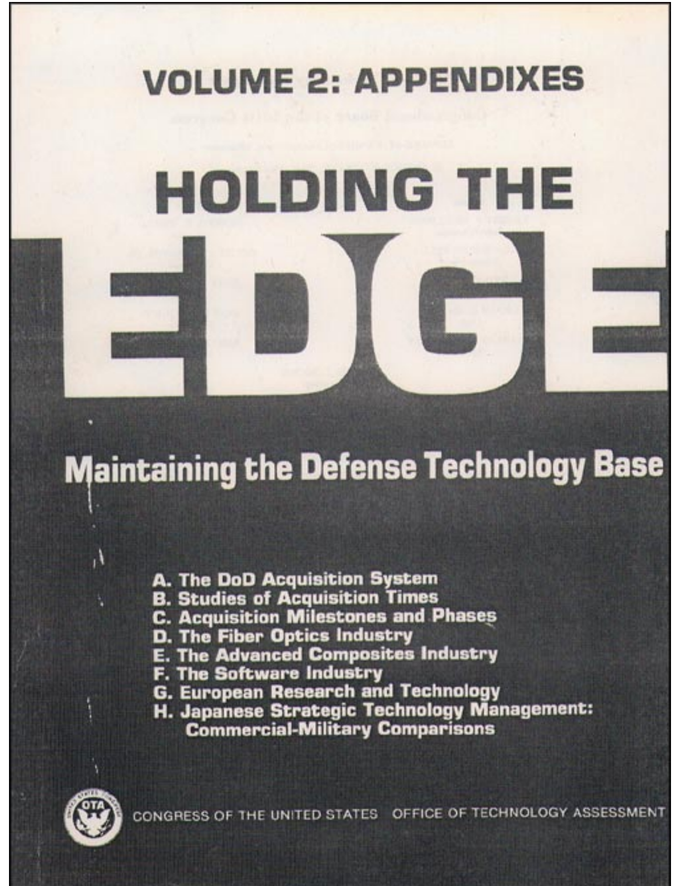
Holding the Edge: Maintaining the Defense Technology Base—Vol. II, Appendices

January 1990

OTA-ISC-432
NTIS order #PB90-253345



Foreword

OTA'S report "Holding the Edge: Maintaining the Defense Technology Base," noted that America's defense technology base has weathered significantly, with challenges to U.S. high-Technology firms from abroad, increasing dependence on foreign and civilian sources of technology for use in military systems, and growing technological sophistication of our adversaries.

These challenges formed the basis on which the Senate Committee on Armed Services requested an assessment of the defense technology base. The first report of that assessment, "The Defense Technology Base: Introduction and Overview" (OTA-ISC-374, March 1988), gave an introduction to the defense technology base, while the second, "Holding the Edge: Maintaining the Defense Technology Base" (OTA-ISC-420, April 1989), analyzed several major problems in depth. It examined the management of Department of Defense laboratories, how technologies are introduced into defense systems, and the exploitation of civilian technologies for defense needs, keeping in mind the questions of encouraging rapid military access to civilian technologies, as well as maintaining the health of the technology base.

In the course of producing the "Holding the Edge" report, extensive analyses were performed that were too voluminous for inclusion in the report. I believe that those analyses are of sufficient interest to be presented in their own right, and they are included in this volume. Three of the appendixes deal with the DoD acquisition processes, three deal with industry case studies (fiber optics, advanced composites, and software), and the remaining two appendixes concern European and Japanese defense technology research, development and management.

The help and cooperation of the Army, Navy, Air Force, the Office of the Secretary of Defense, the Department of Energy, NASA, and the National Institute of Standards and Technology are gratefully acknowledged.

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NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the advisory panel members. The panel does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

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INTRODUCTION

The time needed to field new technology depends critically on the time taken to complete the acquisition cycle, from defining a requirement to deploying operational hardware. Understanding how new technology becomes incorporated in operational forces requires first understanding the acquisition process, which is the subject of this appendix. This appendix is the basis for the concluding section (The Defense Acquisition System") of chapter 8 of the main report.

The purpose of this appendix is to analyze acquisition delays that in turn, delay the introduction of new technology into the field. But, since no single aspect of the acquisition process by itself causes delays, shortening the cycle requires making the entire process more efficient and effective. Therefore, the discussion of acquisition in this appendix takes a broad view.

After first describing the consequences of long acquisition lead times, Appendix A summarizes some studies that have tried to measure the problem. These studies show that the acquisition cycle is not significantly shorter now than it was several decades ago, and in some respects maybe getting longer. The fact that the problem of a long acquisition cycle persists-even with many studies over time identifying many of the same difficulties-is noteworthy.

In light of these findings, the discussion turns to the issue of why defense acquisition problems are so difficult to solve. In particular, it examines the relevance of private sector acquisitions to the Department of Defense (DoD) environment, in view of the marked differences between the two approaches. The remainder of the appendix then analyzes the major defense acquisition problems—together with proposed solutions-that preceding studies have uncovered.

Costs of Delay

For years, defense analysts have been frustrated with the length of the acquisition process. Delays in acquisition lead to lost time in fielding new systems, which threatens our technological lead over the Soviets. Also, the expense of maintaining extended development efforts leads to higher costs. Even more serious than the increased time and cost, according to a Defense Science Board (DSB) panel[1] that studied the acquisition cycle over a decade ago, are the "second order effects'" of delays:

- unsatisfactory results, with systems technologically obsolete by the time they are fielded;
- increased technical risk, since system designers attempt to stretch the state of the art as far as they can to avoid such obsolescence;
- loss of flexibility, since the extended approval process makes it difficult to change the design of a system to meet changing perceptions of its need; and
- added complexity, because delays aggravate the tendency to want systems to do "everything."

Finally, delays lead to even further delays. According to the DSB panel, attempts to fix the problem by requiring earlier and more frequent reviews only serve to extend the front end of the process and make the problem worse. Delays also tend to be self-reinforcing. Costs escalate. forcing programs to stretch out to stay within annual budgetary ceilings. As the expected time for deployment lengthens, planners magnify the anticipated threat, up the system's requirements, and thereby extend development times further.

Growth in Acquisition Times

Several studies of acquisition lead times have tried to determine how serious delays are. and whether the problem is getting worse. These studies. some of which are summarized in appendix B, have generally examined major aerospace systems. To the

[1]Defense Science Board, "Report of the Acquisition Cycle Task Force 1977 Summer Study," prepared for the Office of the Under Secretary for Research and Engineering, Mar. 15, 1978, p. 53.

extent that the acquisition process and/or the level of technology of aerospace programs is typical of other military systems, their results may be generalized. The studies indicate that the development cycle—especially the portion preceding full-scale development (FSD)-has increased somewhat over time. However, this increase accounts for only a small portion of the program-to-program variation in development time over the years. Moreover, as one of the studies points out, increases in the pre-FSD phase "should not automatically be deemed undesirable," since these increases were consistently accompanied in the study data by reductions in cost growth, schedule slippage, and performance shortfall.[2]

These studies found that, once decisions had been made and approvals to proceed had been given, the full-scale development period did not generally lengthen. Based on this finding, one can conclude that increases in technological complexity have not, in and of themselves, extended hardware development. However, production times are increasing as budgetary limitations, coupled with increasing unit costs, reduce the numbers of units purchased per year.

