommittee—PREST—specifically to investigate scientific and technical research policy issues.[14] The subcommittee's mandate was to "examine the problems involved in developing a coordinated or common policy for scientific and technological research; and to propose measures enabling such a policy to be set up, bearing in mind the eventual possibility of cooperation with non-member countries." The specific timing of the decision to create PREST suggests that it was a direct response to a French memorandum of March 4, 1965 calling for the establishment of a common policy for scientific and technical research. PREST was set up immediately thereafter and its president was none other than the director of the French science policy establishment, Maréchal.[15]

The way in which the Council organized PREST is significant. The committee was not a committee of the Commission. Rather, the Council organized both

PREST and the Medium-term Economic Policy Committee so as to include experts from the public administrations of the Member States (like Maréchal) as well as members of the Commission. This form of organization meant that the Commission would work closely with the national science and research policy organizations of the Member States, ensuring both Council control of the committee, and a constant flow of ideas between the Commission and the national organizations.[16]

What were the underlying reasons for the EEC's new interest in research policy? One important reason was a conceptual shift toward greater recognition of the importance of technological innovation for economic growth and competitiveness. Related to this was growing recognition of the need to provide government support for R&D. The shift in thinking began to emerge in the Commission's report for 1963 (published in June 1964):

> Both on the national and the international plane, there is a growing consciousness of the role played by education and scientific and technical research in economic growth. The expression "intellectual investments," despite the apparent contradiction between the words, nicely illustrates the orientation of numerous economic studies. In the Member States, as in other countries, organizations responsible for economic planning as well as science policy have been created. It is only natural that this movement be extended to the plane of collaboration between states.[17]

The Commission's report for the following year expressed the new conception still more strongly and more directly in market terms. Indeed it struck a note of desperation regarding Europe's lag in a domain in which she used to have undisputed preeminence:

> The competition between firms of the large industrialized countries will increasingly depend on the technical quality of their manufactures. Programs of scientific and technical research must therefore be oriented in such a way as to stimulate the most dynamic branches of production, on which the future of the [European] Community rests. We must not allow those industries in which competition rests above all on innovation to be increasingly outdistanced because of insufficient action in the domain of scientific and technical research. The countries of the [European] Community no doubt take diverse measures to encourage research, but uniting their efforts would have a multiplying effect, and would enable European scientific research to recapture the position it used to hold.[18]

Awareness that Europe was not keeping up with the pace of scientific and technological change grew partly out of highly visible American and Soviet technological efforts in their nuclear and space programs (such as the first manned space flights, which took place in 1961 and 1962), partly out of the alarmingly rapid growth of American investment in Europe, and partly out of the compilation of new data by the Organization for Economic Cooperation and Development (OECD) and other institutions which highlighted European weaknesses in scientific and technical research funding. This awareness was also fostered by conferences and meetings such as the OECD conference on policies for education and economic growth, held in Washington, DC in 1961, and a European inter-ministerial conference on scientific cooperation held in October 1963.[19]

Another underlying reason for the EEC's new interest in research policy was the Kennedy round of GATT. These negotiations officially lasted from May 1963 to June 1967, but preparations for them went back to 1962, when the US Congress passed the Trade Expansion Act (October 11, 1962). The importance of the Kennedy round as a stimulus for the emergence of industrial policy concerns at the European level was due to the fact that its goal was to institute large tariff cuts. The Trade Expansion Act mandated across-the-board tariff cuts of 50 percent and in some cases of 100 percent. (In contrast, the earlier Dillon round, which wound up in 1962, produced tariff cuts on average of only 6.5 percent.)[20] Kennedy and his advisers believed that American industry would benefit from more substantial cuts because its greater productivity and technological leads would enable it to dominate liberalized markets. The implications for European industry were clear: New ways had to be found to stimulate productivity and technical development in order to offset the shift to lower tariffs. As a member of the Committee on Science and Technology of the Council of Europe explained, the Kennedy round of GATT would "undoubtedly have the effect of raising, in the next few years, the 'critical threshold' of the research effort necessary to keep certain European industries competitive."[21] This was particularly true in the case of France, which generally had the highest industrial tariffs in the Common Market.[22]

One other reason for the emergence of EEC interest in research policy was its importance for the political and military ambitions of France. Development of cooperation in scientific and technical research in the Common Market would enable France to enhance its technological, economic, and military independence vis-à-vis the United States. France was the only member of the Common Market with a policy of military independence, and De Gaulle and his officials understood that this could not be achieved without substantially improving its technological capabilities. The issue came to a head in 1962, when Britain asked to join the Common Market. De Gaulle wanted to maintain a nuclear force entirely independent of the United States, and to achieve this goal, he wanted Britain's commitment to remain militarily independent of the United States, and British cooperation in military technology. (France still had no nuclear weapons, nuclear submarines, or launchers at this time.) When Britain made it clear, however, that it would remain linked militarily to the United States, General De Gaulle abruptly vetoed British entry into the Common Market in a famous press conference on January 14, 1963.[23]

A few months later, in the spring of 1963, France's technology problem again came to the fore when the United States government refused to allow the export of a large Control Data computer to France, for use in its nuclear weapons program. And in the following year, while IBM introduced its IBM 360 series, leaving European computer companies all rushing to catch up, France saw its major computer company, Bull, taken over by General Electric (GE). France's inability to keep up with the increasing pace of technological innovation led it to promote greater cooperation in scientific and technical research with its European partners. This was the idea behind its 1965 Memorandum. In short, the Common Market became an element of France's policy of technological independence.[24]

PREST, together with the sectoral policy group of the Medium Term Economic Policy Committee, became the vehicles for the initiation of efforts to develop a common SRI policy in computers and data processing. Indeed, the first sectoral study carried out within PREST's mandate concerned the electronics sector. This report was completed in July of 1967 and, after being approved by the Medium Term Economic Policy Committee, was transmitted to the European Council for use in a special session on "problems of technological progress," held October 31, 1967. At this session, the Council adopted a resolution in favor of the development of a common policy in scientific research and industrial innovation. PREST was thereby instructed to study possibilities for European cooperation in seven sectors: Informatics, telecommunications, new forms of transport, oceanography, metallurgy, pollution, and meteorology. The following day, PREST created a subcommittee for informatics (CDP).[25]

Years of Revolution: 1966–1967

Although on the face of it the route from the creation of PREST, to the completion of a study on the electronics sector, and finally to the creation of a PREST subcommittee to explore possibilities for cooperation in CDP was a rational bureaucratic progression, in reality the intervening period was marked by three revolutions. The first revolution involved the organization of the EC itself, which expanded to include Euratom and the European Coal and Steel Community. By a merger treaty signed in April 1965 and which came into effect on July 1, 1967, the administrations of the three organizations were merged into a single European Commission. This change strengthened the bases for the Commission's involvement in questions of SRI, first because it led to the organization of a new branch of the Commission to deal specifically with industrial affairs (DG III), and second because both the Euratom and the ECSC treaties included research mandates. The process of merging meant, however, that during the period between the signing of the merger treaty and its coming into effect, efforts had to be made to coordinate the views of the three executives so as to develop a common front in matters relating to PREST. The three executives therefore formed their own committee for research and innovation issues in October of 1965.[26]

Another major change in the Community's organization occurred in the context of the "Empty Chair Crisis," which extended from July 1965 to the end of January 1966. It brought most activities of the Community to a halt and threatened its very collapse. The crisis was triggered when French President Charles De Gaulle recalled his representatives from the EEC. The issue at stake was the balance of power between Commission and Council. By 1965, particularly as the prospect of the merger of the three communities loomed large, the Commission, under the leadership of Walter Hallstein, attempted to lay fuller claim to the scope of powers permitted it under the Treaty of Rome. The Commission particularly sought to acquire its "own resources" through collection of Community customs duties, so that it would no longer be dependent on Member State largesse. At the same time,

provisions for qualified majority voting in the Council were scheduled to take effect. (In the first phase of the establishment of the Common Market, all Council decisions had to be unanimous.) If these changes had both taken effect, the result would have been a significant shift in the balance of power in favor of the Commission.[27]

The idea of a loss of national sovereignty was anathema to French President Charles De Gaulle. So when it appeared that neither the Commission nor the other five Member States would compromise on the proposed changes, DeGaulle withdrew all French representatives from the Council, from COREPER, and from all committees of COREPER and the EEC. Not until the end of January 1966 (after nearly losing an election) did De Gaulle agree to send his representatives back to the bargaining table. During the entire period, the activities of PREST and the Medium Term Economic Policy Committee ceased, and indeed PREST did not get back to work until the spring of 1966.[28]

The Empty Chair Crisis was resolved by the Luxembourg Compromise, an agreement by which the Council effectively preserved the requirement of unanimous consent among Council members, in violation of the Treaty of Rome. The Common Market thus remained an intergovernmental organization: Each country had the right of veto and the Commission's power was held in check. It did not acquire its own source of revenue, and without majority voting in Council, its power to propose legislation could have little consequence. The implications for the development of a common SRI policy were great, and indeed for European industrial policy generally: Only least-common-denominator projects could hope to see the light of day.

The second revolution that occurred between PREST's establishment (spring of 1965) and the Council's decision to explore cooperation in CDP (fall of 1967) was the implementation of national programs in France and Germany to support CDP development. The reports that laid the groundwork work for the French "Plan Calcul" were prepared in March 1966,[29] and the final document that officially launched the plan was signed on April 13, 1967.[30] The following month, a press release from the German Federal Minister for Scientific Research announced the decision to launch a German program to support the development of data processing.[31] Both were 5-year programs that would give substantial R&D support to industry. The French program promised a total aid package of 650 million francs, while the German program amounted to about 300 million DM overall.[32]

The third revolution that occurred between the spring of 1965 and the fall of 1967 was conceptual, and involved two elements. The first was the emergence of a clearer definition of CDP as a "stand-alone" industrial sector, with the computer as its focus. The PREST sectoral study was mandated to be a study of the *electronics* sector. In 1963, electronics meant, above all, radio and television. By 1966, however, when the PREST study was launched, electronics meant radio and television (consumer goods), and digital computers and process control equipment (capital goods). The emphasis was on the distinction between consumer goods and capital goods. The belief was that the capital goods segment of the sector was gaining in importance relative to the consumer goods segment.[33] By the fall of 1967, when the Council made its resolution, the definition of the sector in need of attention had been further altered to become

"*informatique*" or "*data processing.*" Its core was now the computer, and television and radio were no longer part of the package. The change was subtle but significant, because it involved a new perception about where Europe lagged, and where cooperation had to be promoted.

This change stemmed partly from the establishment of the German and French support programs for data processing. To implement a sectoral support program, it is necessary to define specifically what needs support; the very process of doing so—and of controlling costs, no doubt—encouraged the shift in perspective. Evidence can be seen in the case of the French Plan Calcul. The documents of March 1966 that laid the groundwork for the Plan Calcul were structured within the sectoral framework of electronics, and included radio and television. Yet the finalized "Plan Calcul" that emerged a year later was structured within the sectoral framework of "informatique," with the computer at its core; radio and television were absent. An analogous shift can be seen in the internal documents of the German Ministry for Scientific Research.[34]

Although the conceptual shift from electronics to data processing emerged first within the national bureaucracies, it was soon echoed at the European level, where the legality of the French and German support programs was discussed. As noted earlier, the European Commission was charged with overseeing state aids to industry. Therefore, when the German government informed the Commission in May 1967 of its decision to launch a support program for data processing, the Commission organized a meeting in Brussels (July 1967) with representatives of the relevant ministries of each Member State in order to consider the implications of Germany's aid program. Both the German and French support programs were discussed at the meeting, as well as the broader ramifications of such support. In this way, the new sectoral definition was quickly transferred to the European level.[35]

The second element of the conceptual revolution was a sharpening of public awareness and concern over European weakness in high technology and the subsequent emergence of a possible solution through the idea of a European "technological community." The 2-year period from 1966 through 1967 was the period in which the term "technology gap" took hold of the public imagination. As it did so, the debate over research and technology policy moved beyond specialist committees like PREST and gray-literature OECD reports into the popular press, into parliamentary debates within the EC and the Council of Europe, into the consciousness of European federalist groups (like Monnet's Action Committee for the United States of Europe), and into the speeches of high-level politicians and public leaders like Prime Minister Harold Wilson of Great Britain, Foreign Minister Willy Brandt of Germany, and France's Minister for Science and Technology Alain Peyrefitte. Technology policy acquired mainstream political significance; it became a key element in public debate over the future of European integration. As one contemporary observer put it, "technological problems have erupted suddenly onto the political stage." The observer concluded that "this very topical issue . . . will determine our future, by which I mean the living conditions of Europeans and the political position of Europe in the world."[36] Another observer commented that: "Europe has at last wakened up to the

fact that cooperation in science and technology deserves absolute priority. This subject crops up in all the reports and in all the speeches, and it even creeps into our debates. Is this just a new fashion? I think not; it is a form of realism; it is a sign of something of which we have now become conscious."[37]

The first use of the term "technology gap" that I am aware of grew from the 2nd OECD Inter-Ministerial Conference on Science and Technology, which took place during January 12–13, 1966. The Ministers recommended that the OECD "strengthen its work on the links between science and economy," particularly with respect to technologically advanced sectors. To respond to this mandate, the OECD Council set up a "Working Group on Gaps in Technology between Member Countries." This working group then went on to complete a series of book-length statistical reports on specific sectors, including one on the computer industry. (The computer industry study was completed only in early 1968.)[38] Other sources assert that the term "technology gap" was brought into public focus by Italian Foreign Minister Amintore Fanfani, through a proposal he presented in the latter half of 1966 to NATO, to the Council of the European Community, and to Euratom.[39] This proposal received widespread publicity and was specifically cited by the EC Council in its 1967 resolution in favor of European technological cooperation. Fanfani advocated a kind of "Marshall Plan" for European technology, to be achieved by the creation of a common European technology policy together with aid from the United States.[40] Beyond Fanfani, Jean-Jacques Servan-Schreiber was among those who did most to popularize the concept of the technology gap when he published *Le Défi Américain* in October 1967. The book immediately became a best-seller, selling more copies in France in its first 3 months than had any other fiction or non-fiction book since the Second World War.[41] It created a sense of crisis, a sense of mission, and bound both firmly to the project of European integration. The book had an extraordinary effect in mobilizing public opinion and in pushing politicians and policymakers into action.

Yet Fanfani and Servan-Schreiber cannot be given all the credit for this change of consciousness. They helped to popularize it, but they were riding a wave that had many points of origin and mobilized actors in many spheres. As one observer pointed out in August of 1967, "science and technology are under discussion everywhere. The subject is in fashion, perhaps dangerously so."[42] Already in May of 1966, after the resolution of the Empty Chair Crisis and months before Fanfani made his proposal, Alain Peyrefitte, the French Minister of Science and Technology, gave a speech before the Assembly of the Council of Europe in which he referred specifically to the "technology gap," emphasizing the danger Europeans faced because of "the growing disparity between their own research effort and the altogether spectacular achievements of the United States." This growing disparity, Peyrefitte cautioned, was "reducing the European countries to the position of under-developed countries, vis-à-vis the United States." The solution he offered was for European countries to join forces to create a joint European research policy.[43] The issues raised by Peyrefitte were debated at length and helped provide momentum for a formal resolution by the Council of Europe's Assembly to create a new committee

on science and technology. The resolution was voted on by the Assembly in the fall of 1966, and was subsequently approved by the Council of Ministers. The committee took up its mandate during the summer of 1967.[44]

Perhaps most importantly, the technology gap issue became the central theme in Great Britain's second application for membership in the Common Market put forward by Labour Prime Minister Harold Wilson. To launch the process, Wilson, together with his Foreign Minister George Brown, toured Europe from mid-January to mid-March of 1967. One of the highlights of this tour was a speech given by Wilson at the Consultative Assembly of the Council of Europe in Strasbourg. In it, he raised the fear that Europe's technological lag could lead to "an industrial helotry under which we in Europe produce only the conventional apparatus of a modern economy while becoming increasingly dependent on American business for the sophisticated apparatus which will call the industrial tune in the '70s and '80s."[45] He then proceeded to offer a solution to this looming crisis: Bring Britain into the Common Market in order to lay the foundation for the creation of a European Technological Community. Drawing on Britain's expertise in advanced technology—Wilson often singled out the computer sector for specific praise—this new technological community would counteract American technological ascendancy and allow Europe once again to take charge of its industrial development, which would in turn lead to political and military independence.

Wilson sent an advance copy of his speech to President De Gaulle and, following the speech, proceeded with George Brown to Paris for talks with De Gaulle and Pompidou. There again, he particularly stressed the technology angle in arguing for Britain's entry into the Common Market. De Gaulle replied with his worries that Britain's financial, commercial, and agricultural conditions adversely affected its prospects for joining the Common Market.[46] Nevertheless, according to De Gaulle's Foreign Minister Couve de Murville, who discussed the matter subsequently with British publisher Cecil King, De Gaulle was impressed by "Wilson's argument about the larger base now necessary for technological advance. If Europe did not get together for research, we had no hope of keeping up with the Americans."[47]

The key arguments made in Wilson's Strasbourg speech were echoed repeatedly in subsequent speeches by Wilson, by his Foreign Secretary Harold Brown, by Lord Chalfont (chair of Wilson's committee on European technological collaboration), and by Minister of Technology Wedgewood Benn.[48] The reason for Wilson's focus on technology in his "European gambit"[49] is not hard to understand. In his government's bid to enter the EEC, Wilson hoped to emphasize the advantages that the EEC would gain through Britain's entry. The most significant advantage he could point to (apart from the addition of Britain's population to the size of the EEC market, which was not alone an adequate selling point) was Britain's prowess in advanced technology, particularly aviation, nuclear power, and computers and data processing. Technology was, in the words of one member of the Council of Europe's assembly, "a trump card for the United Kingdom"[50] in its application to the Common Market. In contrast, within other domains like finance, agriculture, and commerce, British entry posed significant difficulties for both Britain and the EEC.

In order to maximize the impact of the technological argument for British entry into the EEC, Wilson and his followers emphasized the link between technology and political power. Lord Chalfont made the point directly in a speech to the Council of Europe:

> It is worth reflecting for a moment on what Britain would bring into the European Community. I have already mentioned our potential political contribution, but political power and influence rest in the last analysis on economic strength . . . As my Prime Minister has said, the one way for Europe to become subservient to others is to become dependent on them for the most advanced industrial and technological inventions. The European countries can achieve a real standing in world affairs only if we work together now within a single market to develop our technology; and the logic of a European technology demands a European political community within which industry can operate efficiently for the common good . . . Britain is ready and willing to play her full and rightful part in building a wider, a more powerful, and a more influential Europe, the Europe of the future. We have set out our offer plainly and directly; and it is now for the Six to make their reply.[51]

Wilson's argument had a tremendous impact throughout continental Europe. It provided the first clear rallying point around which Europeans could transform their common fears of economic decline into positive steps for renewal. In the process, technology came to be seen as "the most powerful pressure now driving Europe towards real unity."[52] The theme was picked up not only by European integration lobby groups such as the Campaign for Europe Movement and by prominent Europeanists like Jean Monnet,[53] but also by the major European organizations: the WEU, the Council of Europe, and the EEC. Dozens of speeches and documents produced within and beyond these organizations echoed Wilson's idea of a European technological community, and agreed that it had to include Britain within an enlarged EEC. The possibility that Britain might withdraw from European technological cooperation if not admitted into the EEC also raised fears that a unique opportunity to overcome the technology gap would be lost "by continuing to make . . . Britain hang about on the doorstep."[54]

Importantly, Wilson's ideas were interpreted as a call for not only an enlargement of the EEC but also for a crucial broadening of its scope. Indeed the concept of a European Technological Community highlighted the inadequacy of the original Treaty of Rome with respect to technology and research:

> Because they made no provision on Community level for the scientific and technological incentives which, in the industrial economy of today, only the public authorities are in a position to offer, the 1957 treaties [establishing the Common Market] are not capable, by themselves, of creating a true economic community. The distinction of having been the first to say this belongs undoubtedly to Mr. Wilson for his announcement that Great Britain was not merely a candidate for membership of the European Communities but hoped that [the latter] would add to their existing functions those of a technological community rather than create a fresh organization.[55]

The conceptual revolution that occurred around the dual themes of the "technology gap" and the creation of a "European Technological Community" had three

significant consequences for European information technology (IT) policy. First, as suggested in the preceding paragraph, the conceptual revolution called attention to the limitations of the original Treaty of Rome with regard to technology, research, and innovation; at the same time it brought about an initial consensus concerning the measures that needed to be taken to create a viable technological community. The limitations of the Treaty of Rome were discussed within both the European Parliament and the Assembly of the Council of Europe. A British member of the Council of Europe put the matter most forcefully in a joint debate with the European Parliament:

> Since this is a joint meeting with our friends from the European Parliament, I hope they will forgive me an observation about how astonished I was that the authors of the Treaty of Rome should have overlooked completely the need for provisions to encourage scientific and technological cooperation among the states adhering to the Treaty. Except for one slight mention of scientific research in agriculture, the Treaty is silent on this major issue. There are no provisions in the Treaty either for setting up the appropriate institutions or for the necessary rights of initiative for the Commission. The adhering states and the whole of Europe find themselves at a considerable disadvantage because of this lack of unified science and industrial policy in Europe.[56]

As for policy solutions, there was widespread discussion of the kinds of measures that were needed. Ideas included, among others, a common European patent, a common purchasing policy by European governments, a legal framework for the creation of trans-European enterprises, more cooperation and research specialization among the European states to avoid unnecessary duplication of effort, and the creation of larger, trans-European enterprises through mergers or cooperative agreements.

The second consequence of the conceptual revolution was that it placed the computer at the center of the technology crisis,[57] while at the same time inculcating a particular vision of the CDP sector that, in turn, shaped the character of European policy efforts in this domain. This vision saw the computer as a "big" technology, analogous to large aircraft or nuclear power plants. Indeed, in discussions of the technology gap, these three technologies were almost always lumped together. One commentator, for example, referred to "the 'big' sectors; the sectors, that is to say, in which the size of the problems renders them more obviously incapable of solution at national level. This would include, needless to say, such sectors as nuclear power stations, computers, spacecraft and rockets."[58]

A corollary of this view of the computer was the belief that only very large firms could successfully innovate in this realm, and then only with significant government funding. As will become evident in the following sections, this vision of CDP shaped the technology policy solutions that were proposed and attempted.

The third consequence of the conceptual revolution was to politicize technological issues in dramatic ways by linking them with the key problems of restructuring and enlarging the EC. Thus, what had begun with the establishment of PREST, in 1965, as a limited initiative to address SRI issues was transformed by the end of 1967 into a major political campaign to refashion the EC. As a result, the EEC's Council of

Ministers meeting of October 31, 1967, with its decision to relaunch PREST's technology policy effort, was—in a conceptual sense—a world away from the meeting that had launched PREST 2 years earlier. During those 2 years, the Common Market had weathered a major crisis and had changed in the process; the Luxembourg compromise now held sway, and the Commission's wings had been clipped. At the same time, the computer had become a major symbol of Europe's problems and prospects, and major schemes to subsidize and strengthen the computer industries of France, Germany, and Britain had been introduced. And Britain was now "hanging about the doorstep" of the EEC, hoping to help launch a new technology community within an enlarged Common Market. How would the EC respond?

From Crisis to Relaunch: 1968–1970

The initial response came less than a month after the October 31 meeting of the Council of Ministers, and not from the EC as a whole, but directly from Charles De Gaulle. The response, given at a press conference on November 28, was a firm "no" to Britain. The causes for this reaction have been widely debated, and it is not my intention to review these discussions. However, two points about the General's "non" are relevant to an understanding of the development of technology policy in the EC.

First, Britain's technological prowess, although used by Wilson as a selling point for entry into the Common Market, solidified De Gaulle in his opposition to the UK's application. To understand why, it is first important to note how Wilson shifted his argument about Britain's application to the EEC when he addressed audiences of British businessmen. On those occasions, he did not dwell upon what Britain could offer Europe, but rather he emphasized the idea that Britain's strength in high technology would give it a strong market advantage within the EEC. Addressing the Confederation of British Industries in May 1967, he explained:

> All of us are conscious of the tremendous opportunities in long-term gains which would result in the opening to British industry of a vast market of . . . 300 million people, and particularly the opportunities this would provide for our highly sophisticated technological products in the fields of electronics, computers, nuclear development, and many sectors of the engineering industry. It would provide a basis on which the enormous research and development costs involved in staying in the vanguard of these advanced technologies could be carried on in a market which was larger in terms of population than either the United States of America or the Soviet Union. The prospects of sales in this market would offer individual manufacturers the expectation—which I know it is sometimes hard for them to see at present—of recovering the large investments involved in moving forward the next step along the road of technological advance.[59]

Gone are ideas about technological cooperation for the good of Europe; instead we have Wilson painting a picture of *individual* British high-tech companies gobbling up sizeable chunks of continental European markets. Would their growing market shares be more likely to come from powerful US firms with strong patent positions and entrenched European operations, like IBM, or from smaller, weaker European firms?

De Gaulle and his ministers were certainly sensitive to this threat. Their actions suggest a policy of using British–French technological cooperation to gain from Britain's technological expertise without giving it free access to the Common Market. Contemporaries noted this "contradictory" dimension of French policy. After France officially vetoed Britain's application at the EEC Council of Ministers meeting on December 20, 1967, a Belgian representative to the Council of Europe's Consultative Assembly commented that:

> Any observer who has been closely following French policy with regard to Great Britain's entry into the Common Market, must have been struck by the apparent contradiction in the French attitude at Brussels, within the Communities, and the repeated French overtures to Britain to co-operate in the scientific and technological fields. Even on the morrow of the decision of 20th December the French Minister for Science repeated that France was still in favour of Britain's participating in European scientific co-operation.[60]

The relative strength of Britain in high technology, combined with the fact that membership in the Common Market would free the United Kingdom from having to "jump a tariff fence of 25%"[61] go far toward explaining France's dual policy.

The second factor in De Gaulle's veto that affected the development of technology policy in the EC was the response to that veto by Britain, by the other Common Market Countries, and by other European organizations. Britain, in a speech delivered by Minister of Technology Tony Benn at the Council of Europe, threatened withdrawal from existing technological cooperation in Europe until the issue of British entry to the EEC was resolved in Britain's favor: ". . . the point has been reached when collaboration on specific projects will become increasingly stultified by failure to achieve full economic union. There could come a point at which some aspects of our cooperation would necessarily be halted until British entry into an enlarged EEC."[62] In that same speech, Benn also announced a policy of seeking closer technological cooperation with Eastern European countries. In practice this meant aggressive marketing of high technology in Eastern Europe with the aim of undercutting French marketing efforts.[63]

Benn's speech was indeed followed by increased marketing efforts in Eastern Europe, and also, as threatened, by decisions to scale down, withdraw from, or hinder several European technological cooperations. Britain refused to work with France on a new gas-cooled nuclear reactor, despite the UK Atomic Energy Authority's desire to cooperate on the project. According to Tony Benn, Harold Wilson "quite rightly laid down that we weren't to do bilateral nuclear work with the French until the question of entry to Europe was settled."[64] Britain also announced that it intended to withdraw from ELDO (European Launcher Development Organization); it refused to take part in building a new particle accelerator for CERN; it held back support for OECD work on technological collaboration; it refused to work with the EEC's PREST committee;[65] it considered abandoning the Concorde project;[66] and it pulled out of the Airbus cooperation.[67] The issue of EEC membership was not the only factor behind these policy shifts. Perhaps an even more important factor was the UK's difficult financial situation, which had led to a devaluation of the pound in

November of 1967 and which required significant budget cuts in 1968. Specific technical and business factors also influenced each decision. Nevertheless, given Benn's very public threat—his speech was read in advance and edited by Wilson—it is hard to avoid the conclusion that Britain was attempting to retaliate against the French decision. Tony Benn did not overtly admit to a policy of retaliation across the board, but some contemporary observers believed that this was Britain's intent. A report by the Committee on Scientific, Technological, and Aerospace questions of the WEU concluded that: "The United Kingdom, assisted by the Netherlands, is trying to hold back existing European collaboration pending agreement on its application to join the European Communities or at least agreement by all six countries on the opening of negotiations."[68]

In its attempt to thwart European technological collaboration, Britain was assisted not only by the Netherlands but also by Italy and Belgium and by the other principal European organizations, the WEU and the Council of Europe. Angered at France's refusal either to consider Britain's application to the EEC or to allow Britain to participate in meetings of the EEC's PREST committee, Italy and the Netherlands retaliated by boycotting PREST. As a result, the EEC's technology policy work was suspended once again for nearly a year, from the end of January through mid-December 1968.[69] At the same time, the Belgian Foreign Minister put forward a plan in September 1968 to create a European political and technological community under the auspices of the WEU, of which Britain was a member.[70] The Council of Europe also responded to the crisis by considering the possibility of sponsoring European technological collaboration under its own auspices.[71]

The combined efforts of Italy, Germany, the Benelux countries, and a spectrum of European organizations over the course of 1968 left France increasingly isolated. At the same time, France had internal political and economic problems: The student revolt of May 1968, which was followed by a general strike; and a rapid depletion of French monetary reserves during the fall of 1968, which threatened the need for a devaluation of the franc. The combination of outside pressure, social unrest, and a weakening economy made it impossible for France to maintain a strong position against Britain, and by the end of 1968, the government began to show signs of relenting. In a proposal to the EC Council of Ministers on November 4, French Foreign Minister Michel Debré proposed to relaunch PREST and other European industrial policy initiatives (e.g. plans for a European patent and a European company law) with the understanding that outside countries (like Britain) would be involved in these efforts. The Council approved this proposal on December 10, and in January 1969 the PREST committee and its subcommittee on data processing began meeting once again.[72]

The Debré relaunch included a series of interrelated projects in the CDP sector. They were characterized by a "pronounced interest for the most direct forms of action."[73] The relaunch in CDP was thus built around specific, product-oriented projects. The first project, envisioned to be completed around 1975, was for a large and powerful computer system equivalent to the largest American machines. The second project, slated for completion around 1980, was for a very powerful and

high capacity computer system at the cutting edge of technology, linked to a data network. Complementing these were projects for components, peripherals, software applications, and the compilation of a library of European programs. The preliminary report outlining these projects reveals that they were all part of an ambitious, overarching plan by which the participating European states would be able to access (through an international data network and more advanced peripherals) a large library of existing and newly developed European programs which were stored in a giant, state-of-the-art central computer. Some of the new applications to be developed were for traffic control, air traffic control, medical applications like toxicology, administrative automation, and database management. To make this European information system viable, plans for developing common standards in components, data communications, and the like were also put forward.[74]

The report set down the industrial policy motivations for this array of projects. Prominent among these was the goal of bringing the major European computer manufacturers together to work on common computer development projects and to agree on common standards, so as to achieve "an integration of forces on a European level."[75] In short, this array of projects was intended to achieve a consolidation of the European CDP sector by forcing the firms to join forces in a single organization (e.g. a consortium) to undertake these projects. At their first meeting, the PREST planners of the informatics subgroup drew up an initial list of companies to be consulted for participation in the large computer project. These included CII, Philips, Siemens, and AEG-Telefunken. It was understood that the British company ICL would eventually be included in this list—its participation was deemed to be essential—but the discussions made clear that contacts with Britain were to be initiated by the Council after receiving an initial report from the PREST subcommittee. These contacts were eventually made in the fall of 1969.[76]

The interactions between the PREST subcommittee and the manufacturers were not carried out on an individual basis. After an initial, private meeting with a representative from each firm, the manufacturers were asked to organize a single committee with a representative from each company. The final list of companies participating in the committee included AEG-Telefunken, CII, ICL, Olivetti, Philips, and Siemens. The committee met to discuss such issues as the carrying out of a market study, further specification of the technical requirements and estimated costs of the large computer system, and the establishment of an appropriate industrial structure (or consortium) to undertake the project. The committee's initial conclusions and recommendations were forwarded in letters to the Chair of the PREST subcommittee. This letter was accompanied by a schedule of meetings extending from the fall of 1969 through the end of 1970.[77]

By July of 1970, a credit of 200,000 ECUs (European Currency Units) had been granted by a committee of the Council of Ministers to fund a preliminary feasibility study for the large computer system, with the understanding that the manufacturers would contribute an equal amount. However, by November of 1970, despite support for the program from the EEC Council of Ministers, the manufacturers' committee had reached the decision that "they did not consider the joint production of a very

large system, as originally proposed, to be justified."[78] Rather, the manufacturer's committee stressed the need for a greater emphasis on the creation of common European standards. With this response, the large computer project, what one contemporary termed "the pan-European monster," was "quietly killed off."[79] However, the plans for the creation of a European data network and a European library of programs were kept alive.[80]

Several aspects of the large computer project and its political context are relevant to an understanding of its relationship to the subsequent formation of Unidata two years later. The first aspect has to do with France's key role in this project. Quite simply, the large computer project was part and parcel of French national IT policy. Its origins went back to 1965, when a group of computer companies, one French and two British (the predecessors of ICL and CII) entered into negotiations for the joint development of a very large computer at the cutting edge of technology. These talks were dropped by the end of 1965, but the idea was taken up by French industrial policymakers in a key document in March of 1966 that helped launch the French "Plan Calcul." Referring to the problem of "the development of very large computers," the document concluded that "the scale of the investments needed for the development and fabrication of these large computers imposes the search for a European solution."[81]

A related element of French IT policy was the conviction that the ultimate success and survival of the French computer industry demanded a further concentration of that industry beyond the national level: "The regrouping of the three or four principal French enterprises alone would be insufficient and the concentration effected within the national territory must be rapidly extended on the European level to include several large foreign firms."[82] However, French policy sought to avoid a situation in which this regrouping would bring about a "takeover of existing French companies by large European rival groups."[83] An international undertaking like the large computer project offered, in French eyes, the ideal means to bring European manufacturers together without jeopardizing the existence or commercial position of the French companies involved. Accordingly, French policymakers concluded that the best way of bringing about the necessary structural reform of the European computer industry was "by the realization of projects of large scope."[84] Undertaking such projects would serve to "facilitate the transformation of the structure of the European informatics industry. . . . The necessary European industrial structures will not develop by themselves if an objective is not assigned to [the industry] and if the states do not intervene financially. This objective of industrial restructuring . . . is preponderant."[85]

How was France able to have its vision predominate within an EC initiative? Part of the reason was because French officials played a dominant role in PREST. The chairmen of PREST who served between 1965 and 1970 were both French officials,[86] and the chairmen of the informatics subgroup from its formation in 1967 up to 1970 were also both French officials—indeed they were the heads of the French "Plan Calcul."[87] Among the stated mandates of the head of the Plan Calcul was to "aid the world-wide diffusion of the products of French industry" by "favoring the establishment of a regrouped European informatics industry."[88]

The other reason why France's vision was able to predominate was because key elements of it were shared by France's partners in the EEC. On the one hand, there was a widespread belief at the time that the technical future lay in large central computers linked into real-time networks to which multiple users would be connected.[89] The French plan also embodied a widely accepted solution to the crucial problem of Europe's "technological lag" in computers, namely, the international regrouping of European computer firms to create larger enterprises. By 1970, belief in the need to foster larger, trans-European enterprises was not just an element of French policy, but was accepted by leading policymakers and policy analysts in Britain, Germany, Italy, within the European Commission and the Council of Europe, and among journalists, academics, European lobby groups, and computer industry analysts.[90] This perspective became so widespread that it submerged alternate viewpoints, which stressed the need to maintain an interaction between large firms and smaller, more dynamic firms in high-tech sectors. The issue was no longer whether there should be an international consolidation of European computer firms, but when and how such a regrouping could be achieved.[91]

The industry-restructuring dimension of the large computer project had a bearing on the development of Unidata in that the two undertakings constituted alternate routes to this goal. Also important was the way this project brought European firms together. During the 1950s, European firms often knew their American counterparts better than they knew one another. But with the process of European integration these firms increasingly began to interact, for example, within UNICE, which was established in Brussels in 1958. UNICE brought together the leading manufacturers' federations of the Common Market states and served as an EEC lobby group.[92] The principal European manufacturers likewise became members of the Ligue Européenne de Coopération Économique, also headquartered in Brussels. In contrast to these umbrella organizations, however, the large computer project specifically required the main computer manufactures to meet as a group and to consider how to work together as a single entity on a common development project. The initial report on the large computer project explained that ". . . projects of such scope and complexity must be directed from a single, autonomous decision-making center. One possible solution would be the establishment of a common subsidiary among the firms involved, but other formulas could equally be taken into consideration, the important thing being that the direction of the project remain unified."[93]

When talks with the manufacturers began, the latter were specifically instructed to study "the problem of the *structure of the Common Group* to be created."[94] Among the first ideas put forward was a common group in which the management would be carried out by delegates from the participating companies. This was the basic framework subsequently followed in Unidata.

Although talks on the large computer project had drawn to a close by December of 1970, it is worth noting that within a year three computer consortia were created. First, a consortium called EURODATA was formed by ICL, Compagnie Internationale Pour l'Informatique (CII), Olivetti, and AEG-Telefunken in order to prepare a proposal for a large, powerful computer system for the European Space

Research Organization (ESRO). This proposal was rejected in 1970 in favor of an IBM system, however, and the consortium dissolved.[95] Second, in June of 1970, ICL and CII together with the American company CDC established a consortium, International Data Corporation, headquartered in Brussels. Its stated aims were to develop common standards to increase compatibility between the products of the three companies, to produce a common catalog of ancillary equipment, to produce a common line of products, and to merge their commercial operations. This consortium also proved to be short-lived. Finally, in 1971 AEG-Telefunken and Nixdorf created a consortium for the purpose of jointly developing a large computer system.[96] These examples reveal the extent to which the consortium approach had become an accepted method for integrating the activities of different firms in specified areas. The large computer project did not create this trend, but it did help to legitimize and reinforce it.

Another important aspect of the large computer project was the organizational context within which the policy was framed and managed. The initiative came not from the European Commission, but rather from the Council of Ministers and the committees it controlled: COREPER, the Comité des Hauts Fonctionnaires, the PREST committee, and the Informatics subgroup. (Recall that PREST and its subgroup were *not* Commission committees, but rather expert committees composed of government officials from each member state, together with Commission representatives.)

The character of the large computer project reflected its organizational roots. It was indicative of a growing bifurcation between the industrial policy views of the Commission and those of the Council. Both sought to overcome the "Technology Gap" threat, and both saw CDP as a key sector needing greater financial support and restructuring. The solutions they favored differed significantly, however. The Commission set down its views in a 400-page "memorandum" published in 1970. It argued that effective support for and reorganization of advanced technology sectors like CDP required *Community-funded* programs, that is, organized and funded by the *Commission* from its own budget, rather than intergovernmental programs in which funding was controlled by Member State contributions. The Commission moreover stressed the need for a common procurement policy so that firms from any Member State could bid for government contracts on equal terms with the firms from the state awarding the contract.[97] The Commission also evoked the need for complete mergers or takeovers among European firms to reduce the overall number of firms in advanced technology sectors. It expressly noted the inadequacy of cooperative projects to achieve the necessary restructuring, explaining that "joint technological development programmes" had

> scarcely any impact on the restructuring of firms for whom such cooperation is considered merely a passing phase. Firms, which participate in such projects, do not always see their potential notably strengthened thereby and once the cooperation is over they must search for a new project and new partners. Thus the opportunity to foster the development in the Community of trans-national European firms capable of facing competition from the most powerful firms in third countries is allowed to slip by.[98]

Significantly, the large computer project had quite different objectives from those advocated by the Commission. It obviated the procurement issue so that the latter could be ignored. It was deliberately structured to ensure that no trans-European takeovers would occur. And it kept funding firmly in the hands of the individual states. In short it was structured so as to promote the technical and commercial development of the European computer industry in a way that maintained nation-state autonomy in funding, procurement, and industrial structuring. We will see that the Unidata consortium was carefully and deliberately structured to achieve the same aims.

Unidata, 1971–1975

The period between the launch of the large computer proposal (spring of 1969) and the onset of negotiations that led to Unidata (fall of 1971) witnessed profound changes in the political landscape of Europe as well as in the economic and market landscape of the CDP sector. These changes had a bearing on the formation of Unidata, so it is essential to review them briefly.

The most important political change was De Gaulle's resignation in April 1969, which was followed by the June 1969 election of Georges Pompidou as France's new president. In his first press conference the following month, Pompidou let it be known that he was not opposed in principle to British accession to the EC, and he suggested that the heads of state of the EC member countries hold a summit meeting to discuss the issues involved. This meeting, which took place in the Hague in December 1969, was followed by months of intensive negotiations among the six to chart a common position regarding the accession of Britain and its co-applicants Ireland, Denmark, and Norway. The official accession negotiations with the applicants began on June 30, 1970 and continued for a year. The accession treaties were finally signed in January 1972, and on January 1, 1973 Britain, Ireland, and Denmark (but not Norway) entered the Community.[99]

The prospect of Britain's eventual entry into the EEC heightened French concerns about the competitive position of Britain's flagship computer company, ICL, relative to CII. The French journal *Le Monde* noted in July of 1970 that ICL was the "only firm to have succeeded in gaining a place on the international informatics market."[100] It was widely believed in continental Europe that Britain had a more advanced computer industry than any other European country. Brian Murphy, ICL's Director of Strategic Planning reiterated this view in a 1969 article, which was distributed to members of the Council of Europe's Subcommittee on Data Processing. He maintained that the European computer industry should regroup under the leadership of ICL: "A glance at the state of development and market share of the existing European [computer] industry clearly indicates that any effort of unification must centre around ICL."[101] ICL's marketing goal was to expand its exports relative to its production for the home market until the company controlled 10 percent of the world market; exports to the EC countries were slated to become a growing component of its trade.[102]

French policy, set down in the official Plan Calcul agreement signed by CII for the period 1971–1975, required CII to participate in a European cooperation "as soon as possible, and in any case before 1973."[103] CII and the French administration very much hoped that ICL would be its main partner. French journalists dubbed ICL the "most glittering fiancé" for CII.[104] Certainly teaming up with ICL seemed better than competing head to head against it. What was wanted, however, was a cooperation that would guarantee the identity and independence of CII. Maurice Allègre, head of the Plan Calcul, felt the form of the cooperative structure to be so important that he discussed the issue in a major policy speech. He maintained that such a cooperation had to meet the

> double condition that it operates between the major partners in an egalitarian manner and that it does not ultimately result in a loss of [national] control of the key elements of the informatics industry notably by their transfer to foreign territories. . . . The firms composing such a group accept a common conception of their growth strategy, which entails an egalitarian division of responsibility at the levels of research, production, and commercialization, but each one of them conserves its personality while maintaining mastery of the key criteria of its development on its own territory. In this case the national reality remains even as it is integrated into a larger international space.[105]

Allègre's requirement of equality and independence was incompatible with ICL's belief that it should lead any European cooperation. Their dichotomy of perspective made it impossible for the two companies to reach any viable agreement. Within the ICL–CII–CDC cooperation organized in 1970, ICL made it clear that it expected to play the leading role in defining non-IBM standards for the other companies to adopt, despite the fact that CII favored an IBM-compatible policy. Then, within the context of bilateral negotiations between CII and ICL that lasted until July 1971, ICL maintained that CII should simply take up the plans ICL had developed in 1969 for a new series of non-IBM-compatible computers, despite the fact that they would be incompatible with CII's existing equipment.[106] French insistence that CII maintain its participation in all aspects of computer development simply could not be squared with ICL's refusal to abandon its own design plans.

CII's quest for a European cooperation was finally achieved with a different set of partners in the context of a recession that shook the industry between 1970 and 1971. The recession had the effect of pushing first Siemens and then Philips into CII's arms. Prior to 1971, both Siemens and Philips expressed a preference to remain independent. One industry analyst suggested that their preference was rooted in the structure of the two firms: They were electrical giants. Their computer activities were of strategic importance for their other divisions, but they accounted for only a small part of their overall turnover, and hence could be subsidized if necessary by the more profitable divisions.[107] However, the recession (and no doubt also, on another level, the prospect of British entry into the European Community) changed their view. In August 1971, Siemens—which manufactured computers under license from RCA—was left high and dry when the latter, as a result of the recession, abandoned its activities in data processing. Siemens immediately turned to CII to negotiate a cooperation, and by January 1972, the two companies had reached an agreement. At that

point Philips, whose losses had also skyrocketed during the recession, asked to join the new venture. Negotiations were therefore begun anew, but with three partners, they required a further year to complete. The final agreement establishing Unidata was signed on July 4, 1973.[108]

What role did the European Community play in this cooperation? Its role can best be described as one of indirect support. The Commission announced in a policy memorandum on IT that it "welcomed the formation of Unidata."[109] There was talk of helping Unidata through the establishment, under the auspices of the Community, of a European Plan Calcul. It would offer budgetary support along with a preferential Community purchasing policy.[110] The Commission of the EC was also eager to extend the Unidata cooperation to include ICL, and helped to organize joint discussions in Brussels on this issue.[111] However, the EC could not ultimately provide strong or more direct support, for two reasons. First, companies that were not part of the cooperation voiced disapproval of any special terms for Unidata. Second, countries left outside of the cooperation were unwilling to back any form of direct support for it. With unanimous voting still intact, nothing substantial could be done for Unidata at the Community level.

In contrast, Unidata was strongly and directly supported by policymakers at the national level, particularly in France and Germany (less so in the Netherlands). They contributed to the establishment of the cooperation, and they monitored, shepherded, molded, and financially supported it from beginning to end. Indeed throughout its existence, high-level French and German administrators periodically met to discuss and negotiate aspects of its organization and operation. They were likewise involved in the complex process of dissolving Unidata after the cooperation was renounced.[112]

To illustrate the important role national policymakers played in the Unidata cooperation, it is useful to take the example of CII and the French administration. CII was itself the product of a government-engineered merger of several smaller firms, and its very life depended on continued government grants. And since the functioning of CII was a central element of the French Plan Calcul, the company's technical, financial, and commercial affairs were closely monitored by government administrators. Moreover any partnership CII might want to enter had to be approved by the Plan Calcul administration. Under the circumstances, no essential aspect of the Unidata cooperation escaped the watchful eye of Maurice Allègre and his subordinates in the Plan Calcul.

French policymakers were particularly concerned to ensure that their criteria for international cooperation in CDP were not jeopardized. A midterm review of the second Plan Calcul (1971–1975) discussed the problem posed by the alliance between CII and Siemens:

> It is vital for the French [informatics] industry that the balance of force established within this alliance, whether or not it is enlarged by the advent of new partners, is equilibrated in favor of CII. This implies that CII dispose of the technical and financial capacities necessary to participate fully in future proceedings whether this means in the development of new lines of equipment (e.g. large computers) or the reinforcement of commercial networks.[113]

The written agreements that were finally reached—both the preliminary CII-Siemens agreement and the more detailed Unidata agreement of CII, Siemens, and Philips—show that the cooperations were carefully structured to ensure that the criteria set down by Maurice Allègre were indeed met.

The structure of the CII-Siemens cooperation was a direct analog of the structure of the EC, as modified by De Gaulle through the Empty Chair Crisis. First, direction of the joint venture was assured by a Standing Council in which Siemens and CII were equally represented, just as the countries were equally represented within the Council of Ministers. And analogous to the post-De Gaulle Council of Ministers, Standing Council decisions had to be taken unanimously. Also as in the EC, where the Council presidency rotated among the Member States, chairmanship of the CII-Siemens Council alternated between the two companies. And finally, all agreements with third parties had to be reviewed and approved by the Standing Council, just as all trade and membership agreements involving third countries had to be reviewed and approved by the Council of Ministers in the EC.[114]

The structure of Unidata followed the same model, although in a slightly more complex form. At the summit of Unidata was the Shareholder's Council, with equal representation from each member company, and a rotating chairmanship. Decisions were taken only on the basis of unanimous consent. The Shareholders' Council took decisions on fundamental issues of strategy and policy, on all relations with third parties, and on matters unresolvable at lower levels.[115] If cases of ultimate inability fail to reach agreement, the Unidata agreement provided for the establishment of an "Arbitral Tribunal," a kind of "Court of Justice" for the consortium. Each member company would appoint one arbitrator, and the three arbitrators would in turn appoint a fourth, to preside and cast tie-breaking votes. The fourth arbitrator had to be "a member of the legal profession," had to have "a nationality other than French, Dutch, or German," had to be a resident of an EEC or EFTA country, and had to "be fluent in the English language." These requirements show how assiduously the member companies sought to preclude any possible dominance of one company or country over another.[116]

One step below the Shareholders' Council was the Board of Management. Its structure replicated that of the Shareholders' Council: Equal representation (consisting of the three managers of the data processing divisions of the three member companies) and decisions by unanimity. Meetings of the Board of Management rotated among the home headquarters of the three managers.

Other aspects of the Unidata agreement reveal that it carefully sought to safeguard the broad technical and commercial competences of the member companies. The agreement outlined a new family of 6 computers (X_0 to X_5) to be developed according to common standards so as to achieve inter-compatibility and joint compatibility with previous product lines of the companies. Each company was assigned to develop specific computers in the family in a way that ensured that CII and Siemens would both get a smaller and a larger computer to develop. Philips was to build the smallest computer, X_0, along with a separate, parallel family of small office systems. CII was to develop the two largest computers (X_4 and X_5) and a smaller computer, X_2. Siemens was to build the X_1 and the X_3.[117]

Regarding the commercial side of the agreement, each country was to maintain financial and administrative control of the sales centers on its own territory. (This involved CII taking over Siemens' sales centers in France, and vice versa for Germany.) In the case of the Netherlands, control of the sales centers was shared with Siemens according to a separate agreement in return for the right of Philips to maintain distinct sales centers for its small office equipment in France and Germany. In outside countries, agreements were initiated to develop unified, common sales centers under joint Unidata management. Finally, with regard to finance, Unidata's profits were not simply pooled and split. Instead, a complex system of transfer pricing was set down, so that each parent company would achieve profit on the computers and equipment it transferred to the other member companies or to the sales centers. Further profits accruing to the sales centers were split according to each member's level of participation in the sales center.[118]

In sum, the Unidata agreement was primarily intended to achieve a careful partitioning of products and markets among the three companies—in order to maintain their independence and their technical and commercial capabilities—rather than to achieve overall economic efficiency in a pan-European operation. To underscore this crucial point it is useful to draw a comparison with IBM in Europe. IBM integrated its operations Europe-wide, which meant that the laboratories and factories in particular countries specialized in a given area of research or production: "The advantages IBM derives from mass production are only possible in so far as the whole range of parts needed in a computer system are not produced by one and the same country. International labor division between the various national companies in Europe [e.g. IBM France, IBM Germany] is what makes rational and competitive production possible."[119]

As an example, an IBM factory in Mainz manufactured the 360/25 and 360/30 computers, using parts shipped in from other factories around Europe. This factory produced the entire worldwide supply of these models except those for the US market. IBM research was similarly specialized and dispersed. An IBM laboratory in Holland specialized in "paper manipulation and identification of characters" while a French lab specialized in long distance data transmission. A German IBM lab specialized in the development of small and medium-sized computers, while the IBM lab in Hursley, Britain concentrated on larger models. In contrast, the Unidata agreement deliberately avoided this degree of specialization.[120]

Despite its cumbersome organization, however, Unidata did work (just as the unwieldy European Community has also worked). The Board of Management set up financial, economic, commercial, and technical committees, and these committees established sales organizations in countries around the world, worked out the technical specifications of the common line of computers, developed an official company identity, built up a marketing plan (which stressed the company's European vision), and struggled with numerous legal, administrative, and economic hurdles (e.g. exchange rate and transfer pricing problems, development of a unified accounting system).[121] In the process of working together, a common identity and esprit de corps began to emerge. Many of the engineers and managers who worked in

Unidata became deeply committed to the venture, including CII's director, Michel Barré.[122] The viability of the technical side of the cooperation can be seen in the fact that the X-series designs became the basis for Siemens' subsequent, commercially successful computer line.

By May of 1975, however, the cooperation was dead. The reasons are complex (and beyond the scope of this chapter). But they did not mainly stem from problems within the cooperation. Rather they stemmed above all from developments in the broader political, economic, legal, and commercial contexts within which the consortium functioned. The key factors in the collapse of Unidata included changing government policies in Germany and France, particularly the latter; strong disapproval of Unidata by one of CII's mother companies, CGE; sectoral developments that affected rival companies in Germany and France and that impinged on the Unidata cooperation; and perceptions that Unidata threatened national companies in related domains like telecommunications. A change of government in France after the death of Pompidou in 1974 also played a central role because it affected the government's financial support of CII and hence its ability to function in the cooperation.[123] When the end came, many felt it marked the end of an era: "the Europe of informatics" and the days of Europe's "cooperation in grand style in the domain of computers" were gone.[124]

Conclusion

Unidata grew out of or reflected European IT policy in three fundamental ways. First, the creation of European-level organizations like the Council of Europe and the EEC—and their growing concern during the 1960s with industrial policy issues—helped to bring firms and national technology policy organizations together. It helped them to begin functioning as an integrated international community. National statistics on technology policy issues began to be collected by the EEC and the OECD, following common criteria. National policymakers began to meet their counterparts from other states on a regular basis within PREST, within Commission committees (e.g. on competition), and within the EC's Council of Ministers, not to mention numerous other contexts. Through a rich and growing network of associations and exchanges of industrial policy ideas, both firms and national administrations began to develop common perspectives on Europe's "technology gap" and how best to overcome it. Within PREST, for example, national policy ideas were transferred to the European level and vice versa. We saw in particular that PREST's large computer initiative grew out of French national policy, and further, that France adopted an internationalist, European perspective in its *national* policymaking, to the extent of formally requesting CII to establish a technological cooperation with one or more European partners.

Second, the Unidata consortium reflected ideas and concerns relating to Britain's entry into the European Community. The debates surrounding Britain's 1967 application to the EC, which focused extensively on technology policy concerns (e.g. the gap with America and the need to structure a coherent European Technological

Community) helped to create a sense of crisis and a new momentum in the realm of IT policy. It was in this period that a belief in the necessity of regrouping the European computer industry came to predominate. This mindset did much to encourage and legitimize the establishment of Unidata. More immediately, after 1970, the knowledge that Britain would soon enter the community raised concerns among continental firms and policymakers about the potential threat of ICL. This fear, together with the impact of the 1970–1971 recession, also pushed CII and its partners toward the formation of Unidata.

Finally, the political history of the European Community had a profound influence on the structure of Unidata. The structure of Unidata reflected the political choices that had been made within the European Community: Voting by unanimity rather than by qualified majority; Council control of the committees that made or reviewed scientific and technological research policies (e.g. PREST and its subcommittees); maintenance of national control of support funds for SRI and CDP; and an emphasis on maintaining the equality and independence of the Member States. Unidata reflected these political choices in two ways. First, in a positive sense, this form of organization was deliberately reproduced within the consortium. And second, in a negative sense, this form of organization represented the only kind of cooperation that could realistically emerge given the political characteristics of the European Community in that period. The Council's refusal to permit the Commission to have an independent budget to support informatics research; its refusal to adopt a Community-wide public purchasing policy; its reluctance to establish a viable European company law; its failure to promote the establishment of European-wide standards; the crises that rocked the Community during this period and entirely shut down the PREST on two occasions—all of these factors made any European-level consolidation or development of the computer industry entirely dependent on the support of *national* policy administrations. In this sense, Unidata was very much the product of the bifurcation of European technology policy that had occurred by 1970.

Unidata embodied the characteristics of a policy approach that was built on an uneasy balance between nationalism and internationalism. Its goal was internationalist in spirit, but the measures taken to achieve this goal were all designed to preserve national sovereignty in data processing. Not until the fundamental political reorganization of the EC in the 1980s did a different kind of European IT policy emerge—and with less nationalistic forms of technological cooperation.

Notes

1. See Wayne Sandholz, *High-Tech Europe: The Politics of International Cooperation*, Berkeley, University of California Press, 1992; John Peterson, *High Technology and the Competition State: An Analysis of the Eureka Initiative*, London, International Thomson Publishing, 1993; Margaret Sharp and Claire Shearman, *European Technological Collaboration*, London, Council on Foreign Relations Press, 1987; Margaret Sharp, "The Single Market and European Technology Policies," in *Technology and the Future of Europe*, London, Thomson

Learning, 1991, pp. 59–76; Luca Guzzetti, *A Brief History of European Union Research Policy*, Luxembourg, European Commission, 1995.

2. European Economic Community, *Treaty establishing the European Economic Community and Connected Documents*, n.p., 1961, p. 17.
3. Ibid., pp. 135–137; Desmond Dinan, *Ever Closer Union? An Introduction to the European Community*, 2nd edn., Boulder, Lynne Rienner, 1999.
4. *Treaty establishing the European Economic Community*, passim; Dinan, op. cit.
5. DeGaulle, among others, held this view of the Commission. In one of his press conferences, concerning the Common Market's agricultural policy, he explained that "in this vast undertaking, all the decisions taken were taken by the Governments, for nowhere else is there any authority or responsibility. But I should say that, in order to prepare and clarify matters, the Brussels Commission worked in a highly objective and pertinent fashion." Quoted from Miriam Camps, *Britain and the European Community, 1955–1963*, London, Oxford University Press, 1964, p. 478. See also Charles de Gaulle, *Memoirs of Hope: Renewal and Endeavor*, trans. Terence Kilmartin, New York, Simon and Schuster, 1971, pp. 183–185.
6. See, for example, Commission of the European Communities, *Industrial Policy in the Community: Memorandum from the Commission to the Council*, Brussels, 1970.
7. Dinan, op. cit., passim; Jeremy Richardson, ed., *European Union: Power and Policy-Making*, London, Routledge, 1996; Pierre Gerbet, *La construction de l'Europe*, Paris, Imprimerie nationale Éditions, 1994, p. 270.
8. Commission of the European Economic Community, *Dixième rapport générale sur l'activité de la Communauté*, Brussels, June 1967, p. 194.
9. The issue of the creation of a European company law can be traced through the annual reports of the European Commission as well as through its various reports and memoranda on industrial policy.
10. Commission of the European Communities, op. cit., pp. 142–145.
11. Ibid., pp. 357–373; Commission of the European Communities, 'Community Policy on Data Processing: Communication of the Commission to the Council,' SEC (73) 4300 final, Brussels, 21 November 1973; "Memorandum from the Commission on the Technological and Industrial Policy Programme," *Bulletin of the European Communities*, Supplement 7/73: May 7, 1973.
12. Commission of the European Economic Community, *Quatrième rapport général sur l'activité de la Communauté (du 16 mai 1960 au 30 avril 1961)*, Brussels, 1961; Commission of the European Economic Community, *Cinquième rapport général sur l'activité de la Communauté (du 1 mai 1961 au 30 avril 1962)*, Brussels, 1962; Commission of the European Economic Community, *Sixième rapport général sur l'activité de la Communauté (du 1 mai 1962 au 30 avril 1963)*, Brussels, 1963; *Septième rapport général sur l'activité de la Communauté (du 1 mai 1963 au 30 avril 1964)*, Brussels, 1964.
13. Commission, *Rapport général*, 1964, pp. 416–419. See also Luca Guzzetti, *A Brief History of European Union Research Policy*, Luxembourg, European Commission, 1995.
14. PREST is the French acronym for the group, whose official title was "Groupe de la politique de la recherche scientifique et technique." The French acronym is used by English writers as well.
15. Commission of the European Economic Community, *Huitième rapport général sur l'activité de la Communauté*, Brussels, June 1965, pp. 296–297; *Neuvième rapport général sur l'activité de la Communauté*, 1966, p. 285.
16. Guzzetti, op. cit., pp. 39–40; Commission, *Rapport général*, 1965, p. 296; *Rapport général*, 1966, pp. 285–287.

17. Commission, *Rapport général*, 1964, p. 414.
18. Commission, *Rapport général*, 1965, p. 296.
19. Ibid., 1964, p. 414.
20. Although the Kennedy round of negotiations did not achieve tariff cuts as steep as had been originally envisioned, it did produce "the largest tariff cuts in modern history," averaging 35%. See Richard T. Griffiths, "The European Integration Experience," in Keith Middlemas, ed., *Orchestrating Europe: The Informal Politics of European Union*, London, 1973–1995, Fontana Press, 1995, p. 49. See also Pierre Gerbet, *La construction de l'Europe*, Paris, Imprimerie nationale Éditions, 1994, pp. 250–269; Herman van der Wee, *Prosperity and Upheaval: The World Economy, 1945–1980*, Harmondsworth, Middlesex, Penguin Books, 1986, pp. 382–386.
21. L. Radoux, "Extension of European Scientific and Technological Co-operation: Methods, Aims and Structures," Committee on Science and Technology, Council of Europe, Strasbourg, Council of Europe Archives, AS/Science (19) 45, p. 5.
22. The EEC Commission repeatedly cited the GATT Kennedy round as a major stimulus for its interest in SRI policy. See Commission of the European Communities, *Industrial Policy and the European Community*, Brussels, 1973.
23. Edward A. Kolodziej, *French International Policy under De Gaulle and Pompidou: The Politics of Grandeur*, Ithaca, Cornell University Press, 1974; Charles Williams, *The Last Great Frenchman: A Life of General De Gaulle*, New York, John Wiley, 1993; Jean Lacouture, *De Gaulle: The Ruler 1945–1970*, trans. Alan Sheridan, New York, W.W. Norton, 1991; Tony Benn, *Out of the Wilderness: Diaries 1963–1967* London, Random House, 1987, pp. 502–503.
24. Georges Vieillard, *L'affaire Bull*, Paris, L'Imprimerie S.P.A.G, 1969.
25. Commission des Communautés Européennes, *Premier rapport général sur l'activité des Communautés en 1967*, Brussels, February 1968, pp. 310–315.
26. Gerbet, op. cit., pp. 269–284; Commission, *Rapport général*, 1966, p. 287; *Dixième rapport général sur l'activité de la Communauté*, 1967, pp. 286–287.
27. Gerbet, op. cit., pp. 269–284.
28. Ibid.
29. Kuhn de Chizelle, "Situation de l'industrie électronique; projet d'avis," Conseil Économique et Social, Section de la prodution industrielle, AK/NP 278/Sec 9/26; Kuhn de Chizelle, "Situation de l'industrie électronique française; projet de rapport," Conseil Économique et Social, Section de la production industrielle, AK/RD 278/Sec 9/26.
30. Bilan du Plan Calcul, 1966–1973, internal document, Délégation à l'informatique. I would like to thank Pierre Audoin for providing me with a copy of this document.
31. "Förderung der Datenverarbeitung," Bundesministerium für Wissenschaftliche Forschung Pressedienst, Nummer 8/67, 17 Mai 1967, pp. 73–74.
32. Arbeitsunterlage der Dienststellen der Kommission für die multilaterale Sitzung betreffend Beihilfemaßnahmen im Bereich der elektronischen Datenverarbeitung, Europaische Wirtschaftsgemeinschaft, Kommission, Generaldirektion für Wettbewerb, 11 Juli 1967, Deutsches Bundesarchiv Koblenz. It is worth noting that these support programs emerged at the very time that the GATT Kennedy round tariff reduction negotiations were nearing completion. The GATT agreement was signed in 1967.
33. "Problèmes de l'industrie électronique," report prepared by PREST, December 1966.
34. op. cit., notes 29–32.
35. Deutsche Bundesarchiv Koblenz, B138, No. 7680.