Comparing the increases in decision time to the relative constancy in the length of hardware development, the 1977 DSB study concluded that "it doesn't take any longer to *do* something; it just takes longer to obtain the necessary approvals and acquire funding to do it and to get to the deployment state once the development is finished."[3] More recent studies have-corroborated this finding.

Persistence of Problems

Making the acquisition process more efficient and effective will not be simple, as the Acquisition Task Force of the President's Blue Ribbon Commission on Defense Management (the Packard Commission) stated in 1986:

> . . . present procedures are deeply entrenched. Acquisition problems have been with us for decades, and are becoming more intractable . . . In frustration, many have come to accept the ten-to-fifteen year acquisition cycle as normal, or even inevitable.[4]

Shortly afterward, the Center for Strategic and International Studies (CSIS) concluded that:

> . . . the process is in serious trouble . . . [it] has become overburdened with exorbitantly expensive management layers, excessive delays in program decision approval, inordinate program changes, and cumbersome oversight and regulations

These pessimistic outlooks are not particularly new. Studies over the previous decades have identified many of the same problems and even proposed many of the same solutions. However, these solutions have not been implemented-or not sufficiently to keep the same problems from cropping up in the next study.[6]

The possibility certainly exists, of course, that none of these studies identified the real problems, which therefore remain to be addressed. Alternatively, perhaps sheer intransigence and bureaucratic inertia within DoD keep it from substantially improving its operation.

More likely, however, is that many difficulties in defense acquisition stem from factors that are beyond the DoD's direct control and that no amount of unilateral activity can address. To the extent that such external factors dominate, improving defense acquisition will require large-scale structural and institutional changes that would not be restricted to the Defense Department.

Some of these changes are impossible within our present system of government. Others would inter-

[2] G.K. Smith and E.T. Friedmann, "An Analysis of Weapon System Acquisition Intervals, Past and Present," The RAND Corp., R-2605-DR&E/AF, November 1980, p. vi.

[3] Report of the Defense Science Board, op. cit., footnote 1, p. 35.

[4] *A Formula for Action: A Report to the President on Defense Acquisition*, by the President's Blue Ribbon Commission on Defense Management, April 1986, pp. 5, 15.

[5] "U.S. Defense Acquisition: A Process in Trouble—The CSIS Defense Acquisition Study," The Center for Strategic and International Studies, Georgetown University, Washington, DC, March 1987, p. 3. (CSIS has since dropped its affiliation with Georgetown University.)

[6] For example, see "Defense Acquisition: Major U.S. Commission Reports (1949-1988), Vol. I," prepared for the Defense Policy Panel and Acquisition Policy Panel of the Committee on Armed Services, House of Representatives, Nov. 1, 1988, Committee Print No. 26. The report was prepared by David Lockwood, Andrew Mayer, and Cheryl Crow of the Congressional Research Service.

fere with different objectives that the Nation has so far-explicitly or otherwise-decided are at least as important as efficient defense acquisition. And still others involve resolving longstanding political disagreements and identifying common ground in the face of seemingly incompatible positions.

PRIVATE SECTOR ACTIVITIES: MODELS FOR DoD ACQUISITION?

Studies

Given the premise that the private sector can accomplish tasks more efficiently and cheaply than the bureaucracy-encumbered Federal Government, previous studies have looked to the private sector to provide a model for improving defense acquisition and shortening the acquisition lead time. In some respects, defense acquisition compares quite favorably to private sector activities. Figure A-1, showing average cost growth of major weapons systems along with that of large, complex civilian projects, shows that in general the major weapons systems do quite well by this *measure.* However, this comparison does not address acquisition time or acquisition procedures, which studies and reports have asserted are far more complex and time-consuming in the government than in the private sector.

The 1977 DSB summer study on the acquisition cycle concluded that the acquisition cycles of commercial aviation programs, unlike those of defense systems, had not lengthened over the preceding two decades. The panel attributed the stability of commercial acquisition programs to their smaller technical steps, a greater degree of concurrency between development and production, and competitive market forces that place a premium on timely delivery.

A later DSB summer study also compared DoD acquisition programs with programs of similar complexity and size in the private sector, The final report of this study[7] qualitatively discussed differences in program structure and management between the commercial programs and various DoD programs, but it did not provide a quantitative comparison. Nevertheless, the Packard Commission—perhaps relying on interim results or personal communications with study panelists-represented the DSB study as concluding that each of the commercial programs "took only about half as long to develop and cost concomitantly less" than equivalent DoD programs.[8] With this premise, along with its own analysis of successful DoD programs that were developed under special streamlined conditions, the Packard Commission concluded that "major savings are possible in the development of weapon systems if DoD broadly emulates the acquisition procedures used in outstanding commercial programs."[9] The study went on to characterize those features of successful commercial programs that could be incorporated into defense acquisition: clear command channels; funding stability; limited reporting requirements; small, high-quality staffs; communication with users; and prototyping and testing.

While there are certainly lessons that the private sector can offer the Federal Government-lessons that the Packard Commission sought to uncover—fundamental differences between the government and the private sector must be grasped before any of these lessons can be applied.

Differences in Mission

Private industry exists to make money. Although it is too simplistic to assert that the bottom line dominates ail corporate activities-indeed. companies respond to a range of interests and motivations that are not adequately described by focusing on any one measure-the premise underlying the generation of capital for use by industry is that such investments will be profitable. Even if profit and return on investment are not the only relevant indicators, at least they are quantifiable measures of corporate performance.