36. Council of Europe Assembly, 19th Session, Debates, Vol. III, 29 January 1968, p. 597.
37. Ibid., Second Part, Vol. II, 26 September 1967, p. 375.
38. OECD, *Electronic Computers: Gaps in Technology*, Paris, 1969, pp. 3–6.
39. Bourgoin, "Draft Report on the 3rd Ministeral Meeting on Science," Committee on Science and Technology, Council of Europe, 12 September 1968, Strasbourg, Archives of the Council of Europe, AS/Science (20) 5; Anthony Sampson, *Anatomy of Europe*, New York, Harper & Row, 1968, p. 162.
40. Commission, *Rapport général*, 1967, pp. 284–285; Sampson, op. cit., p. 162; "Science Policy of the European Communities," Information Document, Committee on Science and Technology, 6 November 1967, Strasbourg, Archives of the Council of Europe, AS/Science (19) INF. 7.
41. Arthur Schlesinger, Jr. "Foreward," in J.-J. Servan-Schreiber, *The American Challenge*, trans. Ronald Steel, New York, Atheneum House, 1968, p. vii.
42. O. Reverdin, "More efficient co-operation in the field of science and technology and the extension of the European Communities," Committee on Science and Technology, Council of Europe, Consultative Assembly, 30 August 1967, Strasbourg, Archives of the Council of Europe, AS/Science (19) 29, p. i.
43. Council of Europe Consultative Assembly, 18th Ordinary Session, Part 1, Official Report of Debates, Vol. I, 5 May 1966, pp. 190–197. See also O. Reverdin, op. cit., 1967.
44. Council of Europe Consultative Assembly, 18th Ordinary Session, Part 2, Offical Report of Debates, Vol. II, 28 September 1966, pp. 472–475.
45. Quoted from Harold Wilson, *A Personal Record: The Labor Government, 1964–1970*, London: Weidenfeld and Nicolson, 1971, p. 334. An excellent and readable account of Wilson's application to the European Community and indeed of the entire history of Britain's relationship with the European Community is Hugo Young, *This Blessed Plot: Britain and Europe from Churchill to Blair*, Woodstock, Overlook Press, 1999.
46. Ibid., pp. 334–341.
47. Cecil King, *The Cecil King Diary*, London, Jonathan Cape, 1972, p. 113.
48. Council of Europe Assembly, 19th Session, Debates, Vol. II, 26 September 1967, Speech by Lord Chalfont, pp. 398–408; Vol. III, 29 January 1968; Speech by Wedgwood Benn, pp. 593–597; Western European Union Assembly, General Affairs Committee, 14th Ordinary Session, The British application for membership of the European Communities, 1963–1968, May 1968.
49. Tony Benn, op. cit., 1987, p. 503.
50. Council of Europe Assembly, 19th Session, Debates, Vol. II, 26 September 1967, p. 375.
51. Ibid., pp. 401, 403, 405.
52. Ibid., 1968, Vol. III, 29 January 1968, p. 613.
53. Ibid., p. 606; Campaign for Europe Movement, "A European Policy for Britain," reprinted in Assembly of the WEU, 14th Ordinary Session, Part 2, February 1969, III, Assembly Documents, p. 92.
54. Council of Europe Assembly, 19th Session, Debates, Vol. II, 26 September 1967, p. 377.
55. Ibid., Part 3, Vol. III, 29 January 1968, p. 599.
56. Fifteenth Joint Meeting of the Members of the Consultative Assembly of the Council of Europe and of the Members of the European Parliament, Strasbourg, 27 and 28 September 1968, Official Report of Debates, pp. 19–20.
57. The importance ascribed to the computer in the technology gap debate can be seen by the fact that the first study commissioned by the EEC's PREST concerned this sector. Likewise, the first study commissioned by the Science and Technology

Committee of the Council of Europe was on the computer industry. Virtually every commentator included the computer industry as one of the key domains affected by the technology gap.

58. Council of Europe Assembly, 19th Session, Debates, Vol. III, 28 January 1968, p. 601.
59. WEU, op. cit., 1968, The British application for membership of the European Communities, Speech by Mr. Wilson, United Kingdom Prime Minister, to the Confederation of British Industries, London, May 17, 1967, p. 58.
60. Council of Europe Consultative Assembly, Committee on Science and Technology, Extension of European scientific and technological co-operation: Methods, aims and structures, Strasbourg, 12 January 1968, Council of Europe Archives, AS/Science (19)45, p. 19.
61. George Brown, *In My Way: The Political Memoirs of Lord George-Brown*, New York, St. Martin's Press, 1970, p. 212.
62. Council of Europe Assembly, 19th Session, Debates, Vol. III, 29 January 1968, p. 596.
63. See Tony Benn, *Office without Power: Diaries 1968–1972*, London, Hutchinson, 1988, pp. 74, 79.
64. Ibid., p. 42.
65. WEU Assembly, Proceedings, 14th Ordinary Session, Part I, October 1968, Assembly Documents, Document 443, Prospects of scientific and technical cooperation, p. 97–98; Committee on Science and Technology, Minutes of Meeting of 2 September 1968, Strasbourg, Archives of the Council of Europe, AS/Science (20) PV 2, p. 5; John Krige and Arturo Russo, *Europe in Space, 1960–1973*, Noordwijk, European Space Agency, 1994, pp. 74–81.
66. Benn, op. cit., pp. 4, 5, 7–8, 96.
67. Keith Hayward, "Politics and European Aerospace Collaboration: The A300 Airbus," *Journal of Common Market Studies*, 14(4): 354–367, June 1976.
68. WEU Assembly, Proceedings, 14th Ordinary Session, Part I, October 1968, Assembly Documents, Document 443, Prospects of scientific and technical cooperation, p. 98.
69. Commission des Communautés Européennes, Deuxième rapport général sur l'activité des Communautés, Brussels, European Commission, 1969, pp. 210–213; Guzzetti, op. cit., 1995, p. 40.
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10

ESPRIT: Europe's Response to US and Japanese Domination in Information Technology

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Introduction

Established in 1983, the European Strategic Program for Research in Information Technologies (ESPRIT) is the oldest of the European Commission's research and technology development (RTD) programs. It is also the largest and has been a model for all the Commission's other RTD programs. ESPRIT arose from the fear that Europe was lagging far behind the United States and Japan in vital information technologies (IT).[1] Collaboration, rather than competition, among Europe's IT companies, it was imagined would yield synergies, the flexibility to adapt in volatile markets, and the shorter product cycles essential to international competitiveness.[2] The complementary notion of precompetitive research allowed the Commission to subsidize RTD while avoiding the accusation of interfering in the market.[3] The collaboration of ESPRIT has attracted considerable academic attention,[4] whatever ESPRIT's success in encouraging innovation, it has become a classic in innovation policy.

ESPRIT in the 1980s was very much the child of the large firms of the European IT industry, the Big Twelve. Some would argue that ESPRIT was still fulfilling their requirements in the late 1990s, when a much broader range of stakeholders was involved in building the emerging information and knowledge societies. Over the years, the Commission has attempted to transform ESPRIT by encouraging the participation of firms from Europe's less developed regions, of small- and medium-size firms from across the European Union, and lately of stakeholders from throughout the IT supply chain, including users from a broad range of institutional settings. Even so, ESPRIT stands accused of retaining its technology-driven approach to IT, not necessarily because this produces more innovation and greater competitiveness, but because of the political advantages offered by the doctrine of collaboration.[5]

The purpose of this chapter is to explore the significance of external linkages for innovation in ESPRIT in the light of the reality of collaboration. The empirical data focuses on ten ESPRIT projects, examined as case studies. Particular attention

is given to the informal networks that link members of ESPRIT projects to the most dynamic parts of the IT world in the United States and beyond. How do these function in the midst of collaboration and the formal networks it imposes?[6] Formal networks are defined as those which are bound by a formal contract between the Commission and project partners. In contrast, informal networks include many unacknowledged partners acquired through interpersonal links that transcend formal agreements.[7] As in other fast developing industries, informal relationships in the IT sector seem to bring the tacit information that is conducive to innovation.[8]

The rest of the chapter is in five sections. In the first section, a brief history of ESPRIT is provided, examining the changes that have taken place within the program to encourage collaboration and innovation in European IT industry. The second section considers the European interpretation of the US and Japanese threat, and the third section describes our research methodology. The fourth section presents the main findings, based on the ten ESPRIT projects, and discusses in some detail the role of external links for collaboration and innovation in two illustrative cases from the world of electronic commerce in the late 1990s. The final section draws some conclusions.

Continuity, Transformation, and Change

In the early 1980s, European firms had begun to realize that their technology was lagging in such core high-technology areas as IT and some had already begun to collaborate.[9] Policymakers were becoming increasingly concerned about the gradual loss of competitiveness they perceived in the European economy and in the European IT industry in particular. The globalization of high-technology industries,[10] and the wide disparities between industrial and technological capabilities of the various country members revealed by the continuing expansion of the European Union (especially evident in the divide between the wealthy countries of the European North and the poor countries of the European South) further reinforced this perception.[11] Moreover, policymakers on both sides of the Atlantic had become very enthusiastic about "Japanese-style" collaborative research and the perceived success of *keiretsu*.[12]

European industry generally was beginning to show much more interest in collaborating in research and development (R&D), previously an activity conducted secretly and independent of competitors' R&D.[13] According to Narula, the underlying objective of the Framework Programs of the European Commission was not to encourage collaboration per se. Rather, it was to encourage collaboration in the run-up to the single European market in 1992. Collaboration would allow EU industry to restructure and be better able to face the competitive environment of the single market. It was hardly surprising, then, that collaborative R&D became central to Commission policy in the early 1980s,[14] and thus that collaboration became central to ESPRIT. In 1981, the Commission suggested that the Big Twelve take a concerted approach to IT, and invited their collaboration in drawing up

a common strategy.[15] Following the launch of a small pilot program in 1983, ESPRIT proper was started in 1984. There have now been four phases of ESPRIT research (ESPRIT I: 1984–1987, ESPRIT II: 1987–1990, ESPRIT III: 1990–1994, and ESPRIT IV: 1994–1998), all jointly funded by the Commission and the participating organizations. The Fifth Framework Program (1998–2002) initiated the Information Society Technology (IST) Program, placing all European Commission information and communication technologies (ICT) research under one umbrella program.

The early ESPRIT was very much driven by the belief that collaboration among industry, universities, and public research institutes across Europe was an effective means of narrowing what was perceived as a technological gap between European companies and their American and Japanese competitors.[16] As Mytelka and Delapierre point out, collaboration among European firms was more attractive than alliances with non-European firms because it was thought to involve less risk and to enable firms to take advantage of economies of scale in one or more of their production processes while remaining separate entities.[17]

Over the last decade, ESPRIT has been through vast changes in its organization and scope.[18] The European Commission has responded to new trends in the collaborative behavior of the IT industry by, for example, expanding ESPRIT participation, encouraging collaboration throughout the IT value chain, and increasing emphasis on the users of IT. Some of these developments are summarized in Table 10.1. Despite these alterations in emphasis, many of the characteristics of the early ESPRIT were evident until the conclusion of the Program in 1999.

Table 10.1. *Summary of changes in ESPRIT and IST programs from the early 1980s to the early 2000s*

Dimension	ESPRIT (1983–1998)	IST (1998–2003)
Participants in collaboration	Dominance of electronic firms, IT suppliers, and participants from northern Europe as well as less favored regions	A heterogeneous group of organizations representing the entire IT value chain and including small- and medium-sized enterprises and user organizations
Nature of collaboration	Precompetitive	Collaboration in competition
Focus of collaboration	Hard science	Soft science (emphasis on socioeconomic research)
Organization of collaboration	Research project	Research clusters and networks
Role in the broader community	Inward oriented, isolated	Outward oriented, integrated

For example, ESPRIT always insisted that the research it supported be collaborative in nature, specifically that there had to be a minimum collaboration in each project of two partner organizations from two EU member countries.

The early ESPRIT was also determinedly precompetitive, focusing on research that was considered to be distant from the individual market interests of collaborators. The notion of precompetitive research provided a convenient label for the activity undertaken within collaboration, one acceptable to the free market ideology of most European governments of the period.[19] It was argued that collaboration in precompetitive research did not constitute government interference with market forces, and fitted comfortably within a technology-push model of innovation.[20] However, sweeping changes in the IT industry, together with improved understanding of how innovation is generated, have encouraged ESPRIT to change its emphasis from technology-push to market-pull. This has required abandoning the idea that partners can collaborate only when they are being precompetitive. It has been accepted that they may also collaborate when they are cooperating in competition. Indeed, the success of the IST Program is dependent on the willingness and ability of partners to collaborate in competitive circumstances.

The early ESPRIT was dominated by the rigid conviction that innovation emanated, quite obviously, from science and engineering. Just as the model of innovation within ESPRIT has changed from technology-push to market-pull, ESPRIT research is no longer confined to science and engineering and now includes at least some social science research. The IST Program acknowledges that socioeconomic research cannot be isolated to a single domain, but must underpin all its IT research. In consequence, the IST Program cannot be accused of fostering innovation intended to benefit only the suppliers of IT equipment: IST innovation is now directed towards all users of IT. It has been accepted that European competitiveness in IT depends not so much on increasing IT research capital as on increasing social capital. There is now no part of the economy which is not heavily dependent on IT.

The research consortium—termed the "project" by the Commission—has long been the primary unit of ESPRIT organization. The project has often seemed to be the only unit. All Commission organization was centered on the project, as was most monitoring and evaluation. In 16 years (1983–1998), some 2250 ESPRIT projects have been completed or are now nearing completion, and more than €5.5 billion has been spent.[21] The project officer—the key Commission official—tended to regard projects as self-contained, to be completed within a specific time frame as specified by a formal contractual agreement.

The changes that ESPRIT has undergone in terms of participation, focus, organization, and orientation were responses to particular trends and developments in the IT sector, and more general shifts in the competitive environment. Throughout the history of ESPRIT, the main objective of the Commission has been to create and sustain a fertile platform for collaboration and innovation. However, it is difficult, perhaps impossible, to confine collaboration and to harness innovation by restricting them to a single geographical region, even one with all the resources of Europe. More important, it may be pointless.

Europe's Response to the Competition

It is important to bear in mind the nature of the times of which ESPRIT was so very much a product. By the early 1980s, the importance of what had come to be called the "microelectronics revolution" was evident, and not just in terms of the technological innovation that helped make the electronics firms themselves more competitive. The application of the transistor and then the integrated circuit in computing and in telecommunications had begun to transform product and process in virtually all industries, and consequently the competitiveness of all was increasingly seen to be dependent on the new technology. The white heat of the technological revolution that Harold Wilson declared would transform the economy in the United Kingdom was to be generated largely by microelectronics. But to recognize the impact of microelectronics was not to contain the impact. There would be implications, socioeconomic implications, and uncertainty about what these might be, what they might affect, and when, caused considerable concern. In such a climate, fear flourished. For example, the adoption of computing equipment was generally perceived to result in the loss of many jobs and in the de-skilling of others. Inevitably, microelectronics assumed a political importance that extended far beyond its economic role. Microelectronics came to symbolize the future to an extent than other technologies could not even begin to emulate—and, of course, with some justification.

Microelectronics, then, could not help but command political attention. Governments in most developed countries were compelled to calm fears of the disruption the new technology would cause. This presented a minor challenge, but where there is challenge there is also opportunity and microelectronics offered a major opportunity of the sort that is attractive to politicians and policymakers. By the early 1980s, it was common practice to perceive microelectronics as but one—although certainly a major one—of a series of new and related technologies considered collectively as "high technology." The benefits of high technology were reckoned to be immense, far outweighing its costs. So, even if some jobs were lost and others de-skilled, new jobs would be created and of a very superior sort. And if high technology sounded the death knell of the old smokestack industries, it brought shiny new ones in their place. The political advantage of being able to bring about such social and economic benefits was not lost on governments, and everywhere they sought to become involved with high technology. Their recent determination to be associated with the Internet and with electronic commerce is not dissimilar.[22]

This presented something of a problem in that the United States, and Silicon Valley in particular, provided the outstanding example of successful innovation in microelectronics.[23] Government intervention had played little part in this success. Consequently, governments elsewhere, desperate to be associated with high technology, could hardly just copy the role played by the US government. They could, though, assist in replicating elsewhere, conditions apparently conducive to high technology that had developed in the United States in the absence of government

intervention. Governments are not naturally equipped to create market conditions and the potential for muddle and mistake is great. The science park phenomenon illustrates this nicely.

Hundreds of science parks, perhaps thousands by now, were created in the developed world in imitation of Silicon Valley, or rather of an understanding of Silicon Valley that fitted the preconceptions and requirements of governments anxious to encourage high technology. The essence of Silicon Valley, on which its innovation is dependent, is the flow of information through information exchange among individuals, often in defiance of organization, system, and control. It is an informal world of high mobility and throbbing information networks, not the sort of world to be readily re-created in distant lands by distant governments. So, these governments chose to perceive a different sort of Silicon Valley altogether, one which better fitted their requirements,[24] the chief of which was to be able to establish centers of high-technology activity anywhere, instantly and cheaply. Government rhetoric depicted a model of high technology unbounded by the physical constraints of old technology and demanding only knowledge to thrive. It followed that a center of high technology could be placed wherever there was knowledge, despite the absence of anything else. A university was perfect and would provide the information for local entrepreneurs to turn into innovation. History was reinterpreted to present Stanford as just such a university, Silicon Valley as its science park, and such firms as Hewlett Packard as its tenants.

Of course, this fabrication was supported by more than just government convenience. The notion of information being an organizational resource like any other, to be bought and sold like any other organizational resource, is not only compatible with the sort of systems governments can encourage, but also confirms the value of these systems. Established interests are also keen to support the fabrication. Universities, academic scientists, and engineers are not averse to confirmation of their seminal role in innovation, providing the seed from which innovation sprouts. Industry and its managers like to believe that they play the major part in what they construe as a process, an innovation process that can be controlled and managed. Administrators generally value the notion of innovation as a process in that they can justify input in terms of output. The irony, of course, was that this understanding of how Silicon Valley works is just about the opposite of the creative, constructive chaos which is really responsible for its innovation.

Similarly, the advantages of applying an organizational model of innovation are evident in the strengthening of the patent system since the early 1980s. The patent provides a means by which the information of invention is protected, and a means by which this information is disseminated. The innovation on which competitiveness depends is now seen to emanate from the former rather than from the latter, to the huge advantage of those organizations and those nations with the resources to develop their own inventions.[25] And again, it was political exploitation of high technology as being critical to US competitiveness and hence to US national security that permitted the extraordinary attempts of the United States throughout the 1980 to prevent the flow of high-technology information from the West to the

Soviet bloc, attempts which were readily extended to preventing its flow to western competitors, especially the Europeans and the Japanese.[26] Perversely, a system intended to ensure that US industry remained innovative and competitive probably had the opposite effect in restricting the information flow essential for innovation.

The nub of the problem is that much information for innovation in high technology flows by informal means, in personal networks, by means of information exchange among individuals.[27] This reality is hard to incorporate in government policy and programs for innovation. In direct contrast, high technology as a malleable construct that can be shaped around existing systems, high technology as myth, immune from testing, is so politically irresistable that its exclusion from government policy and programs is well nigh impossible—despite the possibility of damage to innovation and competitiveness. Thus, the United States in the 1980s persisted in the Sematech venture, designed to encourage US microelectronics firms to collaborate in innovation, long after the deficiencies in this particular model of innovation—especially the restriction of membership to a few old and established firms—were exposed.[28] Sematech was justified on the grounds that microelectronics had become essential to innovation and competitiveness generally,[29] but these very same forces had created a global industry in which the entire world was involved. The United States and Silicon Valley may have led the way, but by the 1980s even they could not innovate effectively in isolation. Similarly, the Alvey Program in the United Kingdom, again based on the notion that governments could orchestrate the collaboration that would generate innovation in IT,[30] probably undermined the innovation of those firms excluded from collaboration.[31] Government intervention was not always behind collaborative RTD. In 1982, for example, some American microelectronics firms chose to form their own collaboration in the Microelectronics and Computer Technology Corporation (MCC), with a pooled staff of about 300, all working together in Austin, Texas.[32] A reaction to Japanese competition rather than an emulation of European policy, the MCC, and other groupings formed in imitation of the MCC,[33] survived rather than prospered.

There was, of course, no doubting the competitive advantage US and Japanese firms held in microelectronics. European governments might console themselves with the appreciation that the advantage of the former had come about through the country's head start, and that they might erode this lead by replicating in Europe the circumstances under which high technology flourished in the United States—a case of policy making up for the European market's failure to act as the US market had done. But the Japanese case offered no possibility of such consolation; there was certainly no way that a Japanese environment could be re-created in Europe. Or was there? European policymakers allowed themselves to become convinced that the Japanese had become so successful in microelectronics because the Ministry of International Trade and Industry (MITI) had engineered the coordination of government, industry, and universities to be innovative in microelectronics. Indeed, when ESPRIT was launched, the Commission had grand ambitions to be a European MITI.[34] The Fifth Generation Computer Program was trumpeted by

the Japanese to European governments already convinced that innovation in microelectronics came through collaboration and that collaboration could be arranged by government.[35] That Japanese coordination was as much a product of Japanese culture as of the efforts of MITI, and that this coordination was deeply dependent on personal links and obligations, were conveniently overlooked, much as the reality of Silicon Valley was disregarded.[36] In a similar way, the absence of cultural context has not prevented the wholesale adoption in Europe of Japanese management methods.

So, Europe, and especially the European Commission, imported from Japan the notion that formal collaboration arranged by government was essential for innovation and hence for competitiveness in microelectronics, and from the US evidence of the conditions required for high-technology industry. It was clear that government in Europe had to do something for microelectronics, and equally clear that misconstruing both the Japanese and the US model permitted considerable latitude.[37] The Big Twelve, for example, the firms that dominated the European Electronics industry and that were to dominate the early ESPRIT, could be portrayed not simply as socially and economically integrated in the Japanese fashion, but also as enterprising and entrepreneurial in the Californian way. The collaboration of ESPRIT might seem very different from the personal information networks of Silicon Valley, but in the context of the scramble by governments everywhere for association with high technology, and in the absence of the need for any appreciation of how high technology really works, formal collaboration in precompetitive research was quite acceptable.

Research Methodology

The sample for this research involved all sixty-seven ESPRIT projects with UK main contractors included in the Prosoma showcase (www.prosoma.lu) between June 1997 and October 1998. Administrative leaders of these sixty-seven projects were contacted by post or/and email between November 1997 and November 1998, and asked to identify the individual they considered to be the technological leader of their project in the United Kingdom. The findings presented here are based on network data collected from ten of these ESPRIT projects. A formal network for each UK main contractor was identified from the Prosoma and Cordis databases (www.cordis.lu) of the Commission. Subsequently, personal informal networks were mapped following a multistep approach. Individuals identified as technological leaders within the participating main contractors were sent postal questionnaires and each was asked to nominate up to seven other individuals who had provided information of significant value for innovation related to the specific ESPRIT project.[38] In the second round, these nominated individuals were themselves contacted and asked the same question. The nomination process continued until resources were exhausted and in some cases extended to five rounds. For the majority of the projects, semistructured, face-to-face interviews were conducted. It is from these that the quotations used in this chapter are derived.

The computerized network analysis made use of two software packages for social network analysis and visualization: Ucinet 5[39] and Mage 5.4.[40] The former was used to compute a set of coordinates for the personal network of each technological leader following a three-step approach. It placed all nominations within a symmetrical socio-matrix, revealing who was connected with whom within a particular project. An assumption was made that all ties were reciprocal in nature since nearly all respondents indicated that they supplied information for other innovation of more or less equal value. Second, it calculated Euclidian distances among the nominated individuals. Euclidian distance is a measure of structural similarity among the nodes of a network. If, for example, two individuals have identical patterns of connections to all others in a network, then the Euclidian distance between them is zero.[41] Third, based on Euclidian distances, a set of (x, y, z) coordinates for each individual was calculated using a three-dimensional scaling routine.[42] Based on each set of coordinates, Mage produced three-dimensional kinetic images for exploring the social structure of each personal network. It is pertinent that Mage was initially produced for the visualization of protein molecules, but has since been used to visualize and make sense of social structures.[43]

Main Findings

Table 10.2 summarizes the main findings of the study, revealing internal linkages (dyadic ties within the EU boundary) and external linkages for the ten ESPRIT projects. A linkage is a nomination tie showing that information considered to be of significant value for innovation was exchanged between two individuals. In some external linkages, both individuals worked for organizations outside the European Union.

Table 10.2. *Internal versus external links for ten ESPRIT projects*

Project	Internal links number (%)	External links number (%)	Total number of dyadic links
Amulet	10 (100)	0	10
Delphi	15 (71)	6 (29)	21
E2S	3 (28)	14 (72)	17
Fires	9 (56)	7 (44)	16
Flacscom	3 (17)	15 (83)	18
Imprimatur	19 (70)	8 (30)	27
Improve	21 (100)	0	21
Pepse	17 (90)	2 (10)	19
Piper	12 (100)	0	12
Timely	9 (90)	1 (10)	10
Total number of dyadic links (%)	118 (69)	53 (31)	171

As Table 10.2 shows, the information flows of only three of the ten projects were confined to the European Union. Out of the 171 dyadic ties, almost a third (31 percent) transcended the EU boundary. This is an important finding, given that none of the ten projects had any formal partners outside the European Union. If there was no contractual need to involve outsiders, it seems that the only plausible explanation for these external links is that individuals in the majority of projects believed that external, informal contacts were particularly useful for innovation.[44] It would seem that the majority of ESPRIT projects with UK main contractors accommodated informal, unacknowledged partners outside the EU with the aim of acquiring information valuable for their innovation.

As might have been expected, the majority (57 percent) of UK main contractors' external linkages were with the United States. EU firms have generally been eager to participate with the US companies because of their technological lead in IT.[45] The cultural and linguistic connections of individuals in UK firms would also explain US dominance of their external linkages. Also striking is the global spread of external linkages: Through these individuals, UK main contractors maintained important links with such countries as Australia, Brazil, and Norway. As it has long been known that UK organizations participating in the Commission's RTD programs have more collaborative links than their partners[46] it is perhaps worth speculating that the attraction of a UK partner may lie less in its intrinsic qualities than in its links with the United States.

Two case studies have been selected to examine in more detail the role of external linkages: Intellectual Multimedia Property Rights Model and Terminology for Universal Reference (Imprimatur) and Secure Internet Commerce (E2S). Some 30 percent of linkages in the Imprimatur project were outside the European Union, and some 72 percent in the E2S project. Semistructured interviews with individuals from these projects indicate that external linkages play a critical role in innovation. They transcended local social circles and brought in valuable information from well beyond the project.

Intellectual Multimedia Property Rights Model and Terminology for Universal Reference (Imprimatur)

Imprimatur was an ESPRIT IV project. It aimed to build consensus on electronic copyright management and intellectual property rights (IPR) protection in the late 1990s. The UK main contractor was the Authors' Licensing and Collecting Society (ALCS, www.alcs.co.uk), based in London.

> The Imprimatur consortium is trying to build consensus around digital rights trading. That sounds very easy. It isn't. At the moment, most content is sold in books, CD ROMs, videos and so forth. When this content migrates onto networks, the question is how can you trade it securely and fairly between the creator, the producer, the distributor and the consumer.[47]

Because the Internet and web disregard national boundaries, problems are caused by differences in cultures, legal systems, and so on. To achieve consensus in such

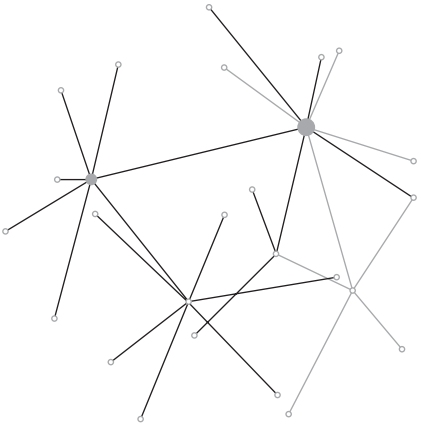


FIG. 10.1. Imprimatur project: Internal (EU)—black and external (EU–US, Australia)—gray linkages

infrastructural issues, a large number of stakeholders must be consulted. Electronic commerce and digital rights are just such an issue.

Figure 10.1 shows the personal network of the Imprimatur main contractor. The balls represent individuals and the ties represent nomination network data. The size of balls varies according to centrality (degree, betweeness, and closeness),[48] and the color of ties varies according to their natures (internal or external). Internal ties are black and external ties are gray. As was expected, the most central individual in the network is the UK main contractor himself (the largest ball at the upper right hand side of the graph). However, what is even more interesting is that a part of his personal network is outside the ESPRIT formal agreement. The network includes sources of information essential to the ESPRIT project in the United States (e.g. Digital Copyright Forum, and the Copyright Clearance Center) and in Australia. The network also includes sources in Scandinavian countries and the Netherlands. It is notable how nominated sources outside the ESPRIT project themselves nominate sources of information within the project so that networks which might have been thought to have been internal to ESPRIT are in fact intertwined with external information networks. The extent of overlap can be seen in the case of an American contact (bottom right hand side of the Fig. 10.1) from the Copyright Clearance Center who is linked with the UK main contractor, but also with two other nominations of the latter: A professor at a Dutch university and an ALCS manager. Such overlaps allow valuable information for ESPRIT innovation to flow back and forth from the United Kingdom to the United States via a number of direct and indirect routes within and outside the ALCS.

It seems that mutual interest and trust hold these information networks together. Neither is easy to establish and both take time and effort. A concern encountered frequently among those interviewed was that the European Commission was

insufficiently sensitive to these arrangements and to the personal investment that had gone into making them. In forcing on those working on ESPRIT projects contacts outside their own personal networks, the Commission put at risk their personal information networks. Consequently, the Commission endangered the very innovation it was trying to encourage. The concern expressed by the technological leader of the Imprimatur main contractor in the United Kingdom is typical.

> My network of contacts spans the world, reflecting the global nature of IPR [intellectual property rights]. It also spans private companies, NGOs, INGOs, supra-governmental organizations like the UN and OECD and governments themselves. One extremely irksome thing the Commission often tries to force on those who work in ESPRIT is the collaboration with people outside this network of contacts. Such people are outside my network of contacts for both personal and professional reasons. Therefore when the EC insists one works outside one's network, such a collaboration is bound to fail because it is not based on mutual interest or trust.[49]

Not surprisingly, there is some tension between project officers in the Commission and participants in ESPRIT projects. Individuals interviewed insisted that their information networks are deliberate constructs which can easily be damaged by the clumsy efforts of the Commission to create its own dedicated networks; "before you marry somebody you have a period of engagement, you meet, you go to parties together. In a sense, ESPRIT has sometimes felt like it was trying to force people into marriages before they actually got to know each other."[50]

Secure Internet Commerce (E2S)

E2S was also an ESPRIT IV project. It sought to develop enabling technologies for secure business to business transactions over the Internet. According to Prosoma, E2S technology is a major step toward ensuring the security of confidential information and commercial transactions over the Internet. The E2S architecture is based on secure electronic transaction (SET) technologies for bankcard payment systems. SET is an open standard developed jointly by Mastercard, Visa, and their technology partners to enable card transactions to be made securely over open computer networks using encryption technology. Now available in Europe, SET is enabling European banks to take a leading role in the international development of secured electronic commerce for consumers. The UK main contractor was ANSA Architecture Projects Management in Cambridge. Other key partners in the project were Hewlett Packard (HP) research laboratories located in Bristol in the United Kingdom, and in Grenoble and the Côte d'Azur in France.

Figure 10.2 reveals that more than two-thirds of the personal network of the main contractor's technological leader lies outside the EU boundary. Only three internal linkages—to the HP laboratory in Bristol, VISA headquarters in Paris, and the Technical University of Darmstadt in Germany—are within. There are no internal linkages in Fig. 10.2 from the other project partners. For example, contacts at HP laboratories in Grenoble and in the Côte d'Azur did not regard those within the project as important sources of technological information about the project.

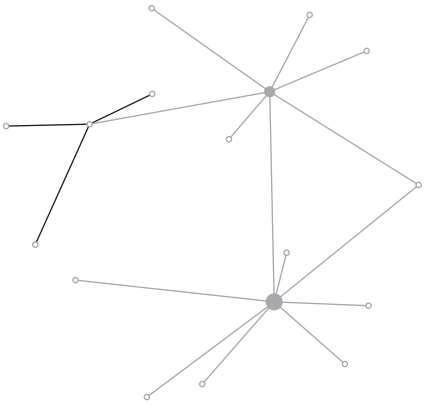


FIG. 10.2. E2S project: Internal (EU)—black and external (EU–US)—gray linkages

The most valued sources are in the east and west coast of the United States. Note that the biggest ball in the network (bottom right hand corner of Fig. 10.2) is the vice-chairman for electronic commerce in an American bank situated in downtown San Francisco. The second most central individual (upper right hand corner of Fig 10.2) is an engineer at Bell Laboratories in New Jersey. It is also interesting that there is a contact at the Citibank Group in New York (right hand side, in the middle of Fig. 10.2) who is common to both the source in the Bank of America and that at Bell Laboratories. It would seem from the structure of this network that UK main contractors benefit most from personal contacts with individuals in the most dynamic parts of the IT world and these are outside the EU.

Conclusions

ESPRIT was the first, the largest, and the longest of the European Commission's research programs. Understandably, it became a model for other research programs, but it was also a child of its time. The early 1980s expected and required government involvement in high technology, in which IT was fundamental.[51] Europe expected to be internationally competitive in IT, both in the industry itself and in other industries through the use of IT. Government involvement took the form of supporting if not national champions then European champions, firms reckoned to be large and strong enough to take on the best and biggest in the world. In the ESPRIT case, government involvement also took the form of supporting precompetitive research carried out in collaborative, technology-driven projects which, because of the way they were formulated, monitored, and assessed, tended to focus on what the Big Twelve, the equipment suppliers, wanted to do anyway.

Technology policy has moved on in the last two decades. The IST Program, which replaces ESPRIT in the Fifth Framework, is very much market-driven and

user-driven. Market-pull has replaced technology-push and the contrived notion of precompetitive research, which did not survive to see the end of ESPRIT any more than did the dominance of hardware over software, has been dropped altogether. And yet, the Commission's insistence on collaboration is as strong as ever. It is true that collaboration in IST can still be justified in the terms in which it has been justified in ESPRIT over the last two decades. It is also true that collaboration among firms is hardly going out of fashion, though it commonly takes the form of mergers, joint ventures, and acquisitions these days. But European firms would rather collaborate with firms outside Europe, especially firms in the United States, than with those in Europe, and they certainly have no desire to restrict their collaboration to technological innovation. It is surely sobering that an indication of the success of ESPRIT is that "prior to ESPRIT European firms sought out American companies for technological partnerships. Because of ESPRIT European companies now seek out European partners."[52]

But collaboration did not endure in ESPRIT and has not been retained in IST for the advantages claimed for it in the early 1980s, nor because it is still fashionable. No, the Commission has retained collaboration in IT research for other reasons altogether, basically so that SMEs, firms from the periphery of Europe, and now the users of IT, can be included in projects.

> The reasons the Commission have to impose some partners is that they will be left out if they don't, and they put money into the pot in Europe, and occasionally they are saying why don't you pick up this company in trouble . . . Yeah, all right we will have them in the project . . . It is a pain but we did it because it helps . . . The EC is full of politics. Full of it, and we try and avoid that, and try and focus rather hard on what we try to do.[53]

Mere inclusion does not guarantee that new participants actually do participate in projects, that they contribute or benefit at all: the reality of collaboration can mean the same old groupings and little new blood. Though the Commission justified its requirement for collaboration among participants in its RTD programs in terms of the advantages for innovation, collaboration also satisfied the Commission's own political requirements. Collaboration may bring political benefits for the Commission, but not necessarily benefits in terms of IT innovation. Much ESPRIT collaboration was nominal in that it was arranged to satisfy application requirements, to improve prospects of funding, or to please project officers with the consequence that some partners made little or no contribution to innovation. Such collaboration could hardly have improved the prospects of innovation. It may even have imposed a cost on innovation for which the benefits brought through informal networks extending beyond the formal collaboration were some compensation.

This study indicates that much of the information for innovation in ESPRIT did come from external sources—external to ESPRIT projects and often external to Europe. Very often it was acquired by personal and informal means. It would seem that the formality of collaboration in ESPRIT managed to accommodate this informal networking, not because the Commission was sensitive to the importance of these networks and anxious not to disrupt their operation, but because their

members were absolutely determined that the Commission would not interfere with their networks.

Non-European firms may now participate in European Commission programs, but as non-funded and therefore unequal partners. This is some concession to reality, but still inadequate recognition of the non-European contribution to European Commission programs in IT. The Commission still requires European firms to collaborate so that they may be more efficient in IT research, more innovative, and thus more competitive, especially against the Americans and Japanese. Such a notion is really no longer appropriate in the modern IT industry, an industry whose product, structure, ownership, research, innovation, and market are utterly global. It is positively surreal in a research program like IST, which specifically seeks to exploit networks and clustering, and in the very IT technology which facilitates information networking, both formal and informal. The consequence of the Commission's continued insistence on European collaboration may well be reduced IT activity in Europe, and this is far too great a price to pay for the political convenience of the European Commission.

Acknowledgments

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11

The Rise and Fall of State Information Technology Planning—or How Norwegian Planners Became Captains of Industry, 1960–1990

Knut Sogner

Seen in a long-term perspective there have been three distinct phases for what we today call the Norwegian Information Technology (IT) industry,[1] the prewar rise and fall of private business enterprises, the postwar rise and fall of a state-supported national industry, and the post-1970s rise of—something else. This "something else" is what this chapter will focus on, and by doing that it will explore the antecedents of the current IT industry.

The Norwegian prewar IT industry was constituted by a host of radio manufacturers, as well as a couple of larger cable and telecommunications companies. While the 1930s were good to the small radio companies (for ships and for public broadcasting), the only two bigger IT companies, cable and telecommunications operations Elektrisk Bureau and STK, were sold to foreign multinationals, LM Ericsson and ITT, respectively. During the postwar period complex relationships between various private business strategies and state activities at several levels developed, the state both promoting technology as well as *national* industry, partly attempting to balance the damage done in the interwar period. The postwar period may be said to have ended around the 1980s when the four big and state-supported companies—Tandberg, Kongsberg Våpenfabrikk, Elektrisk Bureau, and Norsk Data—either went bankrupt or were completely reorganized. While we may indeed lack a certain perspective on what has happened since, some factors seem clear enough: A lot of the current important IT products and IT activities stem from these four companies, though none of these *companies* exist any more. The state is still active at various levels, but has taken a passive nationalistic–controlling role rather than continuing the active structuring–strategic role of the past. This is all the more clear since the state's sole ownership of Kongsberg (similar name, basically same operation, different company) has been relinquished by selling off 49 percent and listing the shares on the stock market. What's more, the old state telecommunications agency has been made a company, Telenor, and the part-privatization of Telenor is completed. In this chapter, I will try to shed light on some of the changes of state policy from the 1970s to the 1990s.

At one level, post-1970s developments may be characterized as going from planning to market-led policies. Such an interpretation would fit easily with the overall characteristics of the period. "Neoliberalism" became a description chosen by some for the change in the general state policy over the western world. And to some extent we have to take into account such broader ideological shifts. On the other hand, there are the internal, national, and sector specific policy traditions to take into account. Governmental policies are still deeply affecting the private sector in Norway, and with it the IT industry, so it would have to be a nationalistically flavored liberalism if such an ideological explanation were to be our sole criterion. In a previous attempt to characterize these changes in the Norwegian mixed economy, I suggested that in terms of state–private relations, the state went from being the master in the 1970s to become the servant in the 1990s.[2] While that description somehow catches the drift of things, it fails to explain *why* the state retracted. What sort of state-activism—that has been rooted in decades-long tradition—just stops abruptly around 1980? What happened to the people who were accustomed to plan?

In Norway market-led policies for industry are very clearly visible today.[3] Even though there are a lot of state institutions to help business companies, those institutions are supported by guidelines emphasizing that initiatives should come from the outside, from the industry itself. The state money is to go where the market leads it. Thus around 1980, the government changed the large and important Business Fund—a public institution for the general development of industry, a remnant of the countercyclical policies of the 1930s, and formerly a tool for activist public policy.

By the late 1970s Norway moved firmly in a new direction. A public investigation of 1979 was made into the countercyclical policies of the 1970s. In its handling of the mid-decade crisis after the Opec oil-price rise, the state was seen as having gone too far trying to preserve the status quo within industry. Market forces were seen as a tool for the creative destruction of obsolete industry. This investigation was headed by a former Minister of Industry and a member of the governmental party, Labour, the electronics engineer Finn Lied.[4] His critique of his own party was a strong reflection of the change and self-critique in the Labour Party. At about the same time, in 1979, the ruling Labour Party was heavily criticized in parliament by the opposition parties for their handling of the so-called Tandberg case. Tandberg was the biggest and most successful electronics company in Norway, but when it hit trouble in 1976, its ambitious strategy was saved by money given by the government, through the Ministry of Industry, and sanctioned by parliament. This extra money did not help, and Tandberg went bankrupt in late 1978. Parliament in 1979 criticized this kind of help to industry in trouble, and it also claimed that it had been misinformed by the government in order to give Tandberg money. Finn Lied had himself been deeply involved in the rescue of Tandberg from 1976 to 1978. As the Lied-led investigation showed, the government's sudden willingness to let Tandberg go bankrupt also indicated that the Labour Party had learned its lesson. One had to consider the market forces.

Finn Lied and the Labour Party's about-turn was dramatic and seemingly fundamental. The state's handling of Tandberg had been strongly tied to long-term state efforts to build a strong and large-scale Norwegian IT industry. Those efforts had reached a kind of zenith in 1976 when an explicit plan at the level of Minister of Industry was made to reorganize the whole electronics industry. The idea was to organize the IT industry around three large companies: Publicly owned Kongsberg Våpenfabrikk, the above-mentioned privately owned Tandberg, and privately owned Elektrisk Bureau. This plan was obviously in some ways modeled on the French market-sharing policy toward Thomson and Compagnie Generals d'Electricite (CGE) of the late 1960s. Kongsberg should concentrate on electronics for the military, Tandberg on electronics for the consumers (radios, televisions, and tape recorders), and Elektrisk Bureau on electronics for telecommunications. The state—broadly defined—was to assist in various ways in the building of these so-called "cornerstone" enterprises. The idea was to make the three companies cooperate closely both technologically and ownerwise.

Groups for technological cooperation were made, and part of the plan was to buy back a large part of the Swedish multinational LM Ericsson's majority share-holding in Elektrisk Bureau so as to make Elektrisk Bureau controlled by Norwegians. The "nationalized" Elektrisk Bureau itself took over a smaller company in crisis, and all three "cornerstone" enterprises between them took over yet another company in crisis. With the help of the Ministry of Industry, Kongsberg Våpenfabrikk, an ambitious producer of a small amount of minicomputers at the time, tried, in vain, to take over the other Norwegian producer of minicomputers, Norsk Data. All in all the three large companies were to constitute strong economic and technological centers within the wider range of a small-scaled Norwegian industry of electronics.

The beginning of the end of the plan came when Tandberg hit serious trouble in early 1977. Due to the plan, the Ministry of Industry supported Tandberg with money through the Business Fund.[5] When the troubles continued, the state refinanced Tandberg and became the sole owner. The state's main representative to lead the firm in 1977 and 1978 was the aforementioned 1979 critic of this kind of policy, Finn Lied. He obviously still favored the idea of this kind of industry support in the spring of 1977, when he became chairman of the board of Tandberg. Those 2 years fighting for Tandberg's survival against "market forces" must have been instrumental in changing his views 2 years later, when he led the public investigation into public policy. Lied and the government could not make Tandberg work, and the plan for the "cornerstone" enterprises had obviously been abandoned already in late 1978 after only 2 years—at the time when Tandberg went bankrupt.

The state of Norway no longer promotes such big schemes. This sharp policy shift was made clear after the bankruptcy of Tandberg when the Ministry of Industry made no attempt to make Tandberg's considerable activities part of either any old or any new plan. In the late 1980s, a troubled Kongsberg Våpenfabrikk was reorganized into various smaller firms, and Elektrisk Bureau was sold to the Swedish–Swiss Asea Brown Boveri (ABB). Before this sudden abandonment of the plan can be understood properly, it is important to look closer at the plan conceived by the

Minister of Industry. While the plan must be understood against the background of the general economic crises of the time, something that will be discussed later, the plan was also an extreme reflection of postwar (Labour Party) thinking. The plan's architect was Jens Chr. Hauge, the first Minister of Defense in the Labour government of 1945. At the time of planning in 1976, he was on the board of both Kongsberg and Tandberg, and generally active in his profession as a business lawyer. He was also informally tied to the Ministry of Industry, and acted on its behalf in 1976. Hauge's plan must be understood as a way of rationalizing the industrial structure, a way to make a small-scale industry benefit from economies of scope and scale, an endeavor which has indeed characterized public policies in postwar Norway.

Hauge's plan was a kind of ad hoc planning. It was planning in the sense that it was meant to direct the whole IT business of Norway. It was planning also in the sense that it was a continuation of 30-year-old schemes that had involved Hauge and Finn Lied. As Minister of Defense in the 1940s, Hauge had made himself known as a modernizer.[6] He was the powerful *political* force behind the Norwegian development of civil and military research in nuclear power. He instigated the National Defense Research Establishment in 1946, where Finn Lied was CEO for several decades. Hauge was also known as a more than normally active and forceful member of the board of the Kongsberg Våpenfabrikk from the mid-1950s, when he and others rebuilt the old armaments supplier into a technologically modern, military enterprise producing numerically controlled machine tools, steering systems for ships and submarines, as well as highly complex rockets for ships.[7] The modern Norwegian computer (minimachines) industry came out of the joint efforts of Kongsberg Våpenfabrikk and the National Defense Research Establishment as computing power was needed for several of these complex products. In this respect, the work done with sonars inside the National Defense Research Establishment should also be highlighted.

There were thus two typical reasons for state intervention in postwar industrial Norway. Rationalizing of industrial structure is one, technological modernization of the industry is the other. The plan of Hauge in the 1970s combined the two. While rationalizing the industrial structure may be said to be a general policy issue at the central government level—and that was tightly bound to a general goal of economic growth—the broader issue of modernization was not as clearly rooted in the middle of the state apparatus. That an *electronics* industry could play an important modernizing part in the development of modern society and economy was mostly the concern of electronics engineers employed by the state. Business leaders and politicians were for some time rather passive. Electronics companies doing their own research were few and far between in the 1940s and 1950s, the industry consisting mostly of producers of radios—although these were fast getting fewer and bigger. The two bigger telecommunications companies were owned by the Swedish and American multinationals LM Ericsson (Elektrisk Bureau) and ITT (STK, a cable manufacturer), respectively.[8]

Both types of state intervention could be legitimized as a kind of *modernization*.[9] Preference was given by the state, for the reason of modernization, to an industry,

a firm, or a person. This kind of policy was new to the postwar era; earlier liberal, nondiscriminatory principles had characterized the Norwegian state prior to the Second World War. The social democratically inclined governments since 1935, and especially since 1945, marked a real departure from these liberal views of the state. On the other hand, that the Norwegian electronics industry was rather small scale in the 1970s, might well be because the old liberal values were not dead by 1945 and could not be killed by central authority. Some state agencies were rather "old-fashioned" in their ways. The defense sector at large did not always reflect Jens Chr. Hauge and the National Defense Research Establishment's modernizing outlook.[10] The state telecommunications agency in particular was both very important and rather old-fashioned in its procurement policies, and a lot of the bad feeling about the state telecommunications agency had to do with its procurement from the two foreign-owned companies, Elektrisk Bureau and STK.[11]

Thus electronics for industrial purposes may well have been suffering in the 1950s. But after the debate in the late 1950s about the "residual factor" (technology, knowledge) in explaining economic growth, this changed gradually. Electronics began to be seen as an independent, important, and integral part of industry and society and not only as a product. By the early and mid-1960s electronics had become an important part of the state's priorities. Now began the development that was to lead directly both to Hauge's plan and the plan's failure. The state instigated a wide-ranging scheme to lend money to industry for various purposes. Therefore, at about the same time as electronics came to be seen as a priority, new institutional settings for the state's promotion of industry began to get settled. While earlier attempts in the 1940s at building such institutions were planned as all-important planning bodies in association with the new Department of Industry, the 1960s marked a new approach. The 1940s institutions had mainly been collecting information and proposing changes, but operating without power. Its power had been derived from its association with the Department of Industry, strictly on an ad hoc basis and directed at the really big issues that had to be tackled in collaboration with the companies themselves.[12]

The 1960s institutions were seemingly less ambitious. Their purpose was to help achieve growth for smaller companies, and their tool was financial assistance for companies that had schemes that fulfilled the state's indicative goals: More regional operations, mergers, more and better foreign marketing, and more and better research and development (R&D) directed at specific products. Not much money was involved, but the state achieved an insight and a commitment to industrial development that was unprecedented.

Although such financially inclined state institutions had existed since the 1930s, the 1960s marked a new and much-expanded beginning. What happened in Norway had more to do with Organization for Economic and Cooperation Development (OECD) developments at the time than with national traditions, and similar developments can be found in other countries, Great Britain for one.[13] Although several independent "funds" were established from 1960 onward, this system had two main phases. In the first phase, the four funds had interlocking boards consisting of

civil servants and business leaders, as well as small and separate administrative staffs. In the second phase—beginning in 1973 and ending in 1992—administrative staffs grew at the same time as the "funds" were being heaped together as one national "Business Fund."

In the first phase, the interlocking boards were in close contact with the Ministry of Industry, trying to achieve a kind of coherent industrial policy. With regards to the IT industry, the "funds" of the 1960s achieved a lot of what they set out to do, something that had to do with the personal positions of the members of the boards. Two members who in particular helped shape the IT industry were the economist Erik Brofoss, former minister in several Norwegian Labour Party governments and from 1954 the head of the Norwegian Central Bank, and Finn Lied, then CEO of the National Defense Research Establishment. They showed both willingness to change industrial structures and to promote the most modern industries. They clearly had an affinity toward the computer industry, and gave important contributions to the rise of, among others, Norsk Data and Tandberg that started developing computing peripherals in the late 1960s, monitors and streamers. They directed at least one merger in this industry. The records of their board meetings show clear signs of typical industrial planning; if they did not always do anything, they often had evaluated the possibility of taking an initiative.

These new funds did not solve all the problems of industry, but the new funds were obviously regarded as successful institutional creations. The one problem was the constantly growing number of tasks. Thus there was a need for administrative expansion and reorganization, and from the start of 1973 several of the "funds" were put under one administrative umbrella. Although that umbrella was to take wide-ranging considerations, it was in particular to address one of the most important political themes debated in the late 1960s, the structure of industry. In Norway, it was generally perceived as being far too small-scale, and mergers and cooperation should be encouraged.[14]

Another perceived problem was that of administrative organization, a new element to become central in Norwegian industrial policy. Up until then politicians and industry leaders playing prominent roles had been engineers and economists groomed in planning. Throughout the many changes in the instruments chosen for industrial policy, these economists and engineers were the important players. But at this point the build-up of funds for the industry was so big and complex that the new Business Fund required something else. For a fund that was to make industry profitable, *business economy* was the profession from which to choose the administrative leader. This was a new element, and strangely it was put in place just at the time the funds were reorganized into one administrative holding, something that gave the new administration increased power.

There was tension in the system right from the start. In 1971 a difference of opinion between Finn Lied in the position of minister of industry and the business economist-led "Business Fund" became clear. Lied wanted to merge Tandberg and a smaller crisis-ridden producer of radios and televisions. Lied argued that the merger would benefit from the economies of scale and scope of

the enlarged company. The Business Fund's administration did not agree, it saw various practical problems in this particular merger. It worked from the angle that its two goals of making industry both bigger and more profitable were not always compatible. When his opinion was overruled by his board and the board's contact with Minister of Industry Finn Lied (who was on leave from his position on the board while he was minister), the Business Fund's administrator did what he could to control the deal according to his viewpoint. As a general rule for support from his fund, he often demanded that firms with problems should make use of professional business consultants, and it became a practice of his to make the use of outside business consultants obligatory if some problem firms were to receive any financial assistance. At least three or more electronics companies were thus forced to make use of business consultants. In this way, the fund worked hard to turn around firms in trouble through decisions tied to the activities of the firm in particular.

While there was a difference of opinion between Lied as minister of industry and the Business Fund in the Tandberg case in 1971, that was only one instance, and something that was left behind and was seemingly unimportant. Lied clearly supported the Business Fund's strong emphasis on helping the firms get their administrative tasks in better shape. The difference of emphasis in the industrial policy of Norway only became important in the huge economic crises after 1973. The crises hit the electronics industry of Norway particularly hard because the industry had a lot of sales to the merchant fleet, the biggest casualty during these turbulent years. Through the Business Fund, the state had a very large portfolio of loans to an electronics industry in deep trouble. The question was, what to do? While the Business Fund and its administration went with its inclination to put pressure on firms to cut costs and concentrate on the most profitable activities, the structural architects like Erik Brofoss, Finn Lied, and Jens Chr. Hauge looked for additional structural solutions. If the industry could be reorganized in better ways, to achieve scale and scope economics, the new and merged firms might withstand the crisis. This was a reasoning typical for postwar Norway, and this is what Hauge hoped to achieve through his plan for "cornerstone" enterprises of 1976.

Thus there were two answers to the situation of crisis. Hauge thought the situation demanded the building of "cornerstone" enterprises, while the Business Fund held that first the firms had to become profitable. On the surface the old beliefs in the positive benefits of economies of scale and scope were the only ones visible, however. These beliefs were expressed both through the revitalization and the reorganization of the Business Fund in the early 1970s and the plan for "cornerstone" enterprises in 1976. But while the last plan, so to speak, sprang directly out of veterans who had been active in the 1940s, 1950s, and 1960s in a spontaneous way, the Business Fund was an institutionalization of the same kind of beliefs. In its official policy the Business Fund came to carry the old beliefs by its very existence. However, beneath the surface the Fund's administration stood for a more practical and down-to-earth ideal, trying all the time to strive for a profitable industry also in the short term and within old business structures.

Hauge's plan was caused by the state's big involvement in the electronics industry, and by the crisis in that industry. Even though it might have been a problem that Hauge and the Ministry of Industry on the one hand (Lied was no longer the minister), and the Business Fund on the other hand, did not agree, the stronger of the two parts won again—as in the Tandberg case in 1971 the ministry's view prevailed. Though the Ministry of Industry's big plan went ahead, the Business Fund recorded its oppositional opinion to the state-supported continued full-scale operation of crisis-ridden Tandberg. And the Business Fund was proven right. Tandberg lost a lot of money over a short period of time, most of it after Lied took over as chairman—or from the very moment the firm became a state-supported cornerstone enterprise. Even a man with such outstanding abilities and such enormous working capacity as Lied could not make the company profitable.

In reality, Tandberg was squeezed between two incompatible features of Norwegian public countercyclical policy. On the one hand, its costs increased through the expansive macroeconomic policies driving wages and interest rates upward, on the other hand the firm was not able to cut unprofitable activities, as the labor force of Tandberg was needed to achieve the ambitious sales targets employed by Hauge's plan. And this is where the Norwegian planning politics ends—at least concerning the electronics industry. What characterized the situation in 1979 after the bankruptcy of Tandberg in 1978, was exactly the lack of broad plans. Suddenly the state owned a large firm with big production facilities, but did not use this possibility in any fashion reminiscent of the plan from 1976. And it was quite a contrast. In 1977 the state of Norway had made Elektrisk Bureau Norwegian-owned; in 1979 the German multinational Siemens was able to buy the computer activities of Tandberg; in 1979 the only target was to make the Tandberg activities profitable again. And this even though the state in 1977 did not have very much it really could dispose of, while in 1979 the state owned Tandberg as well as Kongsberg Våpenfabrikk. All this time a Labour government was in power. Clearly, there had been a shift in policy.

This shift seems to have been caused by two independent lines of development. On the one hand, the bureaucracy that was to administer the active state became a force to reckon with. These industry-recruited civil servants put much more stress on short-term profitability and basic administrative operations than political practitioners. In the Tandberg case, the director of the Business Fund, whose specific task it was to make mergers come about, opposed the Ministry of Industry's "big business" attitude three different times. The establishment of the Business Fund in the early 1970s at first had meant a strengthening of the state's active role, but when the bureaucracy was dominated by people with an industry-internal outlook, the system of active state policy was gradually undermined.

On the other hand, the economic policy of Norway made the differences in industrial policy bigger than they had been. From 1974–1975 onward, Norway practised an expansive countercyclical macroeconomic policy to counteract the international economic crisis. At first this was in line with other countries' policies, but fairly soon oil-rich Norway was alone in this kind of policy. This created a rise in

salaries, prices, and interest rates particular to Norway, and this again created problems for the industry at large and the electronics industry in particular. Therefore, this development was instrumental in creating a need for action in those parts of industry, such as electronics, that were deemed important. Because of the crises, what had been one central industrial–political system divided itself into two opposing solutions. The difference between the new bureaucracy—that is, the Business Fund—and the old politicians—that is, Hauge and his plan—became bigger than it would have been but for the crisis. And afterward it could be argued that the policy promoted by the Ministry of Industry to make "cornerstone" enterprises had not been self-evident. The Business Fund, in retrospect, a sensible attitude, had been overruled by the political leadership in at least three incidents. The Tandberg case explosion in the Norwegian Parliament in 1979 uncovered these aspects, and the political leadership was discredited. In one sense, the bureaucracy "finally" won over the politicians, and it was of course the hard criticism in the parliament that changed the policies. The Tandberg debate in parliament meant the preceding happenings became important on a national level.

It is of course not unambiguously the case that it was the difference between the "modern" bureaucracy and the "old-fashioned" politicians that created a system crisis. The new tendencies toward scepticism of state planning were of course part of a broad international phenomenon that must have influenced everybody: Old politicians, young politicians, old bureaucrats, young bureaucrats. But there seems to be a dividing line in Norway about 1978 that has to be understood in a national context, and it is clear that there was a difference of opinion concerning the public policies. It is also important that the difference occurs between the new independent fund and the political ministry. It is interesting to remember that the fund was built up as part of a state interventionist industrial policy. The original idea, that the Business Fund should be a professional and in some ways independent organization, and help make a strong and profit-making Norwegian industry, hit back at the ministry. The fund could not stop the ministry in the first place, but its views had long-term consequences. While the architects of the "cornerstone" enterprises of the 1940s, 1950s, and 1960s practised their task under great uncertainty, and lacked a strong corrective for their projects, Hauge in 1976 and Lied in 1977 operated in opposition to the Business Fund. When Hauge's plan failed in the short term, with Lied as the practitioner in the important Tandberg case, it could be argued that they had acted against better judgement. The civil servants broke the politicians' freedom of action from within the system.

The continued story of the Business Fund reflects these developments. A national Business Fund is a firmly rooted part of current industrial policies in Norway. Yet these policies are in the main responses to private initiatives. And one will not find a politically responsible ministry directing important industrial structures. Thus there are no state-led national–structural IT policies guiding the future of the current IT industry. On the surface of things, the IT industry may be said to have become wholly market led. It has strong connections with state-agencies, but these are most probably very business-like relationships. It is still tied to the Business

Fund, but the Business Fund—bigger in size and formal importance—is today much more like a normal private bank than a tool for grand industrial policy. The IT industry has changed "with the market."

The old Kongsberg operation is listed at the Oslo Stock Exchange, and partly privatized.[15] The state retains majority ownership with 51 percent, however. But the old connection between the company and the ministries (defense as well as industry) is certainly not there in the same way as before. After its bankruptcy in 1978, Tandberg was divided in several pieces, and the most successful of these pieces, the computer peripherals company Tandberg Data, is listed on the Oslo Stock Exchange. The third of the "cornerstone" enterprises, Elektrisk Bureau, no longer exists under such a name after it was brought into the ABB group. Its IT activities have been split between the Swedish company LM Ericsson and Nera, a company listed on the Oslo Stock Exchange from the early 1990s. Another company should also be mentioned. Norsk Data, the minicomputer producer, was small in 1978, but grew tremendously during the 1980s, only to go bankrupt when the personal computer (PC) out-competed the minicomputer, Norsk Data's main product. The most notable development is the change of the old state telecommunications agency. A few years ago it became a company, Telenor, and as a company, it was in late 1999 in the process of being merged with the Swedish Telecommunications company, Telia. The deal did not materialize, however. All in all, there is seemingly enough evidence to say that the profound changes in state policy in the late 1970s have become permanent for now. The market rules.

Yet, when we look beneath the surface, some interesting facts appear. The CEO of Telenor, by far the biggest IT company of Norway, was until recently Tormod Hermansen.[16] Hermansen was the man who would have led the proposed merged Telenor–Telia company, but more importantly, he was the architect behind the changed role of Telenor. Hermansen, contrary to what one could expect from the role he plays in taking public agencies into the private sphere, has all his background in the public sector. Trained as an economist, his last job before becoming CEO of Telenor was as the highest-ranking civil servant of the Ministry of Finance. The role he then played—if we look beyond his taking Telenor out from the public sector—was that of trying to structure the whole telecommunications sector of Scandinavia. Seen in this structuration perspective, Hermansen's actions have more to do with the likes of Jens Chr. Hauge, Finn Lied, and Erik Brofoss than with the normal business leader. Indeed, it is tempting to compare Hermansen to Erik Brofoss. They were both trained as economists, they were both high-ranking civil servants, and they have both been engaged in structuring Norwegian industry. Is it a coincidence that Hermansen in the late 1960s, as a young man, actually worked for Erik Brofoss with regional planning matters? I will address that question soon, but there is also the case of Finn Lied to be considered.

During the period following the end of Jens Chr. Hauge's plan in 1978, the bigger IT companies of Norway had problems. One of the first companies to get its act together, was the hydroacoustics company Simrad.[17] During the period from 1982, until it was bought by Kongsberg in 1996, it grew tremendously, both

organically and through purchases of other, smaller companies. The company developed a strategy for restructuring the IT industry in Norway directed at the *maritime* sector, something that was continued in a separate division by its purchaser Kongsberg. The chairman of Simrad's board during the years 1985–1995 was none other than Finn Lied. After a life in public employment, he started his career in private stock exchange-listed business at the age of seventy, just when he retired from his position as CEO of the National Defense Research Establishment. After a working life trying to shape the electronics industry from within the state apparatus, he served 10 years as a pensioner doing the same from within a private business company. Labour Party member Finn Lied's change of career is even more remarkable than that of Labour Party member Tormod Hermansen.

The main points are not that Lied and Hermansen are crucial to the changes at Telenor and Simrad. It is hard to pinpoint their exact roles. A tentative guess would be that the younger Hermansen played a more crucial role within Telenor than did the older Lied at Simrad. It is also important to point out that neither Lied and Hermansen, through their state planning and Labour Party pasts, represents the only path to Norwegian structuration of the IT business. The main point is the grand shift of arena that was taking place around 1980. The structuring of business was, prior to that, done to a great degree from within the public sector, and we may call it state planning. Afterwards, in the 1980s and 1990s, structuring of business was done from the other side, from the private side. And this is why the likes of Lied and Hermansen change places. They were concerned about finding the right structural solutions, and to achieve those goals they had to select the right arena. Prior to 1980, that arena was centered around the state. After 1980, it has increasingly come to be the private sector.

To some degree this sheds light on what *planning* is. Planning, in the sense that it concerns structuring of business, may be done both in the public and private sectors. Given the changes in the Norwegian industrial policy, we can, to put it bluntly, say that big-time industrial planning was moved out of the public arena and into the private sector by the developments of the 1970s. The end of state activism did not mean the end of national planning. It only meant the end of *state* planning. Men like Finn Lied and Tormod Hermansen took their initiatives and ideas from within the public sector and moved to the private sector. When state planning had become illegitimate for political reasons, and impractical for state bureaucratic reasons, national planning had to take place elsewhere. The planners helped constitute a new arena.

Acknowledgments

This chapter is based on a paper first presented at SHOT's 1990 conference in Cleveland, Ohio, but it reflects a lot of subsequent work by myself and others. See: Knut Sogner, *Fra plan til marked. Staten og elektronikkindustrien i 1970-årene*, Oslo: TMVs skriftserie/Pensumtjeneste, 1994 and *God på bunnen. Simrad-virksomheten 1947–1997*, Oslo: Novus forlag, 1997. My work on the Norwegian IT industry draws

a number of insights on work done on a larger project of the 1980s studying this industry, and where people like Håkon With Andersen, Bjørn Basberg, Anne Kristine Børresen, John Peter Collett, Stig Kvaal, Francis Sejersted, Olav Wicken, Finn Ørstavik and Per Østby among others have contributed.

Notes

1. I have chosen to use the terms "electronics" and "IT" as more or less the same.
2. Knut Sogner, Fra Plan til marked. Staten og elecktronikkuindustrien in pc 1970-tallet, Oslo, TMV-senteret 1994.
3. The following is from Sogner, ibid.
4. NOU 1979: 35 Norges offentlige utredninger: Strukturproblemer og vekstmuligheter i norsk industri.
5. For the sake of simplicity I more or less use the term "Business fund" throughout the chapter. In reality what was to become the "Business fund" in 1992 has a rather complicated past, starting in the 1930s, gaining momentum in 1960 and 1973.
6. Alf Ole Ask and Bjørn Westlie, *Maktens ansikt. Et portrett av Jens Chr. Hauge*, Oslo, Tiden Norsk Forlag, 1991; Olav Wicken, *Stille propell i storpolitisk storm*, Oslo, Institutt for Forsvarsstudier, 1988.
7. Olav Njølstad and Olav Wicken, *Kunnskap som våpen. Forsvarets forskningsinstutt 1946–1975*, Oslo, Tano Aschehoug, 1997, especially ch. 8.
8. For information about the Norwegian telecommunications industry prior to 1980, I draw upon John Peter Collett's as yet unpublished paper "I skyggen av svensk storkapital? A/S Elektrisk Bureau innenfor LM Ericsson-konsernet," presenter at "nordisk forskarsymposium," Ljusterø 2–5 June 1986.
9. Several authors have used this term, but among the earliest and with respect to the IT industry Kjersti Jensen, *Moderniseringsmiljøet som pådriver i norsk industriutvikling på 50 og 60-tallet*, unpublished "hovedfagsoppgave" in history, Oslo University 1989 should be mentioned.
10. See Knut Sogner, *God på bunnen. Simrad-virksomheten 1947–1997*, Oslo, Novus, 1997.
11. Collett op. cit. But there were exceptions. The directorate for Fishing—as well as the National Defence Research Establishment—helped the producer of hydroacoustic equipment, Simrad. See Sogner, 1997, op. cit.
12. This is my interpretation, as reflected in Sogner 1994 which to some degree is based on Grønlie's work: Tore Grønlie, *Statsdrift. Staten som industrieier i Norge 1945–1963*, Oslo, Tano, 1989.
13. Andrew Shonfield, *Modern Capitalism. The Changing Balance of Public and Private Power*, London, Oxford University Press, 1969.
14. General point of course, well known through Jean-Jacques Servan-Schreiber's 1967 book *Le défi américain*; see Kranakis, Chapter 10, this volume.
15. See Sogner, 1997, op. cit.
16. Hermansen is a well-known public figure in Norway and his curriculum vitae is also well-known.
17. Sogner, 1997, op. cit.