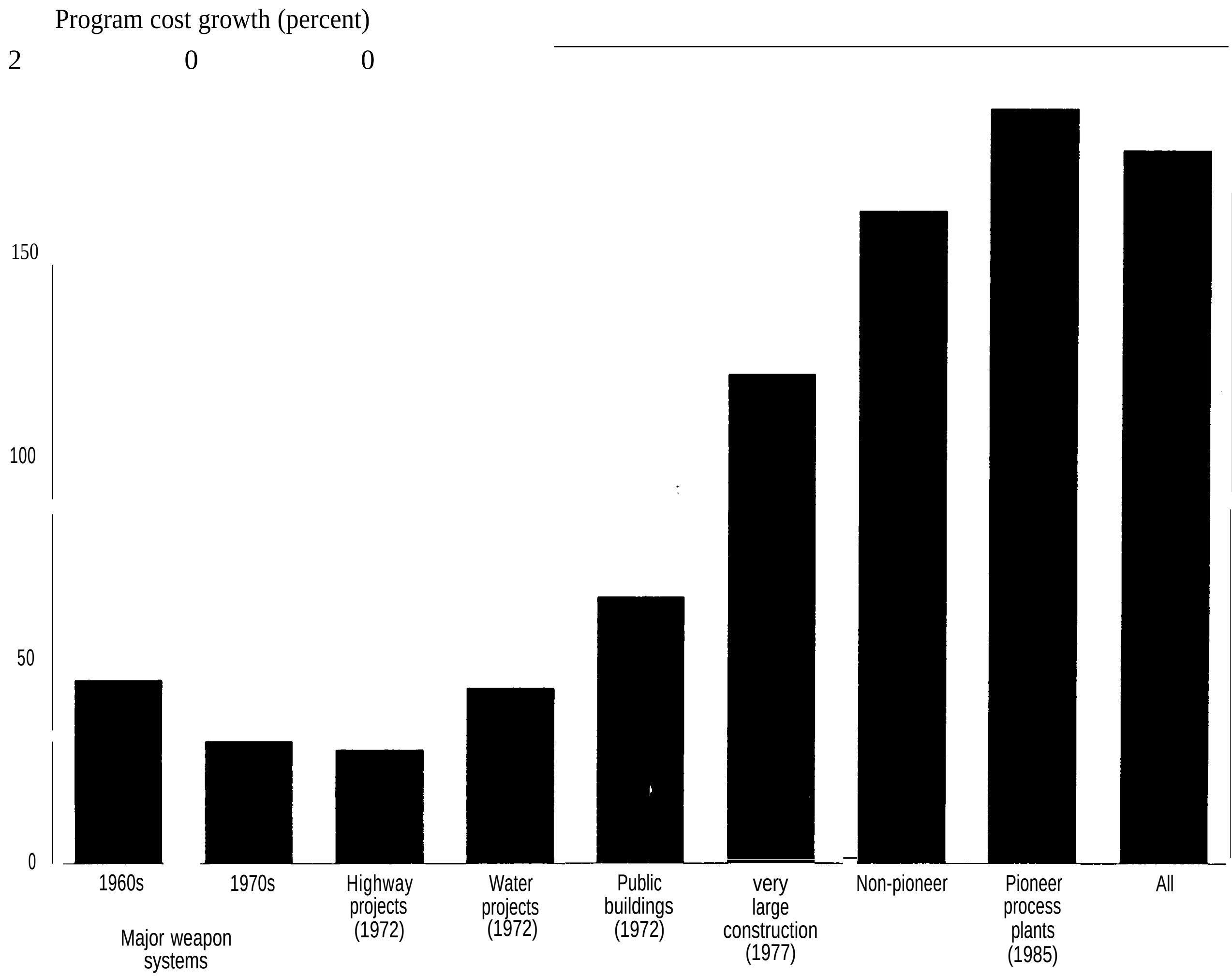
On the other hand. the government's mission of providing services such as maintaining the common defense has no corresponding measure-at least in

7Defense Science Board, "Report of the Defense Board 1985 Summer Study on Practical Functional Performance Requirements," prepared for the Office of the Under Secretary for Research and Engineering, March 1986.

8 President's Blue Ribbon Commission on Defense Management, Op. Cit., footnote 4. p. 11.

9 lbId., p. 12.

Figure A-l —Cost Growth In Major Projects



SOURCE. Michael Rich and Edmund Dews, "Improving the Military Acquisition Process-Lessons From RAND Research" (R-3373-AF/RC), A Project AIR FORCE Report prepared for the United States Air Force, February 1986, p. 11

peacetime. As Secretary of Defense Weinberger stated in his fiscal year 1985 Report to the Congress, "We can never really measure how much aggression we have deterred, or how much peace we have preserved. These are intangibles-until they are lost."[10]

Moreover, just as there is no single measure of government effectiveness. neither is there a single—or even a consistent—set of objectives that govern ment seeks to satisfy. For example, pursuit of objectives such as fairness, environmental protection, equal opportunity, and maintenance of America's economic base may conflict with the ability to acquire defense systems efficiently. With government purchases of goods and services constituting close to a tenth of the 1987 gross national product of $4.5 trillion, the Federal acquisition budget offers considerable leverage for achieving national socio-

[10] Caspar W. Weinberger, Secretary of Defense, "Annual Report to the Congress, Fiscal Year 1985," Feb. 1, 1984, p. 8.

economic goals—leverage that legislators have not refrained from using.[11]

Differences in Accountability and Oversight

Government and industry have very different relationships with" their sources of funds. A taxpayer is not the same as a shareholder. The two have very different attitudes regarding the uses to which their funds are put, attaching to the expenditure of public funds a sensitivity-and a standard of accountability—that goes beyond business accounting practices. Consider how easy it is to set compensation for a member of a corporate Board of Directors compared with that for a Member of Congress.

One of the most significant differences between government and private sector activities, the role of Congress, has no parallel in the commercial world. Congress serves as the "court of last resort" for societal issues that cannot be resolved in any other forum. Issues of high congressional visibility are by definition controversial, and it is unrealistic to expect the political process by which these issues are resolved to proceed efficiently or directly. This process, and the annual budget cycle, will always introduce an uncertainty to defense acquisition that commercial programs do not share. As James Schlesinger, former Secretary of Defense, has stated,

> This is a society that based its system of government on the Constitution, which calls for a dispersion of powers. That means that everybody has to agree, and under normal circumstances, most people don't agree. As a consequence, we are never going to have the kind of model efficiency in the Department of Defense, or in government generally, that some kind of theorist would want.[12]

Moreover, the U.S. Constitution gives Congress specific responsibilities with respect to defense that extend above and beyond its involvement in other government activities, making defense activities even less comparable than other government projects to private sector activities.

Differences in Size

● Although individual projects in the commercial sector may rival individual defense programs in size, the DoD as a whole is orders of magnitude larger than most commercial enterprises. The DoD budget for fiscal year 1989 was roughly equal to the combined annual sales of the top four Fortune 500 fins-General Motors, Exxon, Ford, and IBM.

Bureaucratic complexity increases geometrically with size. leading to inherent inefficiencies of scale. To some extent, these inefficiencies are unavoidable. All military/defense work (except that involving nuclear weapons) has been centralized in a single Department of Defense precisely so that all claims on defense dollars could compete against one another. One possible way to reduce bureaucracy would be to fence off elements of what is now the DoD budget, eliminating them from the competition.[13] This situation existed before 1947, when the Department of War and the Department of the Navy were two independent Cabinet-1evel departments. Combining them into a single Department of Defense made it harder for each component to operate. but in theory the combination benefits the taxpayer by permitting the allocation of available funds where they can most effectively be used.[14]

Differences in "Market Forces"

Ideally in a free market, competition among firms rewards the most efficient ones and penalizes the unsuccessful ones. Duplication of effort-i.e. competition-ultimately serves to improve the quality of those who survive. The Federal Government. on the other hand, is a monopoly; there is only one

[11]Government purchases of goods and services represented 8.4 percent of GNP in 1987; defense goods and services totaled 6.5 percent of GNP. From "National Income Product Accounts," distributed by the U.S. Department of Commerce, Bureau of Economic Analysis, July 1988.

[12]"The Second Annual Report of the Secretaries of Defense," complete edited transcript of a 3-hour conference held at Gaillard Municipal Auditorium in Charleston, SC, on Sept. 30, 1988, produced by the Southern Center for International Studies, p. 24.

[13]This approach is indeed taken, most notably by the recent practice of placing the entire Strategic Defense Initiative Organization out of the ordinary DoD process and making its funds unavailable for any other use. Highly classified or "black" programs also operate outside many of the usual DoD processes; their budgets are protected largely by invisibility.