12

Facing In, Facing Out: Information Technology Production Policy in India from the 1960s to the 1990s

Richard Heeks

A Policy Framework for IT Industries

India, by the year 2000, was a Third World Information Technology (IT) colossus. In 1998/99, it is estimated to have exported some US$2.2 billion-worth of software. In the same year, it produced more than 700,000 computers for the home market, worth more than US$1 billion.[1] Such success has encouraged many other developing and transitional nations to see India as an IT model that must be both understood and imitated. The objective of this chapter is therefore to understand IT production policies and their impact in India, from the 1960s to the 1990s, and to draw some policy lessons from that understanding. Before that, however, it will first be necessary to set out an IT policy framework that will be used to analyze India's experiences.

Policies for the Information Society

Creation of an information society involves two related but distinct components, as illustrated in Fig. 12.1:

1. *IT Production*: the creation within a country of one or more of the technological components of IT. The information society benefits include creation of wealth, employment, and innovation.
2. *IT Consumption*: the utilization within a country of IT as a means to other ends. The information society benefits that these "other ends" entail may include greater efficiency and effectiveness for both government and business.

The two are related in the sense that IT production for the local market can be a necessary lever to IT consumption. They also have some common requirements for an information society infrastructure of accessible technology, skills, and information. Nevertheless, the two areas require different policies, and this chapter focuses on the IT production domain. Within that domain, as summarized in Fig. 12.1, there are many different elements of IT that can be produced. This chapter focuses on just two: computers and software. It will use the term "hardware"

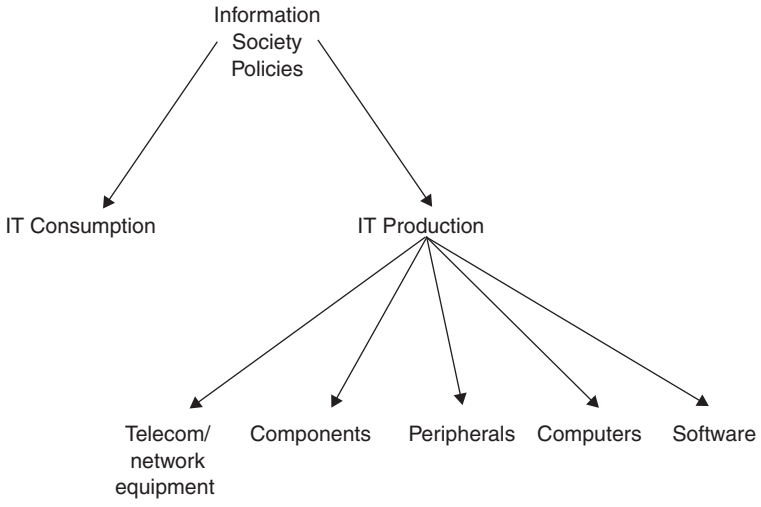


FIG. 12.1. Policies for the information society

interchangeably with "computer" though, as indicated in the figure, there are other types of hardware.

Generic Industrial Policy Models

In order to understand hardware and software industry policy, we begin by analyzing generic industrial policy models. Although much of what follows has applied equally to industrialized countries, the focus here will be specifically on developing countries.

The world of policy and policymaking for developing countries has always been inhabited by a number of possible models which policymakers are exhorted to follow. Overlain on this has been a dynamic such that, at any given time, one of these models will be held up as a paradigm, as *the* model to follow, in order to attain developmental goals. This change is summarized in Fig. 12.2.

When most developing countries were under colonial rule, a nonindustrial model was broadly accepted: "Until the early 1930s there was little disagreement among economists or policy-makers that the system of international division of labor then prevailing—industrial countries producing manufactures and developing countries supplying primary commodities—was more or less equally beneficial for both groups."[2]

In the postwar, independence period after a decade or two of deterioration in the terms of primary commodity trade, a structuralist and pro-industrial model developed which emphasized the benefits of developing country industrialization: "Industrialization seemed the appropriate course because it not only promised self-sufficiency for nations that had just regained political sovereignty, but it also offered external economies accruing from technical progress."[3]

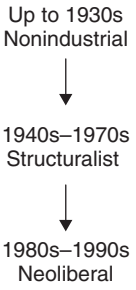


FIG. 12.2. Changing paradigmatic models of industrial policy for developing countries

Structuralist ideas varied but it was generally seen that industrialization would be achieved by government intervention, by protection from imports, and by a process of import substitution. Such views were partly reinforced by the work of the dependency school of writers, such as Frank and Amin[4] (who constituted one element of structuralist thinking), which emphasized the structural constraints within links between developing and developed countries and, hence, the limitations of industrialization involving foreign capital. Although a somewhat diverse body of theories, structuralism remained "the dominant intellectual paradigm in the economics of developing countries over the years 1950–1980."[5] Then, starting slowly in the 1960s and 1970s but gathering pace in the 1980s, a neoliberal model came into the ascendancy which emphasized the importance of price and market mechanisms, and the deficiencies of government intervention and import substitution.

The origins of liberalism can be traced to the writings of John Locke in the seventeenth century, "defending the rights of the individual against the commands of monarchs and other rulers."[6] The ideas of classical economic liberalism were developed particularly by Adam Smith in the eighteenth century, with his concept of the "invisible hand" of the market which would ensure the greatest welfare for all. It is "the philosophy which advocates the largest possible use of the forces of competition as a means of coordinating human efforts and achieving economic ends, and thus rejects most types of coercion and interference in economic life by interest groups or governments."[7]

Neoliberalism is a more recent resurgence of the same ideas, which became recognizable in the work of economists such as Hayek and Friedman.[8] Key writers in relation to developing countries include Balassa, Bhagwati, Krueger, Little, Scitovsky, and Scott.[9] "In one sense, this was, and is a return to the original project of asserting society against the state, the market against planning and regulation, the right of the individual against overpowering authorities and collectivities."[10]

Neoliberal policy prescriptions have guided or influenced policymaking in almost all developing countries during certain periods in the 1970s and, particularly, the 1980s and 1990s, with such prescriptions marking a changeover from earlier, more structuralist influences. Such a changeover has been strongly supported by agencies such as the World Bank and the International Monetary Fund, which have been

repositories of much neoliberal thought, and which have often made the introduction of neoliberal policy prescriptions a pre-condition for receipt of funding.

Components of the Industrial Policy Framework

The structuralist and neoliberal models are sometimes presented in an "either . . . or" context. However, as shown in Fig. 12.3, they are better represented as extremes on a continuum, with liberalization—the central policy prescription from the neoliberal model—being a process of change along the policy continuum away from the structuralist extreme toward (but not necessarily reaching) the neoliberal extreme.

Rather than viewing policy as a single homogeneous continuum we should, rather, recognize that it consists of a set of identifiable policy areas. Different authors choose different ways to categorize these various policy areas, but the most useful for the purposes of this chapter was seen to be that used by Weiss.[11] He highlights four main areas of industrial policy:

1. Trade: Inward-looking ---------- Outward-looking. This continuum is often treated as being equivalent to: Import substitution -------- Export orientation.

Understanding and use of this continuum has been clouded in theoretical terms because many writers use import-substituting industrialization (ISI) and export-oriented industrialization (EOI) as synonyms or near-synonyms for the structuralist and neoliberal approaches, respectively, while others treat the two continua as quite different. There has also been confusion in practical terms when trying to classify countries because one can classify in terms of trade or production or policy; because policies change; and because import-protecting and export-encouraging policies can exist simultaneously. The definitions to be used here draw on the work of McAleese, World Bank, Weiss, and Foley, and they treat inward-looking policy as a subset of the structuralist model and outward-looking policy as a subset of the neoliberal model.[12]

According to most versions of the neoliberal model, free trade is advocated because it would allow export production to fall into line with the international division of labor and with local comparative advantage; that advantage being primarily determined by the relative abundance of factors of production within the country. Although the more sophisticated versions of the outward-looking approach (such as some of Balassa's work) provide something of an exception, it would be generally true to say that outward-looking views have focused more on static comparative advantage (and other indicators), while inward-looking views have focused more on the dynamics of comparative advantage (and other indicators).[13]

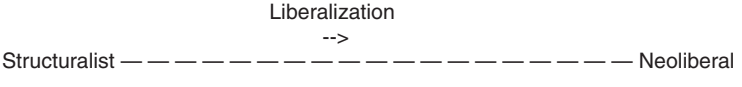


FIG. 12.3. The policy continuum

In the structuralist model, domestic production would receive some subsidy or protection as compared to imports, to ensure the build-up of skills and competitiveness and of long-term growth. In the neoliberal model, free trade would be the goal which, it is argued, would allow economies of scale, greater efficiency (including the X-efficiency gains of technical progress), and rapid industrialization.

It is also argued that, in the structuralist model, domestic market sales are the primary focus and receive higher aggregate incentives than export sales, whereas under neoliberalism there is neutrality such that aggregate incentives are equal.

2. Control of industry: State ---------- Market. This is, perhaps, the central element in the models presented above. The structuralist model argues that state intervention is necessary in order to overcome shortcomings inherent within a market system, including entry barriers, constraints, and imperfections. The neoliberal model argues that markets can guide decision making more efficiently than the state and that: "All direct state actions to promote industrialization (protection, licensing, reserved markets, subsidies to labour or other inputs . . . , state-led research and development) divert resources away from more ultimately profitable uses."[14]

It is generally seen within neoliberal writings that the state should withdraw from intervention in the supply of inputs, from the production process itself, and from demand for final products. "Variables with enormous influence upon long-run outcomes—technology, labour supply and quality, capital stock, natural resources and their replacement—are relegated, in these recent writings, to a category which will look after itself."[15]

3. Foreign investment: Anti ---------- Pro. The structuralist model, at least in its dependency form, argues that penetration of the local economy by foreign capital creates local trade and production patterns geared to the needs of elite groups in developed countries, and not to the needs of the mass of the local populus. The costs of this include overly capital-intensive production, specialization in primary product exports and unequal trade exchange. Such foreign investment, it is argued, should therefore be avoided or at least tightly regulated by the state. By contrast, the neoliberal model argues that foreign companies provide much needed inputs of capital, skills, and technology and it therefore welcomes foreign investment.

4. Ownership: Public ---------- Private. The structuralist model argues that private capital will not be attracted to certain industrial sectors which are important for the long-term growth of the economy, and that nonprofit development objectives will not be achieved by private industry. The neoliberal model argues that private ownership is the best guarantor of efficiency and growth.

The Indian Hardware Industry

The history of policy and industrial development from the 1960s to the 1990s in both of the main sectors of India's IT industry—inward-facing hardware and outward-facing software—will now be analyzed, beginning with hardware.

Indian hardware industry policy

The first computer was introduced into India in 1956 for use at the Indian Statistical Institute. Multinational corporations (MNCs) were allowed virtually free rein in the Indian computer market with the result that the market was supplied with outdated equipment that was all imported. Because India had no local base of computing skills, the Indian government had little choice but to agree to this situation.

As familiarity with the use and maintenance of computers grew in the late 1960s and early 1970s and as skills developed in complementary areas of electronics, the government felt confident to alter policy and severely restrict imports in order to encourage indigenous production. As a result, IBM decided to pull out of India. Production-related capabilities including design and manufacture were built up within the country but these remained confined to one public sector firm (Electronics Corporation of India Ltd—ECIL).

By the late 1970s, though, it became clear that ECIL's machines were just as out-of-date as those of IBM, but that they broke down more often, cost more, and took up to 2 years to deliver. As a result, import protection was maintained but industrial licensing was liberalized, with several private sector firms being granted licenses for the manufacture and sale of small computers. ECIL's market share fell to 10 percent by 1980, but overall demand was boosted by an increase in government and public sector purchasing.

Slight import liberalization in 1983 was succeeded by the true emergence of India into the computer age through three events. First, the arrival in India of IBM-compatible personal computers (PCs), and second, the arrival of Rajiv Gandhi as Prime Minister, with his great interest in computers. Third, the 1984 New Computer Policy, which signaled a substantial liberalization of import policy on complete computers, computer kits, and components (though policy was never completely liberal).

During the late 1980s, most computer industry-related policy remained stable. However, import policy did change because of concerns about the impact of earlier liberalizations, some backlash from local firms adversely affected by liberalization, and changes in the political economy of the state. As a result, there was a steady reversal of some earlier import liberalizations, so that policy at the end of this period was a compromise between the relative extremes of mid-1970s protectionism and mid-1980s liberalization.

Following the Indian economic crisis of 1991, computer industry policy was subject to a broad set of liberalizations—fewer financial or bureaucratic limits on foreign investment; greater freedom of access to foreign exchange; automatic approval for many types of technology transfer; removal of government licensing for all new, expanding, and merging units; industrial registration requirements largely removed; locational constraints removed; new companies exempted from the requirement for steadily increasing levels of local component use (the phased manufacturing program); reduced control of companies covered under the

Monopolies and Restricted Trade Practices (MRTP) Act; increasing use of unlicensed (Open General Licence—OGL) import; and reductions in import duty, import bureaucracy, and excise duty.

Nevertheless, policy was not completely liberalized. Licenses were still required for import of some types of computer, and import tariffs on a range of computers and computer-related components remained in place, albeit at historic lows. Government/public sector purchasing also continued to form the major part of demand, and hardware exports were promoted through the Electronics and Hardware Technology Park scheme.

Analyzing hardware industry policy

In very broad terms, one can summarize Indian hardware policy as shown in Fig. 12.4. However, this very broad picture is not adequate for a full understanding of policy and policy changes, which need to be broken down into the areas of industrial policy noted above.

Inward-looking ---------- Outward-looking. As regards import duties and quotas, policy was protective in the 1960s and heavily protective throughout the 1970s. There was a gradual liberalization in the early 1980s, strong liberalization in 1984, followed by a gradual reversal, so that the situation at the end of the 1980s had reverted to a position similar to that held at the start of the decade. In terms of tariffs and licenses, the liberal nature of changes in the 1990s must be placed in the context that most late 1990s tariffs were similar to those of the mid-1980s, though licensing was relaxed. Procedural measures relating to hardware trade were gradually liberalized during the 1980s and 1990s.

Export incentives were present for the hardware industry but these have not been seen as very important because, by contrast with their "facing out" software counterparts, the Indian hardware industry and policy focused almost exclusively on the domestic market since their inception. Even during the 1990s, when policy began to stress exports more, the industry was still almost entirely domestic market-oriented.

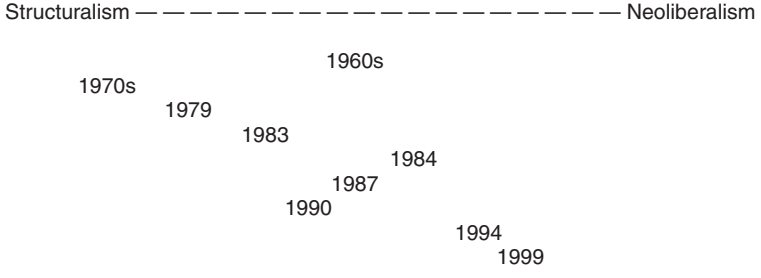


FIG. 12.4. Summary chronology of Indian hardware policy

State ---------- Market. Government regulatory intervention in the industry increased during much of the 1970s, but then steadily decreased from its peak in the late 1970s, reaching a trough in 1984 (though the state still retained a large measure of control even then) before increasing very slightly toward the end of the decade, and then dropping away from 1991. Alongside this change, the state has played a continuous and very important role in its supply-side interventions in skills, R&D, training and investment, and in its demand-side interventions in purchasing policy.

Anti-foreign investment ---------- Pro-foreign investment. Foreign investment in the Indian computer industry was encouraged in the late 1950s and early 1960s, strongly discouraged during most of the 1970s and early 1980s, encouraged again in the latter part of the 1980s and even more strongly encouraged since the early 1990s.

Public ownership ---------- Private ownership. Little role for public sector companies was envisaged in the early days of the computer industry, but this rapidly changed to a desire for the public sector to have the leading role in the 1970s. After that, the public sector has always been felt to have a role but the private sector was unquestionably to form the major part of the industry.

In summary, despite some reversals in import policy, the dominant theme of the 1980s and 1990s in hardware policy was liberalization which initially "shifted the industry from a regime of government controls and regulations to a liberalised one wherein emphasis is laid on minimum viable capacity, scale economies, easier access to foreign technology, relatively free entry to the private sector (including monopoly houses and FERA [*multinational*] companies), with a view to make the industry modern, cost effective and competitive."[16] It then shifted further still, to emphasize foreign technology even more and to de-emphasize local production.

Indian hardware industry outcomes

A specifically Indian hardware industry only began to take off at the beginning of the 1980s, since when it recorded dramatic growth in terms of units of production, growing from less than 1000 computers produced in 1980 to nearly three-quarters of a million per year by the end of the 1990s. Price ratios have fallen: Indian computer prices were more than seven times international prices at the start of the 1980s; by the late 1990s, they floated between 10 and 50 percent more expensive. Technological lag has been removed: Indian firms introduced new microprocessors roughly 4 years later than US firms in the early 1980s; by the late 1990s, there was no discernible delay.

All of these outcomes increasingly favored Indian consumers of IT, but what of the effect on the Indian producer firms? To understand this, one must look beyond simple quantitative measures at more qualitative data. Lall identifies "technological capability" as a crucial determinant of industrialization, yet one which is ignored by most quantitative researchers.[17] Although this variable does not lend itself to outright measurement, some kind of scale can be drawn up for the technological capability of IT producers, as shown in Table 12.1.

Table 12.1. *Scale of general technological capability*

Level 1: Nonproduction operational capabilities
Using the technology
Choosing the technology
Training others to use the technology
Level 2: Nonproduction technical capabilities
Installing and troubleshooting the technology
Level 3: Adaptation without production
Modifying the finished product to meet local consumer needs
Level 4: Basic production
Copying technology
Assembling technology
Full production using existing products and processes
Level 5: Minor production modification
Modifying the product during production to meet consumer needs
Modifying the production process to meet consumer needs
Level 6: Production redesign
Redesigning the product and production process to meet local consumer needs
Redesigning the product and production process to meet regional/global consumer needs
Level 7: Innovative production
Developing a new product to meet local consumer needs
Developing a new product to meet regional/global consumer needs
Developing a new production process
Transferring a production process to other producers

Source: Adapted from Narasimhan (1984), Lall (1987), and Schmitz and Hewitt (1991).[18]

Following Lall, one may define technological capability as the general ability to undertake the broad range of tasks outlined in the table, and technological development as growth in the capability as defined by movement up the categories and regardless of whether or not the final stage is attained. These capabilities are actually embodied in the skills and experience of individual workers, often seen as the most critical resource for IT industries.[19] In this case, technological development will be the accumulation of increasingly skilled workers.

Using this scale, one can identify three main types of firm operating within the Indian hardware industry.

Assemblers. These are companies which import the component parts of a computer, assemble them in India, and then sell the unit under their own name. They came

into existence thanks to import liberalization in the mid-1980s that allowed computer kits and components to be more readily imported and, in terms of company numbers, they have dominated production.

There is quite a range of capabilities within this group around level 4 indicated in the table. At worst, the computer will be imported as a semi-knocked-down kit from Taiwan, assembled in less than half an hour using a screwdriver, and then sold. Most of the companies are of this type. At best, the various components (processor, monitor, disk drives, keyboard, casings) will be sourced from different suppliers, possibly including some local ones. Assembly then consists of component insertion, flow soldering, and limited functional testing. In either case, the capabilities are greater than those of trading companies and it is possible that assembly can form the base on which companies build up to higher capability levels. However, this type of progress has been limited in practice.

Design innovators. These are mainly firms, which built up design capabilities around level 5 in the late 1970s and early 1980s during the period of strong protection from imports. The group differentiated after 1984. Some smaller firms found themselves unable to compete or invest effectively against imports. They shifted to assembly type production and to agency collaborations, and moved design staff into simpler jobs, into marketing, or lost them to companies with substantial R&D teams. As a result, these companies slipped well down the "league table" of producers and of technological capability.

On the other hand, a number of larger firms that built up skills during the early 1980s were able to maintain those skills during the "dormant" period of the mid-1980s and then reassert them up to levels 6 and even 7 during the late 1980s and early 1990s. Such a process helped these companies maintain their dominant position in the Indian market. They even managed to become global innovators in some niches, producing the world's first Intel 486-based computer; first multiprocessing board superminicomputers; first Reduced Instruction Set Chip (RISC)-based multiprocessing minicomputer; and first Motorola-based multiprocessing Unix minicomputer. They also began exporting such machines or their designs, even to the US market.

However, after the early 1990s, design innovation skills began to ebb away with the growth in demand for, and availability of, foreign brands. For example, one of the leading innovators, DCM DP, performed strongly until the end of the 1980s but was then badly affected by internal wranglings and, after the liberalizations of 1991, began to move out of innovation and manufacture into trading. It changed its name to DCM Data Systems and its R&D unit was converted into a Technical Services unit providing consultancy work. Zenith—another innovator of the 1980s—likewise transformed its R&D department into a marketing and technical support division. Minicomp—without a foreign brand tie-up—became just a small assembly firm.

After tying up with Hewlett-Packard, staff in the R&D division of HCL (India's largest IT firm) were transferred to work on HP research projects. Second-placed

WITL similarly tried to hire out its R&D facilities to multinationals. Some R&D capability remained—as evidenced by the production of the HCL Meteor and WITL Synergy hardware range in the mid-1990s—but came under pressure from competing products produced by multinationals with whom the Indian firms now had a tie-up (HP and Sun or Acer, respectively).

Staff from these firms saw a shift from "fundamental R&D" to "value-added R&D"; the latter meaning systems integration for specific customers or, at best, some hardware and software customization. Harindranath therefore draws the pessimistic conclusion: "Liberalisation, and the accompanying globalisation, has done away with any incentive for investing in R&D or manufacturing. The R&D investments that some Indian firms used to make have become irrelevant, unviable and even unnecessary with liberalisation since 1991, and the consequent easy access to state-of-the-art technology."[20] R&D strength only remained in still-protected areas. For example, thanks partly to the US government's earlier block on export of a Cray supercomputer, at least four Indian parallel processing supercomputers had been designed and built by the late 1990s.

Collaborators. These are Indian computer companies which import much of the technology for the computers they produce. They import it from a foreign hardware firm with which they are in collaboration. The number of such computer collaborations rose sharply, from less than 10 in the early 1980s to more than 100 in the late 1990s. The rise was driven by pull from Indian firms, seeking collaboration as a way to access new technology more quickly and with lower risk than by investing in their own R&D. It was also driven by push from IT multinationals, seeking to ensure their products are well-promoted and well-supported in the burgeoning Indian IT market.

Given the background of many collaborating companies in trading or assembly, it is not surprising that their technological capabilities were generally lower than those of design innovators. As a generalization, one can say that many collaborating firms lay between assemblers and design innovators on a scale of technological capability.

Capabilities in agency operations were largely restricted to software services, while R&D in other types of collaboration was more limited than that of the design innovators. From research surveys,[21] it appeared that there were fewer R&D workers in collaborating companies and that they were oriented more toward local sourcing of components, and toward the development of applications software and other adaptations to local conditions rather than toward design innovations. The work of one such company in the late 1980s was typical: "We are not involved in any basic developmental work in the strict sense of the word . . . Rather we would like to look at a product and see what enhancements we can offer, by way of system software, operating systems, ruggedization, etc."[22]

These collaborating companies therefore relied on the R&D carried out in developed countries and embodied in imported technology more than on their own efforts. Because of the opportunity costs of this form of production within a

technologically capable industry and the competition with more capable local firms, collaboration has therefore tended to reduce the average extent of local design and (R&D) work.

The Indian firm PSI's R&D capabilities were reduced to just a handful of systems integration staff when it was taken over by the French computer company Bull and, as noted above, HCL's capabilities were redirected after the HP tie-up. The major expansion of agency operations in the 1990s only served to strengthen this overall reduction in capabilities.

In summary, there are signs that—largely thanks to liberalization—the Indian computer industry swung full circle back to the days of the 1960s. Foreign tie-ups, foreign brand names, and access to the latest imported technology were once again the order of the day by the late 1990s. Consumption, not production, was again the focus, and most so-called Indian "computer" companies actually just produced software for integration with imported hardware.

Of course, there were differences to the earlier period. In those days, there was no production of any kind within India. By the year 2000, at least, there was significant hardware production and a few exports in an industry that employed many thousands of people. Thanks to the creation of local capabilities during import protection, at least some of the MNC tie-ups were closer to partnerships than dependent relationships. Nevertheless, the year 2000 situation was very similar to

Table 12.2. *Models within the Indian computer industry*

Period	Dominant model for trade	Dominant model for consumption/ production	Dominant model for ownership	Best level of local technological capability
1960s	Imports	Consumption	Multinationals	Level 1: Use
1970s	Import substitution	Production	Public sector	Level 4: Basic production
Early 1980s	Import substitution	Production and consumption	Private sector	Level 5: Minor product modification
Mid-1980s	Imports	Consumption	Private sector	Level 6: Production redesign
Late 1980s	Imports, import substitution, and some exports	Consumption and production	Private sector and multinationals	Level 7: Innovative production
1990s	Imports and a few exports	Consumption and some production	Multinationals and private sector	Level 5: Minor product modification

that of earlier years, as summarized in Table 12.2, and increasing liberalization seems to bring increasing similarities.

Overall, the Indian computer industry was in danger of having traveled a very long way to get not very far. Both government and industry were in danger of losing their nerve in the face of the perceived momentum of consumption and liberalization, running the risk that carefully nurtured capabilities would be destroyed and that a separate Indian hardware industry would become a thing of the past.

The Indian Software Industry

Indian software industry policy

A policy for the Indian software industry has existed since 1970, with a particular and continuing emphasis on software exports. For its first 10 years, the policy focused on three main areas: helping software exporters get easy access to imported computers, boosting software education and training, and encouraging location of software firms in export processing zones.

The early 1980s were marked by policy tightening after it became clear that imported computers were being leased or sold on and not used much for software export. The 1984 Computer Policy relented, however, and made imports of hardware and software, entry into the software industry, and access to foreign exchange easier. It was followed by the 1986 Software Policy that boosted the rhetoric and imagery of the software industry while mainly tinkering with policy components.

A fallow period for policy in the late 1980s was followed by renewed liberalizations throughout the 1990s that affected a broad range of policy areas, most of which were described above in the history of hardware policy. At the same time, though, the government also strengthened its promotional interventions, particularly in support of software exports.

Analyzing software industry policy

Inward-looking ---------- Outward-looking. There has been some degree of liberalization. The process has been strongest as regards software imports, which were delicensed in 1986, though the tariffs later increased before substantially decreasing. Hardware imports for software production remained linked to a government certification system but there was a good deal of procedural and tariff liberalization from the 1970s, despite the reversals of the early 1980s.

As regards the export incentives recommended by the neoliberal approach, these were present for some time in the form of cash compensatory support, foreign exchange permits, and export obligations. Economy-wide measures such as export unit incentives, exchange rate devaluation and convertibility, and tax concessions on export earnings also apply to software exports. These have shown mixed changes. Software-specific measures became rather less liberal during the first part

of the 1980s, while general measures became rather more so and largely replaced software-specific ones in the 1990s.

State ---------- Market. Contrary to the prescriptions of liberalization, there was an increasing role taken by the state in the provision of finance, skills, infrastructure, legal regulation, and marketing assistance, particularly since the mid-1980s. There have also been continuous interventions in the form of procurement of custom software from local companies. By contrast, there was a significant liberalization of controls over industrial entry and production capacity in 1984.

Anti-foreign investment ---------- Pro-foreign investment. Both the 1984 and 1986 policies contained measures aimed at encouraging greater foreign investment in the Indian software industry, and procedural barriers were decreased. Post-1991 changes were in line with general liberalization.

Public ownership ---------- Private ownership. While there have been claims of some policy implementation favoritism toward India's two major public sector software producers, there were no significant policy measures aimed at increasing or decreasing their role. The software industry is, and has always been, dominated by the private sector.

In summary, judging the changes in software policy over the past 25 years, one can talk only in loose terms of a broad trend of liberalization rather than the reverse, because the trend has been patchy and has progressed quite far in some areas, yet hardly at all in others. Summarizing the situation in the late 1990s, one can draw the following description of policy areas:

- Liberal: Controls on industrial entry and production capacity
- Fairly liberal: Software imports; export incentives
- Partly liberal, partly controlled: Foreign collaboration; hardware imports
- Not very liberal: Interventions on finance, training, infrastructure, legal regulation, marketing assistance, software procurement.

By comparison with the majority of industrial sector policies in India, however, software industry policy has been much more liberal and much more export-oriented.

Indian software industry outcomes

What was the outcome of this "facing out," export-focused policy? By any standards, the growth of India's software exports has been phenomenal. Exports began in 1974 but made limited impact until the 1980s. From that time on, growth rates have been consistently high, as Table 12.3 illustrates.

However, all is not quite what it seems. This industry has been characterized by an uneven export profile along several dimensions:

Uneven output: Services not packages. Indian software exports have been dominated by export of software *services*, in the form of custom software work, rather than

Table 12.3. *Indian software exports and growth rates (1980–1998/99)*

Year	Software exports (US$ in million)	Growth rate (%)
1980	4.0	
1981	6.8	70
1982	13.5	99
1983	18.2	35
1984	25.3	39
1985	27.7	9
1986	38.9	40
1987	54.1	39
1988/89 (Apr–Mar)	69.7	29
1989/90	105.4	51
1990/91	131.2	24
1991/92	173.9	33
1992/93	219.8	26
1993/94	314.0	43
1994/95	480.9	53
1995/96	668.0	39
1996/97	997.0	49
1997/98	1650	65
1998/99	2,180	32

Source: Heeks (1996); Dataquest (1999).

export of software *products*, in the form of packages. This helps explain the rise in growth rates. This rise partly took place in the late 1990s because of the explosion of services work on the "Year 2000 problem"; then estimated to make up nearly 40 percent of current software export work from India. By contrast, at the very most, just under 5 percent of exports came from packages in the late 1990s.[23]

Uneven locational divisions: Onsite and offshore work. Much of India's export work developing custom software is actually carried out at the client's site overseas ("onsite") rather than offshore in India. Back in 1988, an average of 65 percent of export contracts were carried out wholly at the client site, while 35 percent contained *some* offshore elements.[24] This translated into just under 75 percent of Indian software export development taking place overseas and only 25 percent in India. This was even true of work in India's export processing zones, which were intended to be bases for offshore work.

Subsequent surveys have shown that the amount of work carried out offshore increased within individual firms. The trend is particularly noticeable in the subsidiaries of multinational firms. However, a significant amount of onsite work remained within the industry overall so that, by the late 1990s, it was still true that

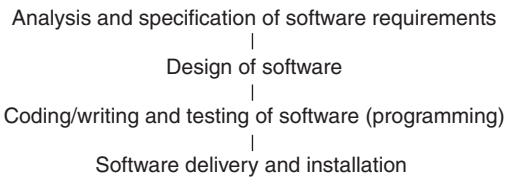


FIG. 12.5. Software production stages

more than half of all software services export earnings came from onsite work.[25] This forms the basis for an international *locational* division of labor within India's software export trade.

Uneven skill divisions: Dominance of programming. Software development is usually seen as being broken down into a series of relatively standardized production steps, as shown in Fig. 12.5.

Software production overall is a skilled task, but this fragmentation forms the basis for a skill division of labor because the earlier stages of analysis and design require higher levels of skill and experience, whereas those of coding and testing are relatively less skill-intensive but more labor-intensive.

During the period 1988–99, at least 65 percent of export contracts were solely for programming work billed on a "time and materials" basis, with programming figuring strongly in the remaining one-third of contracts.[26] As with offshore work, there have been changes within individual client–contractor relationships, but there has been much less change within overall industry averages.

So, in general terms, India's software export trade has been characterized by an international *skill* division of labor such that the majority of software contracts allocate only the less-skilled coding and testing stages to Indian workers. That is to say, Indian workers have far more often been used as programmers, working to requirements and design specifications set by foreign software developers, rather than as systems analysts or designers. In the Indian context, the combination of onsite and programming work has come to be known as "body shopping."