[14]The National Security Act of 1947 created the Air Force as an independent entity and combined it with the Army and Navy to form the National Defense Establishment under a single Secretary of Defense. In 1949, Public Law 81-216 consolidated centralized power under the Secretary of Defense by creating the Office of the Secretary of Defense and replacing the National Defense Establishment with the Department of Defense. Albert G. Dancy, "Department of Defense Research and Development Management," *National Security*, July/August 1977, p. 349.

Department of Defense. To prevent duplication, the roles and missions of DoD components are designed not to overlap. There are, therefore, no corresponding "market forces" that provide built-in incentives for DoD to improve its performance. Moreover, DoD cannot sell off or disband a military service or agency that does not perform as well as hoped.

EFFICIENCY v. EFFECTIVENESS

Defense analyst Edward Luttwak has stated that, "The great irony is that the defense establishment is under constant pressure to maximize efficiency, and that its leaders believe in that goal when they ought to be striving for military effectiveness-a condition usually associated with the deliberate acceptance of inefficiency."[15] The nature of defense acquisition imposes specific requirements that go even beyond the disincentives to efficiency facing government activities in general.[16]

Level of Technology

Much of the technology used in defense systems is ahead of that in the commercial sector—if indeed any commercial analogs exist at all. Although the defense lead is not as pronounced as it has been—and several areas of defense 'technology now lag behind their commercial counterparts-military technology must nevertheless often be developed from scratch for a relatively limited production run.

Responsibility for the Defense Industrial Base

Since the Department of Defense is the only customer for sophisticated military systems, producers do not have the option of selling elsewhere should they not be able to sell to DoD.[17] If the Defense Department wants to maintain a diversity of suppliers, 't must buy enough from each of them to keep them in business, even if their products may not be DoD's first choice. As analyst Edward Luttwak has put it:

> When I go shopping for shoes, I can select them on the basis of price and quality. I need not buy more shoes than I want simply to keep shoe-production lines open. Nor do I have to ensure that this or that shoe manufacturer has enough profit to pay for the design of new shoes. Above all, I have no reason to pay more for my shoes to ensure that there is spare capacity in the industry, to meet a sudden need I may have for a hundred pairs of shoes instead of just one. Yet those are all key concerns for defense purchasing.[18]

In-depth examination of defense industrial base concerns is beyond the scope of this study. Recent studies looking at the interrelationship between DoD needs and policies and the viability of the defense industry have concluded that there is cause for concern.[19]

Low Production Rates

Aggravating the problem of maintaining a viable production base are production rates lower than economically optimal because the required inventories are small and must be divided among firms. To preserve competition, the most efficient producer cannot be permitted to drive the others out of business. Moreover, production rates are typically determined by externally imposed budgetary limits, rather than being derived internally according to what makes sense for the program.

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[15] Edward Luttwak, "The Price of Efficiency," *Military Logistics Forum*, July/August 1984, p. 22.

[16] Leonard Sullivan, Jr., "Characterizing the Acquisition Process," paper presented at the Center for Strategic and International Studies Conference on U.S. Defense Acquisition, November 1986, Washington, DC, pp. 15-16. (Commissioned for "U.S Defense Acquisition: A Process in Trouble," the CSIS Defense Acquisition Study.) Used by permission of the author.

[17] Companies can produce military systems for export, but such exports must be approved by the U.S. Government and are not usually approved for technologies at or above the state of the art available to U.S. forces.

[18] Edward Luttwak, "Behind the Pentagon Scandal: The Real Problem is a System That Treats Weapons Like Commodities," *The Washington Post*, June 26, 1988, p. C-1.

[19] See in particular U.S. Department of Defense, "Bolstering Defense Industrial Competitiveness," Report to the Secretary of Defense by the Under Secretary of Defense (Acquisition), July 1988; and "Final Report of the Defense Science Board 1988 Summer Study on the Defense Industrial and Technology Base," Report to the Under Secretary of Defense (Acquisition), October 1988.

Unpredictability

There is no way to predict how, where, or when war might break out. Procurement needs are therefore impossible to predict, and shut-down of production lines is risky.

Unacceptability of Failure

The inevitable consequence of competition in the free market is the risk of failure, which entrepreneurs willingly accept as the price for the chance to strike it rich. In the commercial arena failure translates to loss of investment or to reduced earnings. Substantial failure on the part of DoD could have far more severe consequences.

The Department must therefore tolerate a far greater degree of redundancy and risk aversion than a commercial enterprise would. This degree of risk aversion should not apply to individual defense programs; indeed, lack of failures would indicate that the overall program was far too conservative. In the aggregate, however, the Department's attitude toward risk must be substantially different than a corporation 's.

Summary

In light of the features that characterize government activities in general and defense acquisition in particular, it may well be true. as defense analyst Leonard Sullivan has concluded, that "many efforts to make acquisition more efficient are simply second-order expedients to paper over largely insoluble first-order problems."[20]

THE ACQUISITION PROCESS

The Packard Commission's report was not the frost attempt to apply lessons from the private sector to defense management. Seventeen years before chairing the President's Blue Ribbon Commission on Defense Management, David Packard (the Deputy Secretary of Defense) established the present DoD acquisition process to emulate industrial practices of project management and sequential review and approval. The basic process is one of distinct phases separated by decision points or milestones. The Office of the Secretary of Defense (OSD) develops policy for major system acquisition programs and conducts reviews to ensure that these programs respond to specific needs and are managed soundly. The military Services and defense agencies individually (for the most part) identify those needs and define, develop, and produce systems to meet them.

The Defense Acquisition Executive and Defense Acquisition Board

Regulations issued by the Office of Management and Budget and DoD have codified acquisition procedures: OMB Circular A-109, "Major System Acquisitions"; Department of Defense Directive 5000.1, "Major and Non-major Defense Acquisition Programs"; and various implementing DoD Directives and Instructions. These regulations specify the milestones that major defense acquisition programs-those exceeding certain budgetary limits or having particular urgency, risk, congressional interest, or other special significance-must pass. The Secretary of Defense conducts milestone reviews of these programs, unless he delegates review authority to a Service or agency head.

OMB Circular A-109 directs the head of each Federal agency that acquires major systems to "designate an acquisition executive to integrate and unify the management process for the agency's major system acquisitions."[21] The role of Defense Acquisition Executive is now assigned to the Under Secretary of Defense for Acquisition [USD(A)], an office created on the Packard Commission's recommendation to consolidate responsibility for DoD acquisition. The Deputy Secretary of Defense or the Under Secretary for Research and Engineering had served as Defense Acquisition Executive prior to the establishment of the USD(A). (The rationale for

[20] Leonard Sullivan, Jr., op. cit. footnote 16, p. 16.

[21] Circular A-109, "Major System Acquisitions," Executive Office of the President, Office of Management and Budget, Apr. 5, 1976, p. 5

establishment of this position is discussed later in this appendix, under "Bureaucratic Paralysis.")

The USD(A) chairs the Defense Acquisition Board (DAB), a panel of senior defense officials that assists the Secretary of Defense in determining acquisition policy and making program milestone decisions.[22] DAB replaced the Defense Systems Acquisition Review Council (DSARC), which had had a similar function but a somewhat different composition. Upon completing each phase of a program's progress, DAB reviews parameters such as cost, schedule, performance, and affordability. programs whose oversight is delegated to the Services or defense agencies follow a corresponding series of milestone reviews at the Service or agency level. These service reviews are conducted through Service Systems Acquisition Review Councils, or SSARCs.