The result of these skews and the single-minded focus on exports has been to create an "export enclave" in which skills and technology only trickle down into the domestic market, rather than flooding in, as had been hoped.[27] Staff working on export projects were far more likely to move on to a Green Card than back to domestic market work. India therefore lost around 15 percent of its software workers every year, largely to the United States.[28] On the one hand, this diaspora helped to bring new export work to Indian firms. On the other hand, some such firms hemorrhaged staff so fast that they "ran in order to stand still," undermining their attempts to move up the value chain.

Even money became partly enclaved. Much of India's export earnings leaves the country to pay for: Travel and living allowances of Indian software staff working onsite, marketing expenses, multinational profit repatriation, and importation of

hardware and software used for India-based contract components. The "headline" figures reported above represent gross earnings, but net income is estimated to be only 40–50 percent of the gross figures.[29] Finally, opportunities must be set alongside opportunity costs. Putting India's brightest software stars to work on applications that boost the growth of foreign firms and foreign economies incurs a large opportunity cost when applications to meet the many pressing domestic needs are consequently sidelined.

This sidelining of the domestic market can be seen quantitatively: It would appear that exports grew from something like one half of all Indian software production in the mid-1980s to around three-quarters of overall production by the late 1990s.[30] These figures take little account of in-house domestic software production, of software sales that are "bundled" with hardware, of software piracy, and of the lower value of domestic software products and contracts compared to exports. Despite this, it is clear that the domestic market has been neglected by the mainstream software industry in comparison to exports; that this industry's production is greater in exports; and that a lower priority has been afforded to the domestic market: "There has been an overwhelming preoccupation with software exports to the detriment of a viable domestic software industry."[31]

In summary, India's software industry has made tremendous achievements in terms of export growth, earnings, and generation of both skills and employment. Nevertheless, any analysis must root itself in realities, not hype, and recognize that such a path has brought costs as well as benefits.

IT Policy conclusions

On the basis of analyzing India's IT industries, one can draw a number of conclusions about IT policy. Before doing this, however, a couple of general points will be made. Firstly, in terms of measuring IT industry development, it is clear that one must look beyond the surface figures—the macroeconomic indicators—in four ways:

1. Wider in a quantitative sense, to take into account not just output and profits but also measures such as price ratios and technological lag.
2. Wider in a qualitative sense, to look particularly at people and their related technological capabilities.
3. Deeper within the experiences of real, individual companies to see how they perform and what goes on inside them.
4. Dynamically, so that the dimension of time is added, providing a sense of history and a sense of trends, which static, cross-sectional measures cannot provide.

Second, despite the importance of policy, we must recognize that an understanding of industrial development cannot be based on state policy alone because the relationship between Indian government policy and industrial development has been only a partial one, such that policy is not the sole or direct cause of many observed

developments. A number of factors which lie outside the realm of local IT policy and which affect industrial development are described below:

Foreign government policies. Other countries' policies, especially those of the US government relating to exports and visas, have affected imports and the extent of offshore software development in India.

Technology. The technology involved and the process of technical change have been important determinants of the type of IT production undertaken; of the price of IT in India and, thus, their use; and of entry barriers into production. For example, technology imports have been raised and small firm production entry barriers lowered because of the advent of microcomputers and of more automated programming tools. The relation between software and hardware technology has also been a significant force shaping the development of the Indian software industry and its foreign collaborations.

User–producer relations. The relations between producers and consumers of software have played an important part in determining the nature of the international division of labor; the growth of both exports and collaborations; and even the level of technology imports. Such relations need to go beyond just trading because they require the integration of separate services and goods into a final product, and an understanding of corporate needs; and because they require an assurance of access and control over skills, products, and production of adequate quality.

Markets. The Indian IT industry's development has also been shaped by the nature of the markets it seeks to address and from which it seeks its inputs. The growth of both hardware and software industries remains crucially dependent on the size and state of their respective local and global markets. In relation to both export- and domestic-oriented production, these markets are not "free" but contain barriers, which prevent entry into certain types of production, and constraints, which prevent changes in the pattern of industrial development. For example, barriers and constraints relating to trust, skills, and technology have helped to produce and maintain the international divisions of software labor already described.

The limitations of IT industry policy must therefore be recognized. Because of the "non-policy" factors described, policy cannot precisely guide an industry's development, particularly when many of the firms are private sector and therefore more removed from government control than public sector firms. Additionally, policy prescriptions must be based on an adequate understanding of the markets within which the industry is operating, and of the nature of the technologies involved, of user–producer relations, of the macroeconomic setting, and of foreign government policy.

Nevertheless, one must not go too far here. Policy has been an important determinant—probably the single most important determinant—of developments in hardware and software production within India. During the 1970s and 1980s, even when liberalizing, the government retained strong control over imports and other activities and even in the late 1990s, it remained a powerful influence. Indeed,

throughout the history of India's IT industries, it is changes to government policy that have been the dominant factors delineating the changing phases and nature of those industries.

Learning from Indian Hardware: The Importance of Import Policy When "Facing In"

The impact of import protection

One of the catch-phrases used by those in favor of liberal imports is "let us not re-invent the wheel." They argue that it is wasteful to try to develop technologies locally when such technologies could more quickly and cheaply be imported. This outlook takes only a static view of the situation and it also neglects India's experience in the 1960s, when the lack of local production capabilities left the country dependent on imports of outdated equipment from multinationals.

The protection from imports offered between 1972 and the early 1980s allowed Indian firms to re-invent a few "wheels" by reverse engineering foreign products. As a result there was a build-up of indigenous production and indigenous technological capabilities, particularly design capability. "The consequences of a policy of protecting not just production, but also 'know-why' is that India has developed a capability to both manufacture and design a wide range of industrial products."[32]

Local firms therefore gathered strength during this sheltered period and it is this, more than anything else, which provided the base for the impressive growth and design innovation seen in a few large firms. Protection, and the consequent increase in technological capabilities, also helped to reduce technological dependence on the multinationals and to compensate for Indian firms' difficulties in achieving scale economies through exports. "For most developing countries, a certain amount of protection would appear to be necessary to counterbalance the enormous technological and cost advantages enjoyed by the computer industries of the advanced industrialized countries."[33]

There seems little doubt that government intervention to protect industries which are "facing in" helps indigenous technological capabilities to grow, and that technological capabilities in a new industry will not grow without some protection.

In the 1980s and 1990s, it was only where protected from imports (and the foreign collaborations that bring them) that Indian companies were able to develop hardware development design skills. If, instead, India had continued to rely on foreign imports—as it was increasingly doing in the 1990s—it is hard to see how local production capabilities could have been built up.

The impact of import liberalization

There are signs that Indian producers were becoming more efficient and were building more up-to-date, competitively priced products during the early part of

the 1980s. Had policies remained the same, it is possible that the producers would have carried on competing and improving behind the barriers of import protection.

However, the computers produced at that time were more costly and less up-to-date technically than world standards. The combined arrival of the IBM PC and of Rajiv Gandhi as Prime Minister shifted the focus from the benefits of protection for local production to the costs of protection for local consumption. The dominant concern came to be that import protection was allowing the Indian industry to be insulated from global technological progress and efficiency levels. Imports of both components and computers were duly liberalized.

Introducing import liberalization into this inward-facing, import-substituting industry allowed the massive increase in demand to be met largely by direct imports, by import and assembly of computer kits, by foreign collaborations, and by a large outflow of foreign exchange. All of these had a role to play in the suppression of local R&D and of local technological capabilities, and the evidence suggests that the same thing was repeated in the latter half of the 1990s.

What local production and capabilities there were during the earlier period remained partly through continuing protection. Only those firms with technological capabilities that predated the major import liberalizations still had those capabilities in the late 1980s and early 1990s, though protection also encouraged some level of capabilities in assembly and collaborating firms that might not otherwise have arisen.

As already discussed, import liberalization did help to bring some benefits to consumers; and it may have had a positive effect on those firms with preexisting capabilities which survived the mid-1980s. The director of one such company stated that there had been benefits in import liberalization in that his company and others like it "are now more alert to competition, to advances in technology, etc."

This therefore suggests the possible utility of some kind of phasing of import policy, with import liberalization following import protection. However, two points are worth making. First, it is widely seen that import liberalization in the mid-1980s went too far, with subsequent policy reversals showing that "the Government is tacitly accepting its mistake in opening the import-window rather too wide."[34] There are similar concerns about the liberalizations of the 1990s.

Second, any benefits to design innovators were more from liberalization of component imports, which they could use to upgrade their systems, rather than kit and complete systems imports, which merely provided direct competition. Any impetus from such competition and from technology upgradation gains must be set against the skills loss in those firms which gave up design innovation in the mid-1980s and against the impact of component liberalization on the component industry. Although this research did not include a detailed qualitative survey of the Indian component industry, it seems certain that component-related capabilities were suppressed by imports.[35]

Overall, then, one can take no simple, polarized view of either foreign collaboration or import liberalization. Many Indian companies have sought and welcomed collaborations. Collaborations may also form the basis for some build-up of technological capabilities but they have more often been associated with a loss or

stifling of such capabilities. Similarly, import liberalization has produced a form of growth but also a type of dependence, with improvements in consumption-related factors being matched by growing dependence on foreign sources of technology and innovation, and a lack of local capabilities: "More liberal policies have assisted the growth in consumption, but have not really helped develop the technology *per se*."[36]

Fortunately, in earlier times, the Indian government never permitted complete import liberalization, always retained some protection, and reversed liberalizations once their negative implications became clearer. In the late 1990s, however, this no longer appeared true, and the dangers of existing and future liberalizations were considerable.

The impact of nonimport policies

Though import policy has been a key part of government efforts to build an indigenous hardware industry for India, complementary policies also matter. Controls on foreign firms and imports need to be supported by promotional measures to encourage local adaptation of imports and local R&D. By the same token, government intervention to promote the development of local capabilities is never more needed than during periods of import liberalization.[37]

The coupling of government demand policies with some level of computer import protection has been central to the growth of production within India, offering additional demand, demonstrator effects to the private sector and learning opportunities for some Indian IT companies.

As well as the complementarity of other policies, the phasing of such policies may also be important. For example, many writers feel that a period of strong domestic competition needs to come before any import liberalization.[38] This was the case in Indian hardware policy with the major relaxations in industrial licensing preceding import liberalization by several years. "The experience of the Indian computer industry demonstrates that a protection against foreign competition has to be accompanied by a high level of domestic competition."[39]

This combination has been beneficial, with the competition encouraged by licensing liberalization in the late 1970s coupled with some protection leading to consumption benefits and the build-up of computer-related technological capabilities, which were so important to India's hardware industry during subsequent years.

Learning from Indian Software: The Importance of Promotional Intervention When "Facing Out"

India's software export orientation has been built on relatively liberal government policies in a variety of arenas, including state controls and imports. However, a simple message of "liberalization is best" should not be taken from this case study. This industry's past success and its future ability to break away from

"body shopping prison" have been equally dependent on a series of government promotional interventions in areas that include:

- *Finance*: Intervening to stimulate the supply of working and venture capital.
- *Education and training*: Acting as the prime source of fundamental skills relevant to software industry development.
- *R&D*: Investing in basic software research and in customization to local needs.
- *Marketing and market information*: Particularly providing help to small and medium software enterprises, which do not have the scale economies of larger Indian firms.
- *Intellectual property rights*: Providing the legal framework that goes hand-in-hand with maturation of a software industry (though piracy has more to recommend it as a strategy for developing countries than is often admitted).
- *Infrastructure*: Investing in India's local and overseas telecommunications infrastructure.
- *Procurement*: Acting in its role as the most important single consumer of Indian software to influence the direction of industrial development.

These promotional measures have at times been delayed in their implementation and characterized by interagency bickering, and there is obviously room for improvement. For example, there are arguments for more and better: More financial procedures matched to the software industry's particular functioning; better supported private sector training and R&D; more industry-oriented public sector training; more (and cheaper) infrastructure; more company-centered marketing; more action on piracy; more firms given public contracts; better (and quicker) bureaucratic procedures; and so on.

Nevertheless, the government has also shown itself to be iterative in its approach, responding to the shortcomings of previous interventions and to the changing needs of the software industry. Many of the interventions were introduced since the thrust to software industry growth in 1986. In them, it can be seen that the Indian government has addressed itself to the fundamental problems affecting this industry's development, particularly the uneven output profile already described. In addressing these problems, the government has adopted an industry-specific approach, increasingly gearing its responses to the particular needs of software development rather than those of Indian industry or the Indian IT industry as a whole.

One interesting aspect of the interventions is that many of them have centered around a series of organizations that have been created or are owned by government but which have been partly autonomous from government and more responsive to industrial needs, with some of them being governed by a joint industry–government board. Even the Department of Electronics (DoE), which oversaw policy until the turn of the century, was more technocratic than bureaucratic and had a relatively positive relationship with Indian industrialists, amongst whom "few see the DoE as hostile and most would admit that the DoE is quite different from the traditional

Indian bureaucracy."[40] The existence of such organizations which differ from the longer-established, more bureaucratic structures within the Indian government may be an important element in the success of interventions.

As Evans notes, the state can have three roles—regulator, promoter, and producer.[41] For much of its post-Independence history, the Indian government focused on the first and third roles. Since the late 1980s the DoE, particularly, led the way in software to a new model which may apply to the whole of Indian industry in the twenty-first century, focusing far more on promotion and support of industry than control and ownership.

Interestingly, a similar "new model" may be seen in the activities of the World Bank. The Bank has been closely involved with the development of the Indian software industry since the late 1980s, funding and supporting a number of the interventions described including elements of finance, education, and marketing. Far from adhering to the stereotyped image of ideological demagogues to whom government intervention is anathema, Bank staff involved have taken a much more pragmatic line to provide help with what the industry itself needs rather than what neoliberalism dictates it should have. "Specific measures within a coherent policy framework will be required to accelerate the development of the software industry."[42]

Earlier, the neoliberal model was shown to argue that the state should not intervene in demand for final products or the supply of inputs, because these will develop "naturally" as the industry develops. The conclusion to be reached here is that what has developed is a series of demand and supply constraints, and that government intervention has played a positive and necessary role in trying to overcome these constraints and in the overall development of the Indian software industry.

The neoliberal model is further discredited because of its unidimensional view of state policy as only economic, and its requirement that the state's economic role should be minimized. Here, the state has been shown to be a multidimensional actor that intervenes with economic instruments, but which also intervenes in financial provision and planning, skill formation, infrastructural and institutional construction, the planning of R&D, as well as in direct software procurement.

However, liberalization and increased government intervention should not be seen as mutually exclusive. They have coexisted in the development of the Indian software industry and, indeed, liberalization produces a requirement for greater intervention. Similarly, intervention has been seen as an integral part of the export-oriented, "facing out" strategy adopted for software by the Indian government, with the growth in exports requiring a growth in government promotional interventions on skills and infrastructure and, to a lesser extent, finance and marketing. This further undermines the simple association of continua suggested earlier since state interventions have now been seen to be part of export-oriented strategies.

Finally, one must note that the promotional intervention strategies like those described above are all well and good, but that they only emerge or sustain when there is a national vision to go with them. India now bestrides the software scene as

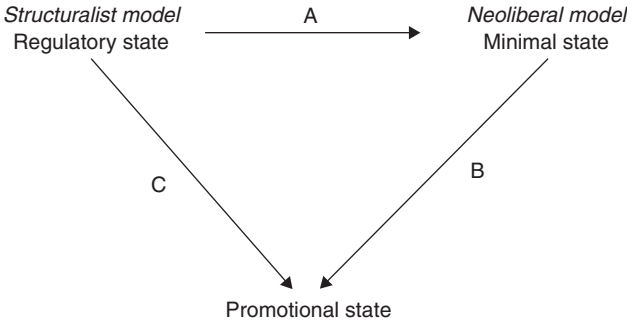


FIG. 12.6. State roles and developmental paths

a Third World colossus thanks to a 30-year dream of software exports, shared by bureaucrats and industrialists alike but carried forward by some key visionaries.

One may finally conclude from the experience of the Indian software industry that the argument should no longer be one of "State versus Market" but a question of how to achieve the most from state and market working together. The continuum of importance here is not that which runs from "All State" to "All Market" but that which runs through a spectrum of different state responses to private industry (and autonomous public enterprises):



Neither a completely state-owned nor a completely market-led approach to the IT industry will create the conditions required for long-term industrial development. Yet, with alternatives to the market being too rarely presented, many countries are being pushed under pressure of structural adjustment along a path from the regulatory state to the minimal state (path A in Fig. 12.6).

This seems most likely to occur in countries where policy has been guided more by ideology than pragmatism; where politicians, business people, and the public are accustomed to seek simple solutions; where an inferiority complex predisposes the government toward external policy models; and where there is a continuing belief in the autonomous power of the state. In these circumstances, policy may flip from one ideology to another—from overactive embracing of state to overactive embracing of market. There is likely to be a long and wasteful process before these states recognize the need to change once again and move along path B.

Generalizing the Indian Experience

This mention of other countries should be a reminder that India is by no means a typical developing country. As noted above, its government has devoted many years to building an industrial and skills infrastructure, and it has therefore been able to

make choices that would not be open to other countries. This ability is reinforced by the size of the economy and population which has permitted strategies of "facing in" and resistance to multinationals that are not open to many other nations.

However, the lessons here are not unique to India. There is similar evidence—about the value of protection and of promotional interventions in developing technological capabilities—from the IT industries of countries including Brazil, China, Japan, and South Korea.[43] Thus, while other nations will not be able to copy the Indian experience exactly, they can still take on recommendations relating to:

1. Encouraging the growth of local IT firms through demand- and supply-side promotional interventions.
2. Providing policy protection where possible and recognizing the "natural protections" offered to some IT products (especially software) due to local languages, legislation, and business procedures.
3. Assisting local firms which are negotiating with multinationals by sharing experiences, by transferring negotiation skills, and by providing a strong legislative framework for agreements.
4. Recognizing the importance of a long-term vision of technological and industrial development.

Having said this, two final caveats will be made.

Hardware and Software Industries as Priorities

The prospects for creation of a viable and independent hardware industry in many developing countries seem limited, at least in terms of mainstream computer production. Therefore, other countries are not likely to be able to start where India started. Instead, they have to start where India was at the turn of the century, where the best that can be hoped for is some arrangement with an existing IT multinational. This might be assembly work for the local market or, just possibly, some peripheral role within the globalized production network. This will create jobs and income, but it seems unlikely that most developing countries would be able to break through to higher levels of technological capability from either of these situations. Production for local hardware niches (i.e. individual vertical markets) could be set up. However, even this is unlikely to be sustainable in the long run without joint ventures and foreign partners to inject new technologies and new techniques.

By contrast, the future for software production seems brighter and it offers greater opportunities for developing countries. Within the overall set of technologies that make up IT, software is vital since other technologies cannot function without it. Software has also been forming an increasing component of overall value within IT and "has become the 'lifeblood' of business, industry, and government."[44]

The development of a local software industry can therefore lead to many positive externalities, and is seen as a necessity in order for developing countries to be able to adapt software technology to suit their particular local needs (again stressing the link pointed out at the start between IT production and IT consumption).

"Software production is nowadays an industry, essential for the growth of the economies of developing countries; and the launching of programmes to promote strong and indigenous software industries is a priority task."[45]

Software production is also seen as the best entry point for developing countries into the IT production complex. For example, compared to hardware production, software production has much lower entry barriers, being less capital-intensive, more labor-intensive, with a lower rate of obsolescence, and (at least for certain types of software) far fewer economies of scale. All of these factors assist developing countries, and software's labor-intensity of production offers a clear opportunity for them compared to many other production processes.

Other countries may therefore be able to follow India's software lead more than its hardware lead. Even here, India had significant "first mover" advantages in the software export arena and others may need to take an approach that provides more balance and linkages between export- and domestic-oriented software production.

The Specificity of Policies and the Political Economy

Successful policy strategies are those which are responsive to an IT industry's needs, and which are flexible and iterative—always trying to improve in the light of past experience and changing circumstances. Because of this, one cannot universally prescribe a particular set of policies which will bring success. Each country will have to choose the policy measures that suit its IT industry best, based on continuous survey of the quantitative and qualitative nature of that industry.

This is also true because of the constraints placed on the process of making IT industry policy. Policy outcomes will finally be determined not by some objective, technocratic choice of the "best path," but by a mixture of this "best path" intention with the balance of power and interests of the various elements in a country's political economy.[46] The outcome will also be determined partly by external factors, especially the actions of the US government, US companies, and multilateral organizations which may try to block certain policy measures while encouraging others.

Acknowledgement

Thanks are due to those Indian government officials and IT industry managers and staff who provided interview data during the 1980s and 1990s.

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13

Information Technology Policy in the USSR and Ukraine: Achievements and Failures

Boris Malinovsky and Lev Malinovsky

After the end of the Second World War, the government of the USSR started to create a computer industry. This became one of the main tasks of the national economy and computer manufacturers began serial production of electronic tube computers starting in 1953 (the 'Strela' computer series, then the M20, BESM2, Ural 1, and Minsk 1). Later, in the early 1960s, semiconductor universal computers (M220. Ural 11, 14, Minsk 22, 32, Razdan 3, Setun, and others) were developed and produced. At the same time, computers for engineering calculations were developed (Promin, MIR1 and MIR2, Nairi), as well as control computers (Dniepr, Dniepr 2, VNIIEM, MPPI, and others). In the 1950s and 1960s, in Moscow, Kyiv, Minsk, and other large cities of the USSR scientific research institutes, plants, and engineering and design companies were founded, and thus began the development and manufacture of first and second generation computers. As a result, all important projects of that time in the field of atomic energy, cosmic investigations, rocketry, and so on, gained the necessary computer support.

In 1967, the Soviet government adopted a decree regarding the future development of the computer industry. The decree covered all problems, from the research and development (R&D) of essential semiconductors and microelectronic circuitry to manufacture of the new generation computers for civil and military applications. According to this decree, computer industry facilities were to be doubled. Thus began the industrial production of the supercomputer BESM6, computers for anti-rocket systems, computers for cosmic space observation systems, rocket-attack warning systems, and onboard military computers for myriad purposes. In the early 1970s, cooperation with the computer industries of Bulgaria, Hungary, Czechoslovakia, and Poland was widened. More than 100 enterprises were involved in computer development and production, with a staff of more than 200,000 scientists, engineers, and 300,000 workers.

Given these advances, by the late 1950s and early 1960s, the Soviet Union had become one of the world leaders of computer industry. The development of computer science and technology in the USSR at that time was going on independently and in parallel with the West. However, at the end of the 1960s, the possibility

suddenly loomed for merging the USSR's scientific and industrial potential with that of Western European countries, toward the development and production of fourth generation computers. This was actually a proposal by ICL, the British computer company, and it was supposed that this mutual effort would help Europe outstrip the United States in the field of fourth generation computers. Prominent USSR computer scientists approved this idea, but in 1970, the government of the USSR decided to stop contacts with ICL and to take the American IBM-360 system (without USA permission) as an industry model. It was huge mistake with dramatic consequences. The idea of trans-European cooperation failed. Instead, enormous amounts of money were spent on a computer system based on the IBM-360. This system soon became obsolete and the Soviet Union moved from being a computer leader in the 1950s and 1960s, to being an outsider in the field of computer industry.

The Main Achievements of the First Decades of Soviet Computer Development

One of the authors (Boris Malinovsky) had the good fortune to be a witness and a participant in the establishment and development of digital computers in the USSR. He worked together with distinguished scientists in this field, such as S. Lebedev, A. Dorodnitsyn, I. Brook, Y. Bazilevsky, V. Glushkov, B. Rameyev, N. Matuhin, M. Kartsev, I. Akushsky, G. Lopato, M. Sulim, N. Brusentsov, V. Melnikov, V. Burtsev, A. Lyapunov, A. Berg, and others. In the difficult postwar years, the efforts of these people and the scientific teams they supervised catapulted the USSR into a leading position in computer manufacture. This extremely rapid development of computer technology was an extraordinary feat, as were the great achievements in the fields of satellite technology, rocketry, and nuclear fission, of which much already has been spoken and written. Though the computer played an enormous role in carrying out this work, this fact has not received great attention.

Despite terrible human and material losses caused by the Great Patriotic War (the Second World War), the first decades after the war were characterized by enormous energy and great enthusiasm by the Soviet people. In those years, the rate of economic growth in the Soviet Union was more rapid than in any other country, except Japan. It must be noted that the establishment and development of computer technology in the USSR advanced in the postwar years without any contact with scientists from the West. Computer technology in the USSR during this period developed in its own way, due to the outstanding achievements of the top Soviet scientists. Most of them were connected with the creation of the digital electronic computers:

The design of the first computer project, in the USSR (I. S. Brook, B. I. Rameyev, August, 1948)

Substantiation of the concepts of computer construction, with a stored memory program, independent of the work of John Von Neumann (S. A. Lebedev, October–December, 1948)

Registration of the first patent of a digital computer in the USSR (I. S. Brook and B. I. Rameyev, December, 1948)

First test launching of a prototype of the small electronic computer (MESM) (S. A. Lebedev, November, 1950)

Approval by the State Committee of the MESM—the first computer in the USSR and continental Europe, put into regular operation (S. A. Lebedev, December, 1951)

Launch into operation of the M-1, the first computer in the Russian Federation (I. S. Brook and N. Y. Matuhin, January, 1952)

Production of the Strela, the first industrial computers in the USSR (U.Y. Bazilevsky and B. I. Rameyev, 1953)

Creation of the most efficient, high-performance computers on the European continent (at the time of their operation), the BESM (S. A. Lebedev, April, 1953), the M20 (M. K. Sulim and V. A. Melnikov, 1958), and the BESM6 (S. A. Lebedev, 1967)

Launch of the SESM into operation—the first matrix-vector processor in the Soviet Union (S. A. Lebedev and Z. L. Rabinovich, January, 1955)

Creation of Ural 11, Ural 14, and Ural 16—the first family of Soviet hardware and software compatible general-purpose computers (B. I. Rameyev, V. I. Burkov, and A. S. Gorshkov, 1960s)

Development and mass-production of the M3 and Minsk 1—the first small universal computers made in the USSR (I. S. Brook, N. Y. Matuhin, and G. P. Lopato, 1956–1960)

The creation and industry production of Setun—the first and only trinary computer in the world (N. P. Brusentsov, 1958)

Creation of the first (and possibly the only one in the world) high-performance, specialized computer, using a system of calculation in remainders (I. Y. Akushsky, 1958)

Development of the theory of digital automatons (V. M. Glushkov, 1961)

Implementation of a proposal of the concept of high-level hardware language (V. M. Glushkov and Z. L. Rabinovich, 1966)

Development of the Promin and MIR computers—the first computers in the USSR for engineering calculations, forerunners of future personal computers (PC) (V. M. Glushkov and S. B. Pogrebinsky, 1959–1965)

Creation of the first soviet semiconductor control computer, widely known as the "Dnepr" (V. M. Glushkov and B. N. Malinovsky, 1960)

First proposal in the USSR of the idea of a multiprocessor system (S. A. Lebedev, 1956)

Proposal of the concept of brain-like computers (V. M. Glushkov, 1961)

Proposal of the principle of a recursive (non-Neumannian) computer (V. M. Glushkov, V. A. Myasnikov, and I. B. Ignatiev, 1974)

Creation of the M10—the world's first multi-format vector structure computer (M. A. Kartsev, 1974)

Creation of the world's first fully parallel computer system—with paralleling on all four levels: Program, control, data, and transfer units, on an M10 base (M. A. Kartsev, 1970s)

The 5E26 computer—first mobile control multiprocessor complex on integrated circuits, with a performance of 1.5 million operations per second (S. A. Lebedev and V. C. Burtsev, 1978)

Development of the first Soviet vector-pipeline computer M13 (M. A. Kartsev, 1978).

These are only the main results of the principal scientific schools, supervised by S. A. Lebedev, B. I. Rameyev, I. S. Brook, and V. M. Glushkov, which emerged in the years of the formation of digital computer technology and which fulfilled the development of the basic classes of computers at that time. Simultaneous with the development of computers for computing centers, systems were also designed and developed for defense systems. The Cold War made it necessary to create an effective rocket-attack warning system (SPRN), a system of cosmic space observation and anti-aircraft, anti-rocket systems (the PRO and the PVO). The SPRN computer were developed under the supervision of M. A Kartsev, the PRO system under the supervision of S. A. Lebedev, and the PVO system by teams supervised by N. A. Matuhin. The inherent secrecy of this work brought a great disconnection among scientists and caused parallelism in research. This tended to blur the objectivity and completeness of Soviet computer history. It is still full of "blank spaces." Quite a number of outstanding scientists and their achievements still have not received their true recognition in the world of computer history and development. We do, however, have profiles of a number of key figures.

S. A. Lebedev was born on November 2, 1902 in the town Nizhniy Novgorod. By the time he was 45 years of age, he was a well-known expert in energy systems. In parallel with American and English scientists at the end of 1940s, he developed the main principles of construction and structure of electronic digital computers. Under his management in 1948–1950, the first stored program computer in Ukraine, Soviet Union, and continental Europe was created. In 1951–1953, this computer (MESM) solved very important problems in thermonuclear engineering, rocketry, space flights, long-distance electrical transmission, and so on. In the next 20 years (after his move from Kiev to Moscow), he developed fifteen high-performance types of computers, each more productive, reliable, and convenient in operation (BESM, BESM2, BESM4, BESM6, M20, M40, M50, and others). From the early stages of creative activity, Lebedev put forward and subsequently realized the basic ideas for supercomputer construction, that is, parallel computing processes. In the first computers, he used parallel arithmetic units for this purpose, then mainframes and later on, pipeline algorithmic structures, multiprocessing, etc.

All the computers created under Lebedev's supervision (from early models based on electronic tubes to those based on integrated circuits) were manufactured and used in computer centers of large scientific research institutions, as well as antimissile systems of the Soviet Union. Hundreds of highly skilled specialists and engineers gained valuable experience in Lebedev's institute and became famous scientists, chiefs of scientific research centers, and designers of more advanced computers (Academicians Melnikov, Burtsev, Rjabov, Ivannikov, Doctors Sokolov, Tjapkin, and many others). The institute established by Lebedev continued the work of creating modern supercomputers.

Other prominent computer scientists of the same period include Academician Isaak Brook and his famous pupils N. Matuhin and M. Kartsev. Isaak Brook was born in Minsk on the November 8, 1902 (the same year as Lebedev). Like Lebedev, Brook began his career working on problems of energy systems. In 1948, together with B. Rameev, Brook designed the first computer project in the Soviet Union and received the first patent for a computer with a unibus. Under Brook's supervision, the M1, the first stored program computer in the Russian Federation was created. The M1 was put into operation in 1952, 2 or 3 months after the launching of the MESM in Kyiv. For the first time, it used semiconductor diodes instead of electronic tubes, a two-level address command system and teletype for data output.

Under the direction of Brook and the active participation of Kartsev and Matuhin the M2 (1953) and M3 (1956) were created. The latter became the initial model for a popular family of computers, MINSK (G. Lopato and V. Prjyalkovsky). The first prototype of the M2 computer with comparable performance was manufactured and put into operation a little bit later than BESM. It was under operation at the Institute of Energy for more than 15 years. Matuhin, who was the chief designer of the M3, later became the chief designer of the family of computers and anti-aircraft systems. Under his leadership, ten types of computers for such systems were developed. The first ones used semiconductors, the later ones, integrated circuitry.

The powerful computers M4, M10, and M13, created under Kartsev's supervision, were responsible for multi-computer complexes for outer-space control and for missile-attack warning systems. Although the M10 was slightly slower than the American supercomputer Cray 1, it surpassed the Cray 1 in versatility, by virtue of its architecture: The number of cycles for one operation for M10 was from 0.9 up to 5.3 (for the whole spectrum of operations) while for the Cray 1 it was from 0.7 to 27.6. On the basis of computers developed by Kartsev's Institute, the largest multi-computer complex in the USSR was created. This complex consisted of seventy-six computers which were connected with 10,000 km of information channels, working at uniform algorithm. In the M13 multi-processor system of the fourth generation, an equivalent speed of special purpose system processors was more than 2 billion operations per second.

Kartsev realized the conception of multi-format vector structure and absolutely parallel computing structure that enabled the project to solve complicated tasks requiring super-performance computers. M. Kartsev was also the author of fundamental theoretical works. He wrote four monographs on the fundamentals of computer arithmetic and computer architecture.

It should also be noted that while Lebedev and his Moscow group ensured the development of supercomputers, computer technology of common usage was designed by B. I. Rameev in provincial Penza. Rameev had no possibility to get a higher education because his father was punished by Stalin's regime (later on, he was absolved). Nevertheless, due to his outstanding abilities, Rameev became chief designer of the "Ural" computer family. These computers were inexpensive and widely used at the former Soviet Union's computer centers. Under Rameev's

management, a whole family of special purpose computers was developed, as well as about 100 peripheral devices. Another key Soviet computer pioneer was U. Y. Basilevsky, the chief designer of the Strela, the first industrial computer, that appeared simultaneously with the IBM 701. Basilevsky worked under the supervision of Rameev at this time. Rameev was also the first in the USSR to formulate the principle of software and hardware compatibility and realized it in the Ural 11, 14, and 16 computers. He formulated this important idea one and a half years before the production of the IBM 360 software and hardware compatible computers.