Program Management

The DoD acquisition process is based on the principle of Program Management, in which one individual-the program manager-is responsible for integrating in a single office the diverse administrative, professional, and technical capabilities required to manage the development and production of a major system. This concept was first formalized—at least within DoD—by the Air Force Systems Command in the late 1950s,[23] although its basic structure originated within industry.[24] The other Services have adopted some version of this process.

The size and organization of program offices vary. The larger ones are self-contained, containing up to several hundred personnel. Others have "matrix" organizations, in which a small core staff is dedicated to each program, while shared support organizations carry out most of the effort.

Under DoD Regulation 5000.1, individual program managers are to be separated from the USD(A) by no more than two intermediate management layers. Program managers are to be given "full authority to manage their respective programs within the scope of established program baselines. " However, besides the program manager and program office,

> . . . there are many additional senior managers and organizations who also have management authority and responsibilities within the overall DOD system acquisition environment. Programs do not belong exclusively to [program managers]. They are DOD and service programs, and represent investment decisions by the [Secretary of Defense] and service

[22] The Defense Acquisition Board was established by DoD Directive 5000.49 in 1987. Its permanent members are:
- Under Secretary of Defense for Acquisition (chair)
- Vice-Chairman of the Joint Chiefs of Staff (vice-chair)
- Deputy Under Secretary of Defense for Acquisition
- Service Acquisition Executive of the Army (currently the Under Secretary of the Army)
- Service Acquisition Executive of the Navy (currently the Under Secretary of the Navy)
- Service Acquisition Executive of the Air Force (currently the Assistant Secretary of the Air Force for Research, Development, and Acquisition)
- Department of Defense Comptroller
- Assistant Secretary of Defense (Production and Logistics)
- Assistant Secretary of Defense (Command, Control, Communications, and Intelligence)
- Assistant Secretary of Defense (Force Management and Personnel)
- Assistant Secretary of Defense (Program Analysis and Evaluation)
- Director, Operational Test and Evaluation
- Director, Program Integration
- Director, Defense Research and Engineering
- Chair of the appropriate Committee
- DAB Executive Secretary

(Acquisition Committees have been established to assist DAB in various function areas.)

[23] Senate Armed Services Committee Staff Report, "Defense Organization: The Need for Change," Senate Print 99-86, Oct. 16, 1985, p. 531.

[24] Albert G. Dancy, "Department of Defense Research and Development Management," *National Security*, July/August 1977, p. 350.

> secretaries who are also accountable for their management and decisions.[25]

Study after study has identified the separation of responsibility and authority—the control exerted over a program's outcome by people and offices who are not directly accountable for it-as a major problem of the defense acquisition structure. Analysts differ as to the degree to which power and accountability can be brought back together in the defense acquisition environment.

The Planning, Programming, and Budgeting System

One of the most important factors external to the program manager is the allocation of resources for the program. Resource allocation throughout the DoD is conducted via the Planning, Programming, and Budgeting System (PPBS) instituted by Robert McNamara. Prior to McNamara, the Secretary of Defense exerted little control over the budget submissions of the Services. The result was that budget decisions were largely independent of long-term plans, Service budgets were prepared independently of one another with little rationalization across Services. and the Secretary of Defense had no analytic basis on which to challenge Service requests. The situation has been summarized as one in which "requirements planning was being done without explicit regard to cost, and budget planning was being done without explicit regard to need."[26]

Although there are formal links between the two, the PPBS is separate from, and largely independent of, the systems acquisition system. In theory, PPBS is supposed to start with assumptions and projections concerning national strategy and future threats (planning) and lead to definition and analysis of alternative force structures and weapons/support systems, including resource requirements (programming). These programs are then translated into budgetary terms and submitted to Congress (budgeting).

In practice, the process has never worked this clearly. In particular, criticisms leveled at the planning stage are that the absence of fiscal constraint makes the process somewhat irrelevant, and that planning often justifies desired force levels and new systems after the fact, instead of forming the analytical basis for setting those levels and initiating those systems. The programming and budgeting stages of PPBS, from which the actual funding request and ultimately the funds themselves derive, have a more direct impact on DoD activities than the planning phase.[27]

The relationship between the acquisition system and PPBS has been compared to that between congressional authorizations (programmatic review) and appropriations (budgetary allocation). However, this analog fails to recognize that PPBS alone integrates programmatic and budgetary considerations.[28] A better model is that acquisition programs proceed along a "dual track."

This relationship poses complications for program managers. Under the acquisition system, they report through at most two higher officials to the Under Secretary for Acquisition. Under PPBS, however, their resources are justified through a much more complicated chain of authority, involving a systems command of their military Service, the military headquarters staff of the Service, the civilian Service Secretariat. and the Office of the Secretary of Defense. The PPBS process is managed and overseen by the Defense Resources Board (DRB), which consists of most of the DoD's most

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[25]Defense Systems Management College, "Introduction to DoD Program Management," April 1986, p. 25.

[26]Senate Armed Services Committee Staff Report, op. cit., footnote 23, pp. 484-485. Original sources are "Planning, Programming, and Budgeting System," by the Joint DoD/General Accounting Office Working Group, pp. 17-18; and (for the quotation) K. Wayne Smith, *Proceedings of the Conference on the Defense PPBS: Past, Present, and Future*, March 1983, p. 50.

[27]PPBS is also criticized on the basis that DoD officials spend so much time preparing and justifying budget requests that they are not able to devote as much attention as they should to monitoring the actual execution of funds once they are appropriated.

[28]Edwin A. Deagle, "Organization and Process in Military R&D," in Franklin Long and Judith Reppy (eds.), *The Genesis of New Weapons: Decision Making for Military R&D* (Elmsford, NY: Pergamon Press, 1980), p. 178.

senior officials and is chaired at present by the Deputy Secretary of Defense.[29] The Defense Resources Board, like the Defense Acquisition Board, seines in an advisory role to the Secretary of Defense, who has final authority over both acquisition and PPBS activities.

The directive implementing the PPBS specifies that coordination between the acquisition process and the PPBS is achieved through common members of the Defense Acquisition and Defense Resources Boards and "by the requirement to develop an acquisition strategy for all major systems."[30] The acquisition strategy is the basis of a program manager's system acquisition plan. Various milestones identified in the acquisition strategy tie into the PPBS process; approval will not be given for a program to proceed to a new acquisition phase unless its sponsoring Service or agency has planned for the program in its budget request through PPBS.

Despite the ties between the two, the relationship between acquisition and PPBS has been controversial, especially concerning which path should "have the last word." According to a House Armed Services Committee report, Richard Godwin, the first USD(A), proposed that "once a decision to develop or purchase a system had been made by the DAB it could not be overruled by the DRB," enabling the acquisition organization to bypass the PPBS[31]

This proposal was not accepted. On September 1, 1987, Deputy Secretary of Defense William H. Taft IV issued a revised version of DoD Directive 5000.1 stating that significant changes in approved major defense acquisition programs could not be made without prior approval of the Defense Acquisition Executive (i.e., the USD(A)) "unless *made during the course of the Planning, Programming, and*

[29] Established in 1979 by Secretary of Defense Harold Brown, the Defense Resources Board originally had five formal members, one ex-officio member (Chairman of the Joint Chiefs of Staff), and five associate members. As of July 18, 1988 (according to DoD), it had 21 Permanent Members and 5 "Attendees":

Deputy Secretary of Defense—Chairman
Secretary of the Army
Secretary of the Navy
Secretary of the Air Force
Chairman, Joint Chiefs of Staff
Under Secretary of Defense (Acquisition)
Under Secretary of Defense (Policy)
Department of Defense Comptroller
Assistant Secretary of Defense (Command, Control, Communications, and Intelligence)
Assistant Secretary of Defense (Force Management and Personnel)
Assistant Secretary of Defense (Health Affairs)
Assistant Secretary of Defense (International Security Affairs)
Assistant Secretary of Defense (International Security Policy)
Assistant Secretary of Defense (Production and Logistics)
Assistant Secretary of Defense (Reserve Affairs)
Assistant Secretary of Defense (Special Operations and Low Intensity Conflict)
Assistant Secretary of Defense (Program Analysis and Evaluation)
Director, Defense Research and Engineering
Director, Operational Test and Evaluation
Director, Strategic Defense Initiative Organization
Associate Director of the Office of Management and Budget for National Security and International Affairs

Attendees:

Chief of Staff of the Army
Chief of Naval Operations
Chief of Staff of the Air Force
Commandant of the Marine Corps
National Security Council Representative

SOURCE: Department of Defense, "The Defense Resources Board," July 18, 1988.

[30] Department of Defense, Directive 7045.7, "Implementation of the Planning, Programming, and Budgeting System (PPBS)," May 23, 1984.

[31] House Armed Services Committee, "Report on the Duties and Authority of the Under Secretary of Defense (Acquisition)," Committee Print No. 15, Nov. 16, 1987, p. 29.

[32] DoD Directive 5000.1, "Major and Non-Major Defense Acquisition Programs," Sept. 1, 1987, Section E.3, p. 7 (emphasis added). 5000.1 also states that the Defense Acquisition Executive "shall be promptly notified" in the event of such changes.

Budgeting System process. "32 Under Secretary Godwin resigned 2 weeks later.

Milestones

Taken in total, the acquisition process consists conceptually of the four activities shown in figure A-2. However, only the lower two-definition of solutions and production of equipment—are specifically associated with new systems. The two upper activities of assessing operational needs and advancing the technology base are ongoing and largely system-independent.

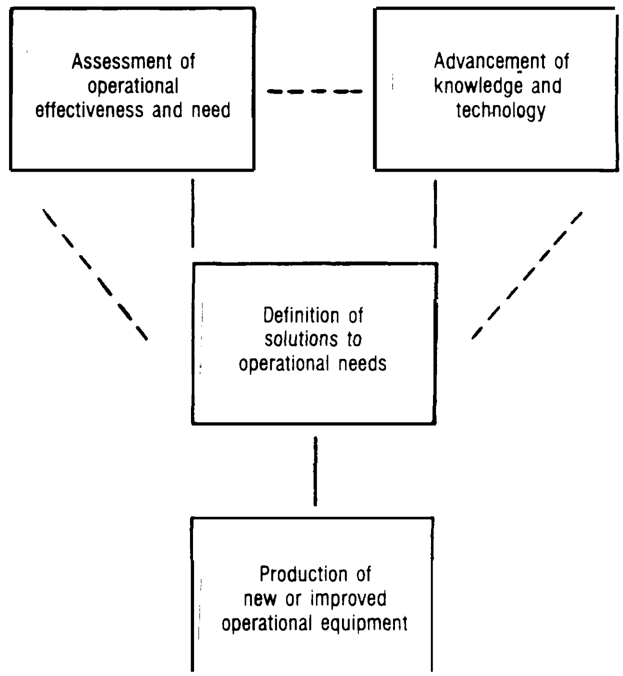
The formal process for major defense acquisition programs-those expected to cross a preset dollar threshold or otherwise qualify as described in the preceding section, "The Defense Acquisition Executive and Defense Acquisition Board"-is normally divided into five phases delineated by distinct milestones. These phases and milestones are diagrammed in figure A-3 and discussed in more detail in appendix C.

The diagram and the description are idealized in that they assume a progressive linear process in which each stage is completed satisfactorily before the next begins. In reality-no matter what the organizational structure-activities in each phase overlap and interact. Research and development is a risky process. Not only are surprises to be expected in utilizing new areas of technology, but they often crop up in what had been thought to be straightforward applications of established techniques.

Appropriateness of Oversight

Through this series of milestone reviews, the OSD exercises oversight over major Service acquisitions. The degree of OSD oversight in the past has varied considerably and remains quite controversial. The DSARC (now DAB) process was originally justified as a means of decentralizing decisionmaking by limiting OSD involvement in major programs to specified milestone reviews. However, the extensive briefings required before DSARC meetings and the

Figure A-2-Components of Defense System Acquisition



SOURCE: Alexander Kossiakoff, "Conception of New Defense Systems and the Role of Government R&D Centers," in Franklin Long and Judith Reppy (eds.), *The Genesis of New Weapons: Decision Making for Military R&D* (Elmsford, NY: Pergamon Press, 1980), p. 67.

need to respond to OSD concerns has led to nearly continuous OSD involvement.[33] While some criticize this situation as OSD "micromanagement," others support a significant role for OSD. According to the General Accounting Office,

> Critics of the system fail to realize that program managers are responsible for expenditures involving billions of dollars in public funds and that a system of checks and balances is essential.[34]

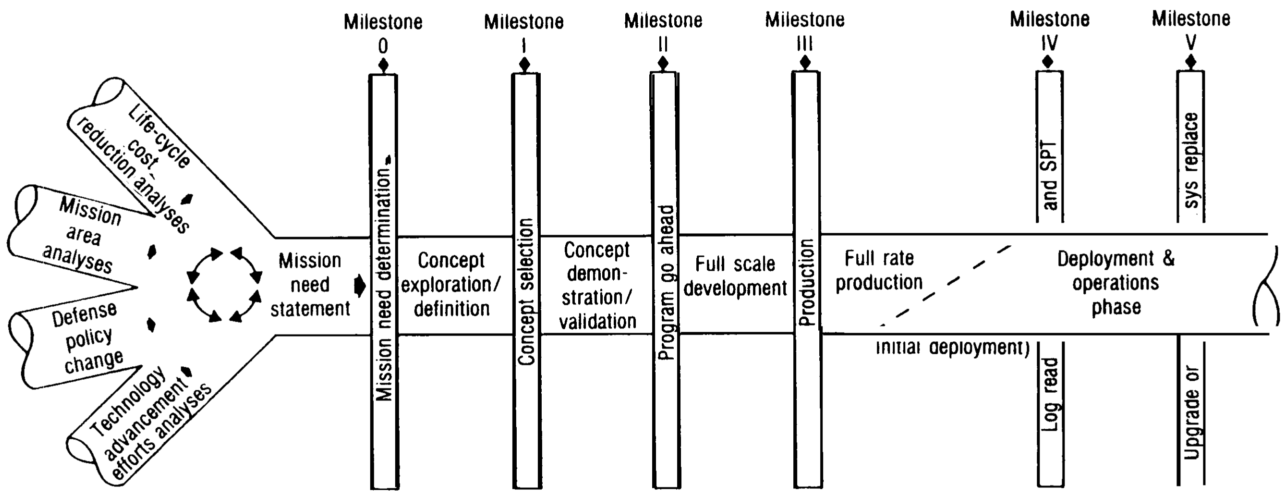
GAO further concluded that micromanagement is difficult to define: "There exists no clear distinction of where appropriate management surveillance ends and interference in day-to-day operations begins."