V. M. Glushkov, of course, deserves to be included in this group of Soviet computer pioneers. He was born on August 24, 1923 in the south of Russia. The name of Glushkov in the history of computer technology was connected first of all with the development of the theory of computer design in his well-known books, *The Theory of Digital Automatons*, *Introduction to Cybernetics*, and so on. The next very important part of his work in this field during the 1950s and 1960s was his investigation in the field of control computers and computers with "high inner intellect." Under his guidance, a series of specialized computers for engineering calculations, the MIR1, MIR2, and MIR3 were designed and became the forerunners of PCs.

The Kiev Cybernetics Institute was founded and guided by Glushkov. It was at that time one of the most well-known computer institutes of the Soviet Union and very quickly gained international recognition. The top achievement of Glushkov's work was undoubtedly the creation of the ES-1766, a macropipeline supercomputer, which had no analog in the world at the time. In the 1960s and 1970s, the computer industry in the Soviet Union manufactured more than fifteen types of computers, designed at the Institute of Cybernetics (Promin, MIR1, MIR2, MIR3, Dnieper, Dnieper 2, Neva, Iskra 125, Pirs, and others). "The scientific works of Glushkov and the practical results of his research for many years will have an influence on the development of computer science all over the world," H. Zemanek, an eminent computer design scientist from Austria, was quoted as saying.

Besides "classical" computer facilities developed by the scientific schools of Lebedev, Brook, Rameev, and Glushkov, significant contributions were made by N. Brusentsov in 1958, with the "Setun", a computer using a trinary notation system and by I. Akushsky who also in 1958 developed the first and probably the world's only special computer using notation in remainders. There are a number of other designers in the field of universal, onboard computers including V. Polin, Y. Hetagurov, V. Levin, S. Majorov, V. Smolov, A. Larionov, V. Priyalkovsky, B. Kagan, and others, but their description is beyond the scope of this chapter.

Wrong Decisions

The Soviet government allotted significant means for the development of the computer industry. Dozens of plants existed (some of them new and ready to start manufacturing) and several big scientific technical institutes in Moscow, Minsk, Kiev, Leningrad, Penza, and Yerevan already had experience in developing second generation computers. The SR Center of Electronic Computer Technology,

SRCECT was established—one of the most powerful scientific organizations in the country. One important detail should also be noted—the official negation of cybernetics (as well as computer technology as a whole) had become a thing of the past. The computerization of the economy, science, and technology was now considered a high-priority task. At the governmental level, a decision was made to create a Unified Computer System (Russian abbreviation—EC), a new generation of computers using integrated circuits.

The creation of a family of computers in the West first took place in the United States. The American company IBM led the way when it developed the IBM 360 computer systems in 1963–1964. The family consisted of models of various productivity, which were supported by a wide array of software. For small models, the operating system DOS 360 was proposed, for large models, the OS 360 operational system was used. The latter operating system was designed because the DOS 360 turned out to be insufficient for large computers. The experience of developing these complex and extensive operating systems (software) showed that they required even more labor consumption (thousands of man-years) than creation of the hardware itself.

Some time later, the British company ICL developed the SYSTEM-4, a family of third generation computers (from the software point of view). Almost simultaneously in West Germany, there appeared an analogous computer family made by the Siemens Company. The first country in Eastern Europe which started development of a series of compatible computers was the German Democratic Republic, GDR (East Germany) where they managed to copy one of the models of the American IBM 360. The discussion concerning third generation computers, their architecture, and structure started in the USSR in the late 1960s. In that period, the strength of electronic technology specialists of the Academy of Sciences of the USSR (AS USSR) was weakened, if not to say more harshly—undermined. By government decree, initiated by Nikita Khruschev, a series of institutes of the AS USSR were transferred to the industrial ministries. So, the Institute of Precision Mechanics and Computer Technology was transferred to the Ministry of Radio Industry and only nominally belonged to the AS USSR.

The Ural computer designers, together with Glushkov, offered a new development based more completely on Soviet experience, with less consideration of foreign achievements. In October 1967, they wrote to the Ministry of Radio Industry (which had been appointed to manage the EC project):

> The decision to copy models of IBM-360 computers which was proposed by the Commission on Computer Technology on October 26, 1967 should be seriously disputed. The proposal to copy the IBM-360 system is equivalent to planning the manufacturing of 1970's computers using the technical level of the early 1960's. Considering the existing trends of science and technology, it can surely be affirmed that the architecture of the IBM-360 will be obsolete in 1970's. It will not be capable of satisfying requirements and challenges in computer technology . . . The design teams of Soviet computers have sufficient experience for the development of a series of computers which would correspond to the level of requirements expected in the near future, and thus, it would be a more

correct decision to develop the architecture of a unified series of Soviet computers on the basis of experience already accumulated in the country, considering the latest foreign achievements.

The 'Ural' designers had solid grounds for such a conclusion. They already had implemented a series of program-compatible computers using semiconductors (Ural 11, Ural 14, and Ural 16). A comparison of the architectural and functional possibilities of the 'Urals' with the same parameters of the foreign systems (IBM-360 and SYSTEM-4) showed that the Urals were fully competitive with the foreign models and in some parameters and features, even overtook them (multi-computer systems, communication channels work, etc.). Moreover, in the Penza Scientific Research Institute development of the multiprocessor computer Ural-25 had just been completed. This system integrated the best features of the Ural 11–Ural 16 series (and its designers were all followers of Rameyev: V. Burkov, A. Gorshkov, and A. Nevsky). Meanwhile, the Ural 21, a computer design project using integrated microchips, was proceeding successfully.

The system possibilities of the Ural family (11–25 series) provided for the creation of a powerful, multi-computer, automated system in which computers were connected with each other through communication channels. Urals from Penza had already been in operation in numerous computer centers, plants, banks, and systems designated for military purposes. Using the semiconductor Urals the multi-computer systems "Bank" and "Builder," special systems for satellite data processing, were created. It was impossible to construct such systems using IBM 360 cluster computers manufactured in that period! Their purpose was mainly batch-information processing in computing centers.

The idea of creating a unified system (EC) of computers received the full support of the Eastern Europe socialist countries. All of them (except the GDR) were against copying the IBM-360. After bilateral negotiations in August 1968, the multilateral document "General Technical Principles of the Creation of EC Computers" was signed (and approved by all delegations, except the GDR), in which the following opinion on all the major questions was formulated:

> The structure of the EC computer should be analogous to the structure of modern systems, like IBM-360, Siemens-4004, SYSTEM-4. During the development process, it should be possible to change the structure in order to take advantage of the latest achievements in computer technology or inventions defended by patents, on the condition of preserving the established project development periods and the guarantee of an accepted degree of software and technical economical features.

During further multilateral talks, an index of nonprivileged instructions for the EC computer that matched the instruction lists of the IBM 360, Siemens 4004, and SYSTEM-4 was unanimously adopted. The problem of privileged instructions was discussed several times, but no decision was made. The GDR specialists who insisted on duplicating the IBM 360 suggested using the IBM 360's list of official instructions. Other delegations did not agree with them. When a special joint meeting in November 1968 dedicated to selection of logical structure of EC computer had not

brought any positive solution, the problem was passed to a Council of Chief Constructors.

The Soviet approach of development of computer technology never denied wide international cooperation. On the contrary, its adherents, S. Lebedev, B. Rameyev, and M. Sulim, quite understood the advantage of cooperation with Western Europe companies. Western European firms, manufacturers of computer technology who wanted to compete with IBM, and who understood the huge scientific and industrial potential of the Soviet Union, and also the unquenchable demand for computers in the USSR and Eastern Europe countries, were the first to make concrete steps in the establishment of cooperation with the Soviet Union in the field of computer creation and manufacturing. The initiator was ICL, the largest British firm which had at that time developed the SYSTEM-4 computer family, in no way inferior to the IBM 360.

Rameyev was an active supporter and participant of these negotiations. He signed a series of bilateral protocols on cooperation with ICL. He hoped that, in close cooperation with ICL (in accordance with the signed protocols), SYSTEM-4 could be copied by one or two engineering and construction bureaus, while the basic potential of the Scientific Research Institutes (SRIs) and construction bureaus could be directed towards creation of a more perfect series of machines using the already accumulated experience and the most recent foreign achievements. In a word, there was every reason to expect that the 1970s would bring great success.

But how did events actually unfold? In the selection of a prototype for a unified EC system computer, the leading specialists of the country, Lebedev, Rameyev, Glushkov, Dorodnitsyn, and Sulim were vanquished, and their opponents won out. Why? This problem was not given proper attention in the mass media, though up to the present day, it is under dispute. Archival material and the stories of participants in the discussion (Rameyev, Sulim, and Dorodnitsyn) allowed the author to reconstruct the events.

The efforts of designers to use foreign experience, software first of all, was certainly correct. It was quite natural at that time to get interested in the two systems that had already been created: The IBM 360 and ICL's SYSTEM-4. In order to duplicate the software successfully it was necessary to establish at least four conditions. First, to obtain the full software documentation of the prototype system, which should be enough for manufacturing, support, and operation of the software. Second, to establish contact with the firm who will provide maintenance of the transmitted information and rendering of assistance in the use of this information. Third, to ensure that the information for the prototype system be sufficient for the guarantee of software compatibility and functioning of the EC computer and the prototype system. Finally, to ensure that prototype computers be fully equipped with reliable software to be reproduced and have the designers of software at their disposal.

The use of the IBM 360 as a prototype model did not match with the above conditions. The IBM company had no intentions of cooperating with Soviet Union in that period. There was an embargo on exports of US computers to our

country. The documentation for the IBM 360 software, available in the Soviet Union, was not complete because it was not delivered to the country from IBM. The purchase of actual IBM-360 computers was possible only through intermediaries, which caused a lot of problems.

The contacts with the English firm ICL were quite different, thanks to the efforts of M. Sulim, Y. Gvishiani (Deputy Chairman of the State Committee of Science and Technology (SCST) in the Cabinet of Ministers of the USSR) and other supporters of cooperation with foreign companies. In accordance with a memorandum from April 26, 1968 signed by the manager of ICL and Chairman of the SCST, on the initiative of the firm the negotiations were organized for scientific–technical cooperation in the area of computer software.

The ICL company agreed with the Soviet side to share detailed information on SYSTEM-4's software and to allot their specialists for the rendering of assistance in the use of this information, under condition that the indicated information should be used for development, production, and accompanying software support of these third generation computers. During the negotiations, the participants, among whom were Sulim, Rameyev, and others from the USSR and representatives of ICL, emphasized that they were ready for mutual development of new generation computer technology. They proposed that, for the sake of creating competition with IBM from European countries, ICL and the Soviet Union could spend significant amounts of money for the development of mutual work.

In April 1969, the Council of Chief Designers, headed by the director of the SRCECT Krutovsky, in spite of the objections of country-participants—Bulgaria, Poland, Hungary, and Czechoslovakia—came to the following decision: For the design of the EC computer. They were to provide compatibility between the logic structures and instructions systems of the EC and IBM-360 computers. This decision was motivated by the work already begun between the SRCECT and its main partner—the GDR, which was already investigating the IBM-360 system and objected vehemently against any another orientation. The main argument was that the same position was supported by Minister Kalmikov and the President of AS USSR Academician Keldish.

So, it happened that the highest leaders had fallen under the hypnotic influence of the proposal to avoid software development. The supporters of the IBM approach said that IBM had the world's richest and most popular software library which could not be rejected by even fourth generation computers, and if we copied machines of this series, then we could use these programs, so as to gain time and money. A few months later, the Ministry Board finally approved the decision, in favor of the IBM-360 system. The scientifically substantiated solution to this important problem—of what was to be the basis of the EC computer—was nullified by the administration's order to copy the IBM 360 system. The management of Radio Industry Ministry, AS USSR, and managers of SRCECT did not take into account the opinion of leading scientists of the USSR and other socialist countries. The negative (or to be more exact—tragic) consequences of the adopted decision on Soviet computing technology would eventually be confirmed. Despite huge

labor efforts, when it was eventually produced, the EC computer system appeared to be obsolete and noneffective.

In the 1970s, the government authorities made yet another unreasonable decision—the so-called "splitting" of the computer industry into three pieces: The microelectronic industry (Ministry of Electronic Industry, MEP), universal computers (Ministry of Radio Industry, MRP), and control computers (Ministry of Instrument Building, Automation and Control systems—the Ministry of PSA and SU). As a result, each of the ministries separately began development of a whole range of computers without coordination between the various projects. MRP and Ministry of PSA and SU, where the best specialists were gathered, actually lost their access to an advanced microelectronic base, and therefore, their developments were destined to failure. Furthermore, MEP had no desire to cooperate with the other ministries. Having a huge microelectronic base, but lacking the trained personnel in computer construction, they simply decided to duplicate the designs of American computer firms, which caused many years lagging behind the world level. The last reason for the decline of Soviet computer technology was an underestimation of the value of the connection between academic science and the computer industry. This hindered the realization of advanced scientific results which, as a rule, come only from great efforts made over time.[1]

Post-Soviet IT Policy: Developments in Ukraine

Following the break-up of the Soviet Union the many newly formed ex-Soviet countries have had to organize their economic, scientific, and technological policies and strategies in a newly independent way. From the outset, many were optimistic that this would mean a radical switch to more market-oriented activity, with consequent rapid advance. Ex-Soviet countries were, however, faced with a range of problems or opportunities, reflecting the legacy of the Soviet period and the assets available in terms of modernization. Ukraine is a very interesting case in this respect. The country was the site of dense IT industry activity throughout the Soviet years, much of which was linked to the military sector. Fundamental studies in the computer sciences were carried out in a number of Scientific Institutes of the Ukrainian Academy of Sciences, as well as in many educational institutions. Important fundamental research was also completed in special industrial scientific research institutions. In addition, a large-scale industry for serial computer production was established and the training of computer specialists was organized. So, the contribution of Ukraine to the establishment and development of the computer industry in the former USSR is hard to overestimate.

However, these Ukrainian achievements, as well as a great deal of outstanding research by Ukrainian scientists, were regarded as secret in the "cold war" years and thus only some specialists were aware of them. Worth mentioning here is the outstanding achievement of the famous Ukrainian physicist, Academician Vadim E. Lashkarev, who in 1941 discovered the so called p–n junction in semiconductors, the physical phenomenon which became the basis for the further creation of the

transistor—a basic computer element. In October 1948, under the supervision of Academician Lebedev, the development of a Small Electronic Computer (MESM) was initiated. Independent of western scientists he worked out the basic principles of electronic computer design. For the next three decades the main contribution to computer science and technology was made by the world-renowned scientist Academician Victor M. Glushkov, founder of Cybernetics in Ukraine and the Institute of Cybernetics of the National Academy of Sciences of Ukraine. The Institute carried out a whole series of important applied R&D of new computers for control systems in technological processes—power generation, control of military installations, automatic control of scientific experiments, etc.

More than one-third of all serially produced computers in the Soviet Union were developed in the Institute of Cybernetics of Ukraine. Since the 1960s, the design and serial production of computers for control of technological processes and power generating plants have been implemented at the Severodonetsk "Impulse" Scientific Production Complex. Most of the USSR's industrial control systems were developed with "Impulse" participation.

Much less well-known, or completely unknown, was the work on computer development for military applications, for example, a whole family of unique computer radioelectronic and hydro-acoustic systems providing a high technical level of navigation devices, the target designation, and control of ships and submarines, including nuclear vessels of the USSR Navy. This work was undertaken at the Kiev "KVANT" Scientific-Production Amalgamation and Kiev "Hydropribor" Scientific Research Institute. Close cooperation of the Kharkov "Hartron," Scientific-Production Complex, the "Kiev Radio Plant" Production Complex, and the Dnepropetrovsk "Uzhny Machine Building Plant," led to the serial production of four generations of complex rocket guidance systems with on-board computers, that strengthened the military might of the Soviet Union and guaranteed strategic parity with the United States.

During the 1960s and 1970s, the Kiev "Krystal" Scientific Production Complex developed and manufactured, for the first time in Europe, large integrated circuits for calculators and other technical devices, using digital elements. Ukrainian plants produced about one half of all semiconductor products of the USSR. The Kiev "Electronmash" Production Complex, together with the Severodonetsk Plant, were the first enterprises to organize full-scale production of control computers for all of the Soviet Union. Ukraine fully satisfied its own needs in terms of computer and microelectronic specialists and even helped other republics of the Soviet Union, as well as many foreign countries, to train qualified specialists. Departments and faculties of cybernetics were founded at the Kiev Polytechnical University, Kiev State University, and others institutions.

After the collapse of the Soviet Union, the newly independent Ukraine inherited not only the Soviet's network of huge scientific and research institutions, for the most part connected with the Military–Industrial Complex, but a host of problems with their financing and conversion. At present, Ukraine faces a challenge: How to carry out the technological re-equipment in practically all branches

of industry, while at the same time improving their productivity by means of efficient management systems. The scale of this task is comparable to the rebirth of the Ukrainian economy after the terrible devastation of the Second World War.

If one considers the rates of technical re-equipment of different branches of Ukrainian industry, real progress is evident in only one area. This is the sphere of information technology (IT), but this is based nowadays mostly on foreign hardware and software. Annually, Ukraine buys hundreds of thousands of PCs, work-stations, and network equipment. The Ukrainian computer market, according to data of the Institute of Cybernetics of the National Academy of Sciences, engages about 1500–1800 commercial companies, about half of which operate in Kiev. Practically, all of them are dealers, resellers, or distributors of various foreign companies.

About 300 companies deal with software. Seventy percent of these are concentrated in Kiev. Only one-third of these companies develop commercial software, the rest are engaged in distribution and system integration. About 133 companies, controlling over 80 percent of this sector of the economy, are included in the 1999 reference book *Who's Who in the Ukrainian Information Technology Market*. In 1998, about 200,000 PCs were sold in Ukraine, 75 percent of which were assembled locally. However, domestic enterprises are involved only with final assembly and control of imported units and practically all modern IT is based on these computers. So, it is evident that Ukraine has the essential resources for the rebirth of the national computer industry. Yet, in 1998, only three enterprises were dealing with domestic computer production, namely: "Electronmash" (Kyiv), "Impulse" (Severodonetsk), and "Magnit" (Kaniv), which produced only about 1000 computers.

The main economic and technical factors which have resulted in the present state of computer and IT in Ukraine, are as follows. First, isolation from the world labor market in the sphere of computer and IT. Second, weak inter-branch communication and overcentralization of the National Economy. Third, lack of interest among enterprises in working directly with customers. Fourth, disorganization of the computer industry forced by the disintegration of the Soviet Union. Finally, the uncontrolled influx of foreign computer companies into the domestic market.

To solve the problems of coordination in the IT sphere, and particularly, to establish analytic information systems for the state bodies, the President of Ukraine founded the National Agency on Informatization. World experience has already demonstrated the great potential in using IT for solving socioeconomic problems, which would suggest Ukraine undertake adequate steps on a nation-wide scale, to form and implement both unified state policy and strategy on information services for the establishment and usage of a national information infrastructure in the interests of every citizen, society, group, and company in Ukraine.

The main declared tasks of the state information policy are:[2] to increase considerably the level of adequacy, efficiency, and accessibility of various information data for every Ukrainian citizen; to improve the provision of the state control system with informational data; to improve the information-marketing supply of economic entities of all forms of property; to use comprehensively the IT systems and networks for a full-scale solution of social and humanitarian problems, improvement of

the educational system, and healthcare, as well as the development of science, culture, and art; to intensify the international information exchange for the sake of development of political, economic, social, and humanitarian relations; and to provide an adequate level of information safety and information protection.

To implement these tasks the state policy on information is based on the following principles. First, legal conformity of interests, rights, and obligations, and observation of the constitutional rights and freedoms of each citizen in the information sphere. Second, the compliance of the National Legislation with International Regulations. When observing these principles, it is necessary that the normative and legal regulations on information infrastructure, technologies, means, and system development be directed to solve the following tasks. First, to attract private investments in development of IT, equipment, systems, networks, etc. Second, to encourage competition in information services, as well as to ensure free access to the IT market, based on the principles of justice, mutual advantage, and parity in relations between economic entities of different forms of property. Finally, to ensure a permanent international exchange of opinions and information with the National Regulatory Body on development and introduction of proper regulations to support IT, equipment, systems networks, etc.

A great number of Legislative Acts have been adopted to regulate activity in the IT field. Under the leadership of the National Agency on Informatization, a National program of informatization was worked out and adopted by the Verkhovna Rada (high ruling body) of Ukraine. The concept "informatization" was considered in a wide sense as one of the directions of economic restructuring, with the goal of development, implementation, and wide-scale usage of ITs, systems and networks to solve state political and social–economic problems. Macro-effects of such innovations, on the basis of world experience, are very important, and include, in particular, the increase of the general technical level in the sphere of import–export, acceleration of innovative processes, changes of employment structure, etc. The National program is a unified multi-project, which unites ten basic directions in informatization on the basis of a common state policy. This program is intended to solve the following main tasks: To establish legal, organizational, scientific–technical, economic, financial, methodic, and humanitarian conditions for information development; to implement and develop modern IT in the various spheres of social life; to form a system of national information resources; to create a State information support network for science, education, culture, and health protection; to create State systems of information and analytic support for state, regional, and local bodies; to form and support the market for IT products and services; and to integrate Ukraine into the World Information Community.

Technological and communication structures are peculiar to any society and culture. But the level of its development is based on the community support of its own intellectual potential. It is not an abstract notion. It is derived from placing a high value on qualifications, skills, creative and intellectual work, as well as respecting a high moral character in a person, creating possibilities for personal self-improvement, as well as for enrichment of spiritual life, and establishment of conditions for mutual

professional and personal contacts. Hence one of the most important task of the state policy and the National program for informatization of Ukraine is to ensure the realization in practice of the constitutional right of every citizen to search, receive, transfer, create, and distribute information in any legal way.

It is impossible to achieve this task without an adequate level of information and analytical supply in relation to the bodies of state control. At the same time, the existing IT infrastructure of the State control bodies does not fully meet these modern requirements. Information has achieved the status as the most important factor of state government, which ensures the formation and implementation of strategic decisions at the proper level. Persons authorized to make important decisions, can nearly drown in the data flow, on one hand, and badly require informational data depicting adequate situations and development of social economic, and political processes in the country, on the other. There are several reasons explaining this state of affairs. Different information systems and networks have been developed in Ukraine independently, practically without any coordination between them. When developing these systems, the main attention was focused on information transfer, while questions of the rational organization of data flow, the development of informational support for the processes of decisionmaking, etc. were ignored. Data storage, formation, analysis, and output, show the effects of past periods. Insufficient attention was paid to the operative data processing and strategic forecasts, revealing drawbacks of the approved decisions, when implementing them. That is why the National program of informatization has formed a strategically important task to establish an information-analytic system for the bodies of state control.

In this period of social and economic development, the future of Ukraine greatly depends on the resoluteness of the people and all bodies of state control to implement the strategic target of introducing our country to the world economic community, as a developed country, contributing much of its intellectual labor to the national Gross Domestic Product. There is a great potential to achieve this task: Sufficient scientific potential, qualified personnel, great experience, and world-class level of design and production of numerous products in aviation, space, machine-building, military, and other technologies. However, it is necessary to maintain certain conditions to achieve such a strategic aim. One of the main tasks is to achieve a world level of informatization of society, mainly to increase the authenticity and effectiveness of decisions, which are made on different levels.

Modern IT has made countries more open, and the existence of global information systems allows for the provision of information services, practically independent of state borders. For many countries, including Ukraine, the real opportunity gradually appears to be reaching the updated levels of IT requirements. Taking into account the great know-how and potential of Ukrainian IT engineers and researchers, the most important directions for Ukrainian integration into the world IT community might be: Software design; the application of PCs into different technological projects; hardware design of data—signal processing and control systems; joint projects with IT specialists worldwide; and improvement of information flow in IT designs.

Notes

1. Material for the preceding section of this chapter is based on B. Malinovski, *The History of Soviet Computer Technology in Personalities*, Kyiv 1995, currently available in Russian only.
2. A. Matov, "The Problems and Possibilities of Ukrainian Integration into the Global Information Community," *Proceedings of The International Symposium "Computers in Europe. Past, Present and Future,"* Kiev, October 1998: 316–324.

14

Romania's Hardware and Software Industry: Building Information Technology Policy and Capabilities in a Transitional Economy

Richard Heeks and Mihaiela Grundey

Background

The Communist Party took power in Romania after the Second World War and, under Nicolae Ceausescu's authoritarian regime, the country formed part of the "Eastern bloc" of Soviet satellite states. The Romanian regime was at times portrayed as taking a somewhat independent line on certain issues. Nevertheless, it adhered largely to the model of state socialism found in the other Comecon countries, based around central planning and a high degree of state intervention. The dramatic events of December 1989 overthrew Ceausescu's regime and ushered in a new era for government. In common with other transitional states (those in transition from a centrally planned to a market-oriented economy), the Romanian government introduced a series of policy liberalizations that affected areas such as trade, where there was a reduction in import barriers, some reorientation away from import-substitution and toward exports, and devaluation/convertibility of the national currency. State controls were affected, with a decline in central planning, fewer regulatory controls on industrial production, fewer promotional investments by the state in industry, and a reduction in price controls and subsidies. In addition, there was increasing encouragement for foreign investment, and a reduction in regulatory barriers to such investment. There was also a reorientation away from public ownership and investment toward private ownership and investment, including the privatization of state-owned enterprises.

The process of liberalization has been gradual rather than revolutionary. For example, foreign investment has been limited and the state sector remains a hugely significant part of the economy. In part this can be put down to the great degree of change required in setting up a market economy, and to budgetary constraints. In part, too, slow progress with reform has been laid at the door of a lack of political commitment and of administrative incompetence within government up to 1996. As in a number of other countries, liberalization was also beset by a series of political and financial scandals. Since 1997, government has voiced a stronger commitment to the process of liberalization though the process remained one of constant challenge and constraint.

This chapter focuses on the pre-transitional and transitional development of one particular part of the Romanian economy—the information technology (IT) industry. This can be seen as covering a wide variety of products, but here the focus will be on just two: Hardware and, to a greater extent, software. The discussion of hardware will look mainly at production of computers, and discussion of software will look mainly at provision of software services.

The Romanian IT Industry Under Communism

The trade regime under Ceausescu was one of protectionism verging on isolationism. No information technology was readily imported from Western economies, except through clandestine routes. Even IT imports from other Warsaw pact countries were relatively limited. Opportunities for IT staff to travel or even to access foreign IT publications were limited.

Isolation from the West arose partly because it was externally imposed by COCOM (the Coordinating Committee for Multilateral Export Controls), which blocked the export of many IT items to Communist regimes. However, this is by no means a complete explanation since export of computer systems with limited power was permitted. Romania's isolationism also arose from a self-imposed desire to prove and develop national independent capacity; the national obsession with having no trade deficit; and from governmental suspicion about Western IT applications, with fears that computer science and related IT disciplines were, as one interviewee put it, "capitalist sciences likely to bring unemployment."

Autarky and development are not mutually exclusive, even in relatively high-tech areas. Indeed, strategies of autarky and, particularly, less extreme strategies of protectionism have worked well for some countries. Open economies can become awash with imported products representing foreign capabilities. Where these foreign capabilities can be kept at bay behind trade barriers, local capabilities can instead be developed based around local production and local products. Nevertheless, such strategies have been a mixed blessing. On the one hand they may allow local capabilities to be developed. On the other, they may allow local production to remain uncompetitive, prices to remain high (and consumption concomitantly low), and technology to remain out-of-date.

The secret of successful protectionism has been to ensure that it is an actively managed protectionism with clear goals and a competent bureaucracy. This strategy aims to reap the positive benefits of protectionism, but damp down the negative outcomes as they emerge (see, for example, Heeks, Chapter 12, on India, in this volume). In Romania's case, protectionism was not actively managed. Instead, the Communist regime maintained a fairly steady isolationism until its demise. The result can, at best, be regarded as very much the mixed blessing described above.

The Development of IT Capabilities Under Communism

On the positive side, Romania built up reasonable levels of technological capability in the production of both hardware and software following the building of its first

computer in 1957.[1] Lall identifies "technological capability" as a crucial determinant of industrialization, yet one which is ignored by many quantitative-oriented researchers.[2] Although this variable does not lend itself to outright measurement, some kind of scale can be drawn up for the technological capability of producers, as shown in Table 14.1. In Table 14.2, this general scale has been modified for one of the IT areas—software—to provide a clearer idea of what is involved (levels 3 and 4 are reversed because of the ease of copying software).

Following Lall,[3] one may define technological capability as the general ability to undertake the broad range of tasks outlined in the tables, and technological development as growth in the capability as defined by movement up the categories and regardless of whether or not the final stage is attained. These capabilities are actually embodied in the skills and experience of individual workers, often seen as the most critical resource for IT industries.[4] In this case, technological development will be the accumulation of increasingly skilled workers.

Table 14.1. *Scale of general technological capability*

Level 1: Non-production operational capabilities
a. Using the technology
b. Choosing the technology
c. Training others to use the technology
Level 2: Non-production technical capabilities
a. Installing and troubleshooting the technology
Level 3: Adaptation without production
a. Modifying the finished product to meet local consumer needs
Level 4: Basic production
a. Copying technology
b. Assembling technology
c. Full production using existing products and processes
Level 5: Minor production modification
a. Modifying the product during production to meet consumer needs
b. Modifying the production process to meet consumer needs
Level 6: Production redesign
a. Redesigning the product and production process to meet local consumer needs
b. Redesigning the product and production process to meet regional/global consumer needs
Level 7: Innovative production
a. Developing a new product to meet local consumer needs
b. Developing a new product to meet regional/global consumer needs
c. Developing a new production process
d. Transferring a production process to other producers

Source: Adapted from Narasimhan (1984), Lall (1987), and Schmitz and Hewitt (1991).[5]

Table 14.2. *Scale of software technological capability*

Level 1: Non-production operational capabilities
a. Using a system of menus icons
b. Using a conventional package (e.g. word processor)
c. Choosing a software package
d. Training others to use software

Level 2: Non-production technical capabilities
a. Filling a package with situation-specific data (e.g. spreadsheet)
b. Filling a package with situation-specific data (e.g. database)
c. Installing and troubleshooting software

Level 3: Basic production
a. Making copies of an existing software product

Level 4: Adaptation without production
a. Creating a situation-specific application from a package (e.g. creating menus and queries with simple programming; using macros; developing Web pages)

Level 5: Simple software production
a. Creating a new set of interfaces for users
b. Creating a program to move data between applications
c. Creating a small utility program
d. Modifying an existing program to meet user needs

Level 6: Software redesign
a. Redesigning a program to meet local user needs
b. Redesigning a program to meet regional/global user needs
c. Minor process change: modifying the software production process

Level 7: Skilled software production
a. Local product innovation: developing a new program to meet local user needs
b. International product innovation: developing a new program to meet regional/global user needs
c. Major process change: redesigning the software production process
d. Process innovation: designing a completely new software production process

During the Communist era, most of the state's IT institutions could be rated at around levels 4–6a on the scales above. This represents a significant achievement when compared, say, with the situation in many developing countries. For example, Romania had one main computer production facility, the imaginatively named Computer Manufacturing Company (FCE Bucharest), that produced mini/microcomputers for the local market.[6] There were also a number of producers, including ROMCD (Romanian Control Data), making computer peripherals (disk drives and printers) for domestic consumption. ROMCD also had a "steady, but modest, hard currency export market."[7] The work of these organizations included both product and process modification for the Romanian market. They

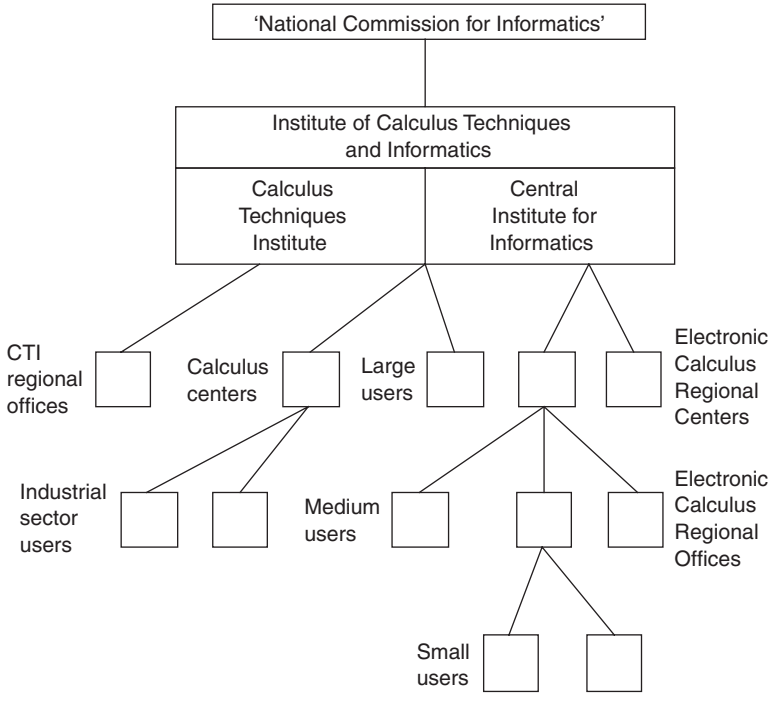


FIG. 14.1. Romanian IT institutions (pre-1989)

were capable of producing industrial process monitoring and control equipment, which used microelectronic components and operating software put together in a customized way for particular applications.