The 1977 DSB study determined that "the DSARC, OMB (Office of Management and Budget),

[33]Franklin Long and Judith Reppy, "The Decision Process for U.S. Military R&D," in Kosta Tsipis and Penny Janeway (eds.), *Review of U.S. Military Research and Development, 1984* (Washington, DC: Pergamon-Brassey's, 1985), p. 14. Original citation on this point is to Acquisition Advisory Group, *Report to the Deputy Secretary of Defense*, Sept. 30, 1975, vol. 1, p. 23.

[34]General Accounting Office, "A Critique of the Performance of the Defense Systems Acquisition Review Council; Billions in Public Funds Involved," PSAD-78-14, Jan. 30, 1978, p. i.

Figure A-3—Life Cycle of Major System Acquisitions



SOURCE: Defense Systems Management College, unpublished materials.

and PPBS processes are reasonable with respect to the provision of external review and control over acquisition program budgeting and management."[35] However, the study panel did identify weaknesses in the process that lead to delays. In particular, it worried that annual budget deliberations, and the ease with which unfavorable decisions in one venue could be reopened in another, had unnecessarily extended the "front end" of the cycle. Moreover, the study predicted that things were likely to get worse unless changes were made.

It is certainly true that the DAB oversight process and the PPBS process-both inherently bureaucratic, both involving the participation of a great many people, and both having significant impact on programs-pose problems for the program manager. Commenting on the 1977 study, one analyst agreed that "the endless sequence of reviews, interventions, and delays caused by the struggle for access to decisions both within and outside the Pentagon is a program manager's nightmare."[36] However, this individual disagreed with the DSB study's particular recommendations for streamlining the initial stages of the cycle. Although "compression of the front end of the acquisition cycle would be a program developer's dream," he argued, "to all the other participants in the process-OSD, OMB, and the Congress-it would be a nightmarish return to all the evils which brought McNamara to inject OSD forcefully into the process in the first place."[37]

ANALYSIS OF THE ACQUISITION PROCESS

Problems in defense acquisition can be separated into a number of categories, including program variability (sometimes called program instability); the requirements generation process, including the process by which resources are allocated and weapons systems selected; bureaucratic paralysis; inappropriate organization of the defense procurement system; and the quality of and incentive structure facing acquisition personnel.

Program Variability

Constant changes in defense acquisition programs-and the ensuing inefficiencies. cost increases, and delays they cause—have become the rule. According to a study by the Center for Strategic and International Studies,

> Few, if any, defense acquisition programs follow either the course for which they were originally planned or any other stable pattern of development or production. Many purists refer to this real-world phenomenon as program instability—a term that captures their frustration, but not the facts of the complex legislative/executive system.[38]

Program variability, the more appropriate term used by the CSIS study, results from a number of factors: the requirements process; the risks inherent in developing new technology; the political/budgetary process; and personnel turnover. While the disruptions introduced by these factors can be controlled to some extent, their underlying causes cannot be eliminated.

Whereas the unwillingness to reexamine requirements in the light of technological difficulties can drive up the cost and complexity of weapons systems, changing requirements too frequently can make sound management impossible. In the past, according to analyst Jacques Gansler, the military Services have "felt free to change their minds frequently" concerning the requirements and budgets for new systems.[39] Now, in a process called "baselining," internal contracts are developed between program managers and the senior management of their Services concerning the cost, schedule. and performance milestones for new weapons systems. Since changes to the baseline require equally high level review, formalizing a baseline represents an attempt to reduce the amount of change that programs undergo within DoD.

In practice, however, baselining requires that the program manager have the authority to reject changes to his or her program that are imposed from

[35] Defense Science Board, op. cit., footnote 1, p. 66.

[36] Edwin A. Deagle, op. cit., footnote 28, p. 175.

[37] Ibid., p. 176.

[38] "U.S. Defense Acquisition: A Process in Trouble—Acquisition Study, The CSIS Defense," op. cit., footnote 5, p. 32.

[39] Jacques Gansler, "Improving Weapons Acquisition," *Yale Law and Policy Review*, vol. V, No. 1, Fall/Winter 1986.

BoxA—Concurrency [1]

One method that has been used to shorten acquisition times is to overlap some of the phases in the process, specifically y those of full-scale development and procurement. In highly concurrent programs, production starts well before fill-scale development is completed on the assumption that, although changes will inevitably be made as development proceeds, it will be possible to accommodate these changes without disrupting production. Overall, a significant amount of time can be saved.

Besides shortening the time needed to field new systems, concurrency can in principle achieve cost savings and management efficiencies because reduced development time means lower overhead and more continuity and stability in the labor force. Concurrency can also reduce program changes that would otherwise force cost increases and delays. However, the principal risk of increased concurrency is that significant problems uncovered after production has begun may necessitate major design changes, forcing extensive rework on completed systems. These changes lead to cost overruns and schedule slippages, countering the very goal of concurrency in the first place. If adequate solutions cannot be found, the program must accept diminished technical performance or even face cancellation and the consequent writeoff of sunk costs.

Concurrency has historically been emphasized during wartime or periods of national emergency (e.g., depth charges developed in World War 1, the Manhattan Project in World War II, the missile programs undertaken in the 1950s, and'' smart" weapons developed for use in Vietnam). But, until the 1960s, concurrency was rare in peacetime defense acquisition programs. Since then, the practice has gone in and out of favor as the time savings have been seen to outweigh, or conversely not to justify, the risks. Problems encountered with systems developed in a highly concurrent manner in the 1960s led DoD to establish a "fly before buy" system that emphasized prototype development and testing prior to production decisions. The 1977 DSB study nevertheless concluded that "the policy of 'no concurrency' is being applied too rigidly and is inefficient and costly in many cases."[2]

Despite this recommendation, pressures against concurrency appear to be increasing after major problems were encountered with two recent weapons systems, the B-l B bomber and the Division Air Defense (DIVAD) gun, developed in a highly concurrent manner. The Packard Commission has urged that prototypes be built and tested before full-scale development, let alone production, begins.[3]

The current regulatory and legislative environment provides no clear direction concerning concurrency. While existing DoD regulations do not prohibit and in places encourage concurrency, legislation has constrained it. On one hand, Directive 5000.1 states that "commensurate with risk, such approaches as. . . reducing lead time through concurrency. . . shall be considered and adopted when appropriate."[4] On the other, the 1987 Defense Authorization Act stated that "a major defense acquisition program may not proceed beyond low-rate initial production until IOT&E (initial operational test and evaluation) of the program is completed." This Act also stressed competitive prototype development that will likely have the effect of inhibiting concurrency.[5]

In attempting to determine the effects of concurrency, the DSB study found that "there is no convincing evidence that concurrency necessarily adversely affects program outcome in terms of cost, performance, or field utility." Therefore, the blanket ban on concurrency should be eliminated since "the acquisition time span . . . can be minimized if concurrency is properly employed.'[6] A Congressional Budget Office study 10 years later found that "no strong relationship exists between concurrency and schedule delay" but that "a modestly stronger relationship exists between concurrency and cost growth." The more highly concurrent programs experienced higher cost growth.[7]

[1] Much of this discussion is drawn from the Congressional Budget Office (CBO) publication "Concurrent Weapons, Development and Production," August 1988.