Thanks to national IT programs in 1967 and 1972, there was also state funding for a major series of research and development (R&D) institutions administered by the forerunner of the National Commission for Informatics (NCI) (see Fig. 14.1). These undertook R&D work on both hardware and software, and they created a large number of skilled employees. Although they were involved in theoretical work, these institutions also undertook a lot of "applied research," which encompassed the development and implementation of thousands of computer applications in many different Romanian organizations.

In most economies, there is a divide between state-funded R&D institutions, and private sector software development and implementation firms. Only the latter tend to be thought of as "the software industry." In Romania, no such divide existed and the former therefore constituted its software industry. The largest and most important research institution—located in Bucharest under the government's watchful eye—was the Institute of Calculus Techniques and Informatics (ICTI), which employed around 3000 IT specialists. It was divided into two parts. First, the Calculus Techniques Institute (CTI), founded in 1968, which focused on hardware

components, boards, and microprocessor operating systems. It had a set of CTI Regional Offices representing it throughout the country. Second, the Central Institute for Informatics (CII), founded in 1970, which focused on software production. In the main, this was produced for major national projects, such as the running of the Cernavoda nuclear power plant. There was also a very limited amount of "export" work writing software for state institutions in other Warsaw pact countries or in friendly nations such as China and India.

The CII also had responsibility for coordinating the work of 40 Electronic Calculus Regional Centers (ECRCs), which were spread throughout Romania. Their first role was to design, construct, implement, and maintain information systems for factories and other state-owned organizations (e.g. town halls), which lacked sufficient resources to develop their own systems. These organizations collaborated with the ECRCs partly because central directives instructed them to do so, and partly because all the information systems work and equipment was paid for from central funds funneled through the ECRCs.

The ECRCs also provided advice and assistance for larger state-owned organizations, which could afford to purchase their own hardware, but which needed help in setting up a data processing department and/or help in writing the software to drive their applications. In many cases, the ECRC would write and maintain the software, leaving the "client" with only a few data processing clerical staff. In addition, ECRCs provided a variety of training courses for computer operators, analysts, and programmers. The ECRCs also had a fourth responsibility—that of coordinating the work of the Electronic Calculus Regional Offices (ECROs). Several of these came under each ECRC, each based in a small town within the particular ECRC's remit region. The ECROs were essentially computer bureaux running ECRC-written software on ECRC-owned hardware. The clients of these regional offices were the local factories and other state organizations that lacked the resources to install and run their own computers. They provided input data to the ECRO, which would then produce required output reports.

There were two further locations of IT expertise in Romania under Communism. The first were the computer departments of the very largest state enterprises, which could afford to set up an autonomous operation without the need to refer to their local ECRC. The second were "Calculus Centers," which specialized in servicing the needs of particular industrial sectors (e.g. the mining industry). Where software was developed, then in almost all cases applications were custom-built, representing the greatest use of technological capabilities (see Box 14.1).

The software developed covered all types, from programming tools to operating systems to horizontal applications (such as word processing) to vertical applications that addressed a particular industrial sector or particular organizational function. The degree of local innovation within such software varied, since at least some of it was based on "reverse functional engineering."[8] This is the process by which Romanian software developers—unable to access the program source code of packages pirated from the West—relied on discovering what the software did (i.e. what its functions were) and then imitating these by writing their own programs.

Box 14.1. Software development approaches and technological capability

There are four main approaches to software development, each of which involves a different set of technological capabilities:

- *Custom-built*—creating an entirely new piece of software from scratch; typically involves capabilities up to level 6.
- *Re-engineering*—modifying an existing custom-built piece of software; typically involves capabilities up to level 5.
- *Customization*—modifying an existing software package to suit a particular user's needs; can involve capabilities up to level 5, though sometimes only at level 2 or 4.
- *Software package*—buying a ready-made program "off-the-shelf"; typically involves capabilities up to level 2.

The Downside of Communist Policies

Having presented the positive achievements of Romania's Communist-era isolationism, we now turn to the negative aspects. As stated, there were many thousands of computer applications in Romania developed by the research institutions. However, the quality of these was poor and they were "all characterized by a low degree of integration and effectiveness."[9] Romania's R&D base in IT also remained limited (though more limited in hardware than in software), with an estimated value of installed computers equivalent to less than US$5 per head at the end of 1989. The applications produced were heavily skewed toward certain sectors. In particular, IT was focused on military applications and on internal security, with applications such as tracking movements of "suspects" (of whom there were many under the paranoid eye of the Securitate) and tapping, recording, and analyzing telephone conversations.

By contrast, other applications of IT were provided with much more limited funding, leading to delays in systems development of anywhere from 3 to 20 years.[10] The state research institutes were significant users of IT, as were some of the large state-owned enterprises. Within these, the focus was on relatively low-tech "number-crunching" applications such as statistics, payroll, and accounting systems. There were no major public applications and awareness of IT was consequently low in Romanian society. There was no policy of large-scale IT diffusion but, more, there was an active policy to constrain diffusion. Government suspicion of IT was noted above. This constrained IT diffusion partly as a result of concerns about unemployment, and partly because IT was seen as a tool of potential power and control which should remain largely in the hands of the elite or their trusted subordinates, not in the hands of the populus at large. Consumption of IT was therefore very limited, very undemanding, and very much related to politico-institutional linkages rather than any kind of market mechanism. An uncompetitive domestic market isolated behind high trade walls had the expected effect of producing IT of poor quality at high cost and very slowly. As so often, there were isolated pockets of genuine state-funded innovation and professionalism, but these arose more by accident than design.

Despite its isolationism, Romanian IT was largely based on Western technology. However, there was a major technological lag between Romanian-produced hardware and that available in Western nations. The mainstays of Romanian production during the 1980s were minicomputers such as the Felix C, licensed from the French Iris-50, which was compatible with, and based on, the Honeywell Bull C11; the Independent which was compatible with, and based on, the DEC PDP/11; and the Coral which was likewise an unlicensed relative of the DEC VAX 11/730. ROMCD was—against all the odds—a joint venture with the US IT firm, Control Data Corporation, making products under license, with its main product of the 1980s being a 58 MB disk drive licensed in 1977.[11]

In all cases, the technology was at least 10 years out of date. While the West was in the throes of the PC explosion, Romanian computer operators were still running batch jobs using punch cards, with waiting times of several days at some installations because of the backlog of runs. Eventually, toward the late 1980s, a combination of reverse engineering, access to components from South-East Asia, and some local innovation produced the first Romanian microcomputers: The Felix M18 and M118 series that ran CP/M, which were then succeeded by the Felix PC that initially ran a localized MS-DOS variant in 128 K of memory. To be fair, this represented some degree of "catch-up," being only just over 5 years behind Western technology. However, Romania did not really succeed in its goal of independence. It did not attain the higher levels of technological capability in hardware production, and it remained a dependent follower of Western IT trends more than an independent innovator. Interest in local microcomputers was also limited at a time when foreign PCs were starting to leak into the country. The lag in software was smaller but still present, with the programming mainstays being Cobol, Assembler, Fortran, and Pascal. Again, isolation had bred belated imitation, not independence.

In summary, Romania's IT industry under Communism built up a base of capabilities but one which was limited and which was, as Goodman notes,[12] oppressed on all sides: by Ceausescu's isolationist policies; by weak indigenous R&D and poor management of R&D funds; by centralized government control of all major industries; by a lack of domestic supporting industries; by undemanding internal markets; and by COCOM export controls.

Romanian IT Policy in Transition—Policy Institutions and Changes

After 1989, Romania represented an economy in transition from state to market. The transitional arrangements for IT institutions and for IT policy are discussed immediately below, with the impact on Romania's IT industry discussed in the section that follows.

The National Commission for Informatics was created in 1990 as the apex government body dealing with IT in Romania. It has been responsible for developing strategic national IT policies and plans, and for ensuring that they are implemented. NCI shares responsibility with a number of other government institutions

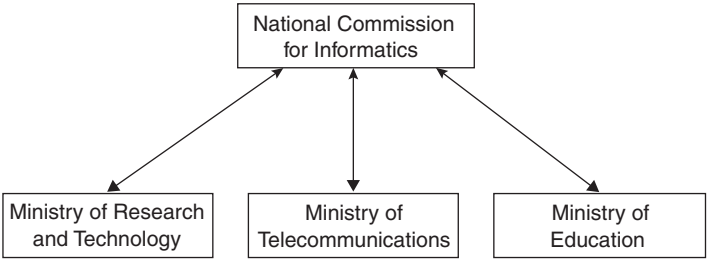


FIG. 14.2. Romanian IT policy institutions (post-1989)

for particular aspects of informatics policy, as summarized in Fig. 14.2. With the Ministry of Research and Technology (MRT), it initiates and coordinates national R&D programs in the field of informatics. NCI collaborates with the Ministry of Telecommunications on issues of public computer network creation and connection to international networks. NCI and the Ministry of Education plan the programs for educational institutions in the domain of informatics.

Romanian IT policy changes after 1989 can be described overall as "measured liberalization" with the maintenance—albeit at declining levels—of existing promotional interventions for the local IT industry and a slower recognition of the need for new promotional measures. Changes to general policies that affected the IT arena include a removal of import blocks and a reduction in import tariffs that enabled foreign hardware and—to a lesser extent—software to become the norm for Romanian users. This clearly represents a major change since 1989, when IT was often an out-of-date copy of foreign IT but was, nonetheless, locally produced. Export of IT has been encouraged only to a limited extent. There was also a slow reduction in state regulation and investments, requiring previously state-owned IT institutions to become more autonomous. The granting of permission for, and encouragement of, subsidiaries of foreign IT multinationals also took place. This, too, represents a major change from pre-revolution days. In addition there was a gradual divestment of public ownership. As generally, progress on this has been modest in the IT sphere.

One IT-specific measure was the introduction in June 1996 of a new Copyright Law, which particularly covered the issue of software piracy. Piracy levels have historically been high throughout the Eastern bloc. The roots of this lie in the Communist era. First, pirating of Western software was encouraged at the time: It helped develop the national IT base, it saved money and, for the ideologically minded, it could be seen as a blow against capitalism. Second, there was no concept of personal intellectual property.[13] Software did not belong to the programmer who made it, or even his or her organization: It belonged to the state and, hence, to everyone. Such attitudes have been hard to change.

As has been the case in many transitional and developing economies, the new law was introduced as much for external as internal consumption. In other words, one

principal intended effect was that Romania should be seen to be doing something about piracy in the eyes of foreign IT multinationals, foreign governments, and multilateral organizations. There was the commonly observed subsequent pattern of implementation challenges. Piracy levels in Romania remained high—as in the rest of the former Eastern bloc—but the law encouraged some decline. The legitimate software market therefore became both sufficiently large and with sufficiently high growth rates to attract the attentions of software multinationals and to support a local software industry.

On the international front, Cocom rules were steadily relaxed until they and the organization ceased to create any effective impediment to Romania's IT trade. Cocom was disbanded in 1994 and Romania was itself a founder member of its successor—the Wassenaar Arrangement—which was launched in July 1996.

Direct funding for the state IT industry has fallen considerably and steadily since 1989. For example, by the mid-1990s the total budget for R&D on electronics, higher education, telecommunications, and IT and computing applications, was less than US$20 m. Of this, less than US$1 m was allocated specifically for informatics R&D.[14] However, this figure is deceptively small since ministries and public sector enterprises spend much more than this on the "applied research" that is, effectively, a set of public sector contracts for information systems development. Put together with EU funds for the development of applications in government, these sums mean that the state remains by far the most important locus of money for the local IT industry. State spending on IT procurement and R&D plus state-oriented EU funding ensure the continuing employment of several thousand IT staff and, hence, the continuing preservation of Romanian IT capabilities.

The single most important input to the IT production process is skilled labor. So too, IT consumption levels cannot rise without a skilled workforce. Limitations on IT skills and IT training have therefore represented a key constraint to Romania's post-1989 vision of a more IT-intensive future. The main focus of government activity has been initial IT education in schools. Private training institutions have rushed to fill the demand for job-related IT skills, but they frequently suffer from problems of inappropriate content, inappropriate training techniques, and inadequate resources. As a result, IT workers have still had to pick up a significant proportion of their technological capability "on the job," and local software development has been perceived—often justifiably—as being of poor quality.

After 1989, telecommunications remained a state monopoly, with prices set by the Ministries of Telecommunications and Finance, and with Romtelecom providing the main telecommunications services. The major towns had digital transmission and switching technologies introduced, but most other links remained unreliable. After 1993, there was an explosion of independent commercial operators working in partnership with foreign firms to provide a range of telecommunications equipment and services outside the core services reserved for public sector monopoly. In general, though, the state of telecommunications in Romania has held back both IT consumption and IT production. Computer networking applications, which became the norm in Western nations, have lagged behind in Romania. IT producers seeking

local and foreign partners have similarly been constrained by telecommunications problems.

The Romanian IT Industry in Transition

After the 1989 revolution, the leading IT R&D institution—the ICTI—was split into three institutions. These comprised the CTI, the Research Institute for Informatics (RII) and the Informatics Perfection Centre (IPC). The CTI was partially privatized, but remained substantially state-funded. The institute has found it hard to maintain its hardware R&D work and has consequently been struggling to extend its role into software development. The RII remained state-owned under the National Commission for Informatics, but financially autonomous and has to win all its income through contract bids. The IPC is partly state-funded and is mainly involved in running training courses in (foreign) computer applications such as Microsoft Office.

The ECROs were closed down while the ECRCs and Calculus Centers became independent commercial societies (SIS, Societies for Informatics Services). They are financially autonomous, have been actively seeking foreign investors for future privatization purposes, and receive no subsidy from the state, but are still seen as a responsibility of the NCI. The NCI provides them, for example, with journals, magazines, and other material to help keep them up-to-date with the latest IT developments. Hardware-producing enterprises similarly became financially autonomous, but with close links to government for those that survived.

In some ways the work of the surviving institutions has remained quite similar to the pre-1989 pattern. For example, they are still involved in a mix of research, development, consultancy, and systems integration, with the emphasis on practical and applied development work for paying user organizations. They also continue to depend heavily—either directly or indirectly—on the Romanian state. To some extent, state funding has enabled these organizations to retain and maintain their existing technological capabilities. However, pay and morale have been low. There has been a dramatic exodus of staff; in some cases of the most capable. Staff losses range from 20 percent of staff in the case of RII to 75 percent or even more in the case of the SISs (former ECRCs and Calculus Centers). A substantial number of these staff joined the post-revolution brain drain, particularly to the United States. The brain drain is not entirely negative. Through remittances home, it offers a source of foreign exchange. It can offer an overseas "shop window" to Romanian software talents, encouraging foreign firms to consider Romania as a site for offshore software development. Romanians based overseas may themselves be in a position to subcontract work back home. However, the brain drain also represents a serious loss of technological capability from the country, and a loss of investments in education and training. Worse, this Romanian talent ends up working for foreign enterprises (some of whom may be competing with Romanian enterprises) rather than helping local organizations.

Less adventurous IT workers have stayed in Romania but drained from the public to private sectors in various ways: To work for multinational subsidiaries in the case of the most fortunate (given the much higher wages paid); to work in the IT

departments of large local enterprises; or to set up on their own. Many in the last group set up small software firms, while others moved into PC trading and assembly. Finally, a small minority of staff have drained right out of the IT sector into other work that presented greater opportunities for income generation. These represent the severest loss of IT capabilities. They form part of an "internal brain drain" of Romanian IT specialists to other economic activities, that must be set alongside the "external brain drain" of specialists who go overseas.

The RII was the successor to the main work (and staff) of the former CII. RII has been able to retain many of its pre-revolutionary resources (especially staff and buildings), but has had sufficient income/investment to allow the build-up of a formidable set of new IT resources (formidable, at least, in comparison with that available to most other software enterprises in the country). With some 360 staff, it remains both the largest R&D institution for software in Romania and the largest software-producing enterprise.[15]

The RII has a relatively secure position because of its government links. It relies heavily on state direction and support and, for example, has no formal marketing operation since government and other pre-existing contacts provide all major contractual work. R&D contracts are either awarded direct in the case of work of a sensitive nature (e.g. work for the Ministry of Defense) or via a bidding process advertised in the national media in the case of other applications (e.g. standard public administration developments). RII is the only viable contender for the direct contracts. It also wins a lion's share of the bid work.

Given the continuing importance of state funding in support of the Romanian software industry, some software R&D enterprises have been created since 1989 to try to tap into such funds. Although the enterprises are new, the founder members are often ex-employees of the old R&D institutions. They are likely to be involved in a varied portfolio of work, but to have a key focus on winning R&D contract projects from or related to the government. These projects arise in three principal ways, most of which are related to government, including the Ministry of Research and Technology. First, enterprises may bid for Romanian government/public sector contract work to develop software. Second, the bid may be for work connected with European integration, often involving development for government agencies. Third, companies may submit proposals and feasibility studies to MRT for the development of information systems to meet a need that is perceived by the company.

Commercialization of the outputs from this work remains poor, so state funding and state-oriented EU funding for software R&D therefore remains essentially a jobs subsidy that keeps this part of the Romanian software industry going and prevents software technological capabilities from atrophying. Programmers would otherwise be likely to leave the country or metamorphose into data entry operators or IT trainers.

One highly visible change since 1989 has been the arrival of foreign IT products and multinational IT firms in Romania. In the case of both hardware and software, actual capital investments have been quite limited, but there are differences

between the two technologies. Software companies such as Microsoft, Novell, SCO, and Oracle are all represented in Romania but, as has been the pattern in a number of other countries, hardware multinationals have been more active and more visible than those in software. Hardware firms have tended to set up their own local subsidiaries whereas software firms have used existing local firms as authorized resellers and distributors. The work of the local hardware representatives includes consultancy on equipment acquisition, installation, maintenance, and training. One major component is software oriented, involving systems integration to put locally relevant software onto the parent company's hardware platforms. Rather than writing software from scratch, this has often involved the provision of Romanian interfaces for existing applications and some customization. IBM, for instance, has been customizing Western computer-integrated manufacturing systems for Romanian enterprises.

Hardware-producing enterprises have fared badly in the transitional era. As Western hardware began to become available, comparisons with Romanian-produced computers and peripherals were unflattering. Romanian hardware was seen to be slower, lower capacity, harder to maintain, energy-inefficient, costlier, and generally out-of-date. As state funding for mainstream computers also dried up, demand for local hardware consequently imploded and the firms were forced to diversify. Although nominally autonomous, their survival has relied on state contracts for mass production of items such as cash registers, electronic scales, and telecommunications equipment. ROMCD, for example, saw its joint venture lapse and it then merged with other companies to form Romanian Cable Systems, focusing on production of telecommunications equipment. Some of the technological capabilities created prior to 1989 have been retained, but many have not and many skilled staff have also left these enterprises to go overseas, to set up their own company, or to work for the locally based subsidiaries of IT multinationals.

In addition to a few medium-sized (10–50 employees) software firms, Romania has a very large number of one- and two-person software firms with low turnover. These are often set up by IT professionals who have left one of the R&D institutions, or by recent IT graduates. Their work ranges along a capability continuum from custom-building software to meet the needs of PC users in the small but growing market of smaller enterprises and home users; through customizing existing software packages for the same market (building databases and spreadsheets, using application programming languages like Visual Basic, and/or adding a Romanian interface to the package); to simply trading imported software packages, which has been and is a growth market. As noted in Table 14.2 and Box 14.1, the first of these activities is relatively skilled; the last requires few, if any, software skills; and the second lies somewhere in between.

The Romanian language and the specific requirements of Romanian legal, government, and business practices provide a continuing "natural protection" for the local software industry in a way that does not apply in hardware. Western packages cannot be transferred directly to work in most Romanian settings. Nevertheless, with the influx of some software multinationals, growing awareness of foreign

software standards (largely driven through piracy), and a growth in the use of English, the Romanian software market has undergone—and continues to undergo—a process of commoditization. That is to say, where once the entire market was for custom-built software, consumption is increasingly dominated by software packages which, at best, have been customized to some extent.

The consequential outcome—less dramatic than with hardware, but present nonetheless—has been a suppression of higher-level local technological capabilities in favor of the foreign capabilities incorporated into imported products. This is also seen in the creation of software packages by Romanian firms. Since the revolution, there has been no serious development of operating systems, databases or complex applications as there was before. Locally produced packages now only exist in dwindling vertical or niche markets. Trading or supporting imported packages is more profitable and more attractive.

Vertical market applications, such as accounting or medical or manufacturing information systems, have the natural protections described above. They are likely to survive for some time. However, it will become increasingly attractive for multinational producers of vertical applications to collaborate with a local partner who can customize the foreign package to local needs and practices. Romanian niche market products include anti-virus and communications packages. Apart from their interface, these are not Romania-specific and foreign analogs exist, which can potentially compete. In earlier days, markets and profits were seen as too small to attract foreign products. However, as the overall IT market grows, such niches come to the attention of Romanian entrepreneurs who seek to find an imported product that will fill the niche, and for which they can act as the distributor. Although new niches may continually emerge, the larger ones will increasingly be filled by imported products.

Prior to 1989, only the very largest state enterprises had their own IT departments. Now, all large and some medium-sized organizations have an in-house IT capacity. In a few cases, this in-house capacity will only be involved in installing, troubleshooting, and maintaining foreign hardware and software. In a greater number of cases, staff will customize packages to meet in-house needs. In perhaps an equivalent, though declining, number software will be custom-built, either because the organization cannot afford a package or because in-house needs are so particular that no package can meet them. In either of these situations, staff are kept busy by the continuous process of change in the legislative and economic environment, forcing constant updating of organizational information systems. This in-house capacity represents a substantial, growing, yet largely hidden site of IT capabilities in Romania. The overt IT industry taps into these capabilities largely through the process of staff turnover, if in-house staff move to a software firm (which high in-house salaries dissuade them from doing).

Liberalization, State Intervention, and Technological Capability

Technological capability (TC) is a key measure of industrial development. According to this measure, Romania's Communist-era policy of isolationism had a positive

effect of creating IT capabilities. However, this build-up came at a high price—particularly in constraining local IT consumption—and the government of the time failed to use the capabilities as a base from which to create a strong, innovative IT sector. Quite the reverse, in fact, since capabilities were atrophying and policy was directionless during the final years of the 1980s.

The period of transition and gradual policy liberalization since 1989 saw much of the country's hardware capability lost or corralled into specialized niches. Liberalization also caused a loss of software technological capabilities through both external and internal brain drains, through the conversion of some software developers into software traders, and through the conversion of some software custom-builders into software customizers. Nevertheless, greater retention of software TCs was possible than was the case with hardware skills.

Liberalization led to the suppression of some existing higher-level technological capabilities. However, it cannot be just "painted black." Liberalization led to a significant expansion in local IT consumption. This drew in the multinationals but it also encouraged a large number of new local entrants into the IT industry. Within these local entrants, there was widespread creation of at least low-level technological capabilities in areas such as consultancy, installation, maintenance, training, and software customization.

The use of computerized systems was still seen mainly as the preserve of IT specialists. As liberalization helped IT to spread out of these enclaves into homes, schools, managers' offices, and the like, demand began to increase for localized systems created by local software developers. Secondly, Western spreadsheet, database, and other packages are no more than shells which must be customized to particular organizational needs. As these packages spread, demand increased for customization work undertaken by local software developers.

The benefit for local IT *production* of liberalization-stimulated IT *consumption* depends, obviously, on the degree of linkage between the two. In the sphere of hardware, there has been little linkage. Stimulating microcomputer use in Romania, for example, benefited hardware multinationals, not local producers. That is not to say that all benefits flowed overseas since local import, distribution, installation, and maintenance capacity all reaped rewards. Nevertheless, the spin-offs for local production were much greater in software.

In summary, while liberalization suppressed some *existing* capabilities, it simultaneously created a pool of *new* (albeit lower-level) capabilities. The difficulty for any nation is to build from this base to higher things rather than being confined to a prison of secondary skills. On the other hand, Romania's retention of existing capabilities has not been the result of liberalization and of market forces—quite the opposite, in fact. Retention of software TCs has, instead, been based on two factors discussed below: "Natural protection" and government intervention.

The natural protection that protects software capabilities is based on unique Romanian user requirements. These derive from Romania's particular organizational practices and social, economic, political, and cultural environment. Elements of this already identified include the Romanian language, the importance of personal

contacts rather than mass marketing, and the process of transition and the continuous changes it demands. Protection has also derived from the high cost of imports in an impoverished economy. Economic and political uncertainties afford a further measure of protection because legal purchases of larger foreign packages represent a long-term investment that many enterprises cannot risk.

These protective factors have meant that local software consumption has been—to some degree—delinked from the global marketplace. This ensured that—piracy notwithstanding—while Microsoft may have been the main beneficiary of growth in Romanian software consumption, there were plenty of opportunities created in local package customization, in training, in support, and even in the custom-build arena. However, this will only remain true if the natural protections remain in place. At the time of writing, there were clear signs that they were being eroded by three factors. First, Western European languages were increasingly part of educated Romanians' skills portfolio. They have been both willing and able to use packages that lack a Romanian interface.

Second, Romanian organizations face a choice in their use of software. On the one hand, they can have a program custom-built by a local firm to meet their particular needs and way of working. On the other, they can adapt their working methods to match what is provided by an imported package. The latter route may be quicker, cheaper (especially where the package has been pirated), and more in tune with ideas of modernizing the Romanian economy by rejecting the "old ways" and embracing Western methods. It may also produce a higher-quality, better-tested application. Third, the major software multinationals have themselves been investing in software localization to match their packages to the languages and practices of individual country markets. Some multinationals have also been "localizing" their prices. These factors particularly affect software demand from business enterprises. The Romanian public sector is more likely to remain a redoubt of unique needs met by local software developers. State intervention via its procurement strengths may therefore be critical in sustaining the local software industry.

In addition to the natural protections, continuing state intervention has helped retain software capabilities. Direct funding for the state IT industry fell considerably and steadily after 1989. Nevertheless, state funding of R&D and public sector procurement of information systems (often via EU funding) remained important props that supported Romanian technological capacity in IT. The Romanian government has been criticized for not liberalizing policies as much as neoliberal blueprints would require, and the roots of this are seen to lie in inefficiencies or the protection of personal and political interests by one section of society. However, government's actions can be viewed in a more positive light. The IT industry—like the whole of the Romanian economy—has been opened up to the forces of market capitalism. If undertaken suddenly, such a process can create a shock that, in economic terms, is potentially lethal. Whether by luck or judgement, changes in Romanian state policy created a process of manageable transition that provided access to up-to-date technology for some Romanian *consumers* without destroying all the technological capabilities

of Romanian IT *producers*. It is therefore argued that the process of transition in Romanian IT has not been managed perfectly, but neither has it been a disaster since both IT industry and IT policymaking institutions continue to exist.

Future Directions for Romania's IT Industry and IT Policy

The future for Romania's hardware industry seems limited, at least in terms of mainstream computer production. The best it can hope is for some arrangement with an existing IT multinational. This might be assembly work for the local market or, just possibly, some peripheral role within the globalized production network. It seems unlikely to break through to higher levels of technological capability from either of these situations. Mainstream markets are likely to remain dominated by existing global production locations.

The future for software seems rather more positive. Compared to hardware, Romania has built up and retained a greater depth and volume of software production capabilities. Development of new capabilities is also easier since software has much lower entry barriers than hardware production because it is less capital-intensive, more labor-intensive, with a lower rate of obsolescence, and (at least for certain types of software) it has far fewer economies of scale. All of these factors work in Romania's favor given its particular macroeconomic circumstances. Yet there remain many constraints to the development of the software sector; constraints that software firms themselves cannot overcome. Higher authorities must therefore become involved.

The obvious higher authority to involve is government, but not all commentators support this. Many US-based companies and development organizations, for example, claim that the best development path is that provided by reliance on market forces and "rolling back" of government intervention. Out of the possible responses of government to private industry (see Fig. 14.3), many of these commentators therefore favor "laissez faire."

These advocates of the free market approach are suffering selective amnesia. America built its IT industry on government money pumped in during critical early growth years in the 1940s, 1950s, and 1960s. Those preaching market forces today do so only because their industry is now fully established and because the market-only approach means more sales and less competition for US software products. Yet state promotion continues at home, with DARPA (the Department of Defense's Advanced Research Projects Agency) having poured hundreds of millions of US dollars into US IT industry research and development during the 1990s.

Advocating a "minimal state" approach also flies in the face of Romania's historical experience of state-supported industrial development. Selective liberalizations may play a part in future developments but further liberalizations may well bring

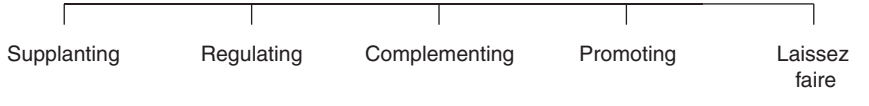


FIG. 14.3. Possible government responses to private industry

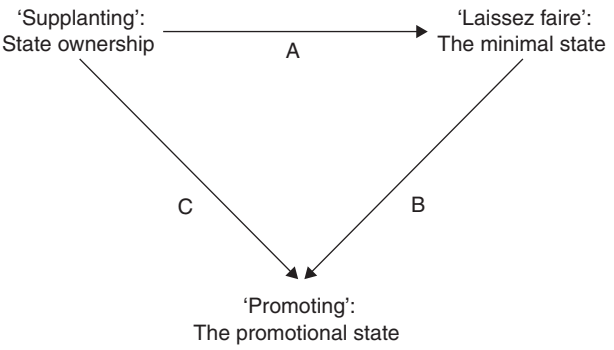


Fig. 14.4. State roles and developmental paths

diminishing returns. The recommended focus for government should be more on supporting and sustaining the capabilities that are left rather than washing them away in a further flood of market forces.

One may conclude that the argument should no longer be one of "state versus market" but a question of how to achieve the most from state and market working together. The recommended role for the Romanian government today is therefore that of a "promotional state." In practice this means a range of measures to support the provision of better financing, better education and training, better research and development, better infrastructure, better market information, and better spread of best practice.[16] The proposed transition path for the Romanian state is therefore path C as indicated in Fig. 14.4.

There are two dangers. First, that the Romanian government reverts to a supplanting and regulatory role. Despite the relatively measured pace of liberalization in Romania, this seems most unlikely. Liberalization has already progressed too far in the country, and internal and external pressures for liberalization are too great, to imagine any serious reversion to past form.

The second danger is that Romania will be pushed along path A. This danger arises because of Romania's past and the associations of state activity with negative aspects of the Communist era. Government intervention comes to be associated with inefficiency, delay, failure, and political interference. Logically, a shortcoming—even a failure—of government intervention in the past is not an argument for recourse to the market. It should, instead, be an argument for improved intervention next time.

In Romania, though, there are some pressures for policy to jump from one ideology to another: From over-enthusiasm for the state to over-enthusiasm for the market. Some industry managers have reacted to liberalization and the lifting of what they see as the "shackles of state interference" by seeking a future devoid of state intervention. They often have a genuine psychological block about viewing government as anything but an encumbrance. Unfortunately, this would create a long and wasteful process before Romania recognizes the need to change once again and move along path B.

In practice, though, this also seems relatively unlikely (though less unlikely than the first scenario). Romania has had more than a decade of transition in which this danger has not emerged. The government machine has been able to resist pressures for an end to intervention and—due to its own self-preservation urges and the political support from those whose livelihoods depend on government funding—the state has been keen to find a continuing role. The role of promotional state provides this and, indeed, can be the basis for a renewal of confidence in the role of the Romanian state.

Acknowledgment

Data presented in this chapter was gathered from a research project undertaken during the late 1990s, including interviews with government officials and with IT industry managers and staff in Romania.

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