[2] Defense Science Board, "Report of the Acquisition Cycle Task Force 1977 Summer Study," prepared for the Office of the Under Secretary for Research and Engineering, Mar. 15, 1978, p. 53.

[3] President's Blue Ribbon Commission on Defense Management, op. cit., footnote 4, p. 19.

[4] DoD Directive 5000.1, Section D.9.b, Sept. 1, 1987, p. 5.

[5] Congressional Budget Office, op. cit., footnote 1.

[6] Defense Science Board, op. cit., footnote 2.

[7] Congressional Budget Office, op. cit., footnote 1, p. ix. CBO defined the degree of concurrency as the fraction of the initial operational test and evaluation that occurred after the decision to proceed with low-rate initial production. The congressional ban on concurrency prohibits the *full*-rate production decision from occurring during this period.

sources outside the program. Granting this degree of authority would be extremely difficult within the present DoD environment. For example, although specified in a program's baseline, one of the most important program parameters-its budget—is ultimately established by a PPBS system external to the acquisition process. Moreover, it is often changed (i.e., annually) by Congress.

Increased emphasis on technology demonstrations and prototyping can be expected to help control program changes caused by technological risk. If, however, such demonstrations further extend the entire cycle, they could increase uncertainties due to changes in the threat and in projected program budgets.

Changes imposed on defense acquisition programs by the political process-e.g., battles over program budgets, policies, and control-originate at every level of activity within DoD, the executive branch of government, and Congress. The key difficulty here is politics-not in the pejorative sense of backroom deals, influence trading, and pork barreling that the word has come to acquire. but in its true definition as a struggle between competing interests. Examining major strategic weapons systems such as the MX and Trident, analyst Edwin Deagle illustrates the larger context in which defense acquisition fits:

> The MX and Trident are not simply expensive programs deserving of careful management. They are also: major commitments to specific solutions of the complex problem of strategic nuclear deterrence; affirmation of roles and missions within and among the military services; explicit choices about the importance of strategic weapons relative to other military activities: explicit choices about the importance of strategic weapons relative to other public initiatives such as urban housing, national health insurance, energy security or middle class tax relief: and, by no means least commitments to particular commercial enterprises which, as a result, will employ people in specific places. In short, these weapons systems and the R&D process which yields them lie in the center of the competition among values, purposes, and programs inherent in the process of public choice—by nature a political process. Organizational and procedural imperatives designed to support this political process are likely to be vastly different from, and perhaps in conflict with, those designed to yield efficient management.[40]

Granted, the programs Deagle has chosen to discuss are among the largest and most politically visible of defense programs. Nevertheless, the point he makes-that political judgments are inherent in resolving competing demands on public resources—applies to all defense programs.

Even without political influences, change is inevitable:

> Development will always be difficult, uncertain, time consuming, and more expensive than expected. Threat, doctrine, and resources will change, requiring constant reevaluation of the system. **That is how it should be, and efforts** to **isolate the acquisition management process from such pressures in the name of coherent and sound management are sure to introduce crippling distortions into the political structure of the process.**[41]

The fact that the political process necessarily introduces uncertainty into defense acquisition does not, however, mean that nothing can be done to mitigate the effects of this uncertainly. Actions within both Congress and the DoD can improve the coupling between the political and the acquisition processes,

Congress

The" level of congressional oversight-many would say micromanagement—has risen dramatically over the past 20 years. A few statistics reflect this growth: In 1970, the defense authorization act was 9 pages in length and was accompanied by a 33-page conference report. Congress made 180 adjustments to the authorization, and 650 to the appropriations bill, during that year's budget review. By 1985, the authorization act grew to 169 pages and the conference report to 354; congressional adjustments to defense authorization and appropriation legislation totaled 1,315 and 1,848, respectively.[42]

[40]Edwin A. Deagle, op. cit., footnote 28, p. 162.

[41]Ibid., p. 179. Emphasis added.

[42]Senate Armed Services Committee Staff Report, op. cit., footnote 23, p. 591.

Today, 29 committees and 55 subcommittees oversee defense activities in both houses, and over 20,000 congressional staffers and employees of congressional agencies deal with some aspect of defense.

This growth has not occurred in a vacuum. The DSB Acquisition Cycle task force concluded in 1978 that:

> A significant portion of the "blame" for this increasing congressional "micromangement" can probably be laid to the fact that the DoD has exhibited a chronic inability or unwillingness to adequately forecast program, cost, schedule, and performance information and projections to the Congress.[43]

The Defense Systems Management College, the organization that trains DoD program managers, includes the following interchange in a discussion of congressional oversight:

> Senior DoD acquisition official, appearing before an authorizing committee:
>
> "Gentlemen, what we'd like to know is when are you going to stop micromanaging our business?"
>
> Senior, veteran professional staff member of that committee:
>
> "Sir, when you start."[44]

Congressional action on the defense budget is often an extension of debates conducted in other arenas.

> Much of the so-called Congressional micromanagement is, in fact, stimulated by factions within the Pentagon hying to reverse, through selectively leaked information to Congress, unpalatable decisions made within the executive branch. In this sense many Congressional actions on weapons programs are an extension of internal decision making by the Department of Defense.[45]

Underlying much of the congressional interest in details of the defense budget is, of course, its direct impact on a great many congressional districts-those having major defense contractors, defense bases, or large numbers of defense workers. Although Members of Congress are responsible for national policy, they are accountable to their individual constituents. It should not come as a great surprise that Members of Congress therefore look out for their constituents' interests in the course of their legislative responsibilities. To put it bluntly, they have every incentive to pork barrel. Damaging as this practice may be on the national level, it is difficult to see how changes in congressional procedure can substantially reduce it, given the underlying incentives built into the United States Constitution.

In specific cases where national consensus exists on a matter of high priority, Congress has shown that it can rise above parochial tendencies. A good example is the recently enacted legislation that will permit the DoD to close down unneeded defense bases. Although every Member of Congress wants to eliminate waste from the defense budget, none considers bases in his or her own district to be wasteful. Moreover, many Members of Congress are convinced that DoD uses base closures to threaten legislators considered insufficiently "pro-defense.'* Therefore, Congress has enacted legislative roadblocks over the past decade or so, effectively making it impossible for DoD to close any bases. To break this impasse, Congress established a commission to draw up a list of bases to be closed on an "all or nothing" basis, forcing any legislator seeking to remove a particular base from the chopping block to torpedo the entire package. By this means. Congress and DoD cut through the storm of political controversy surrounding individual closures.

Congressional review of the defense budget presently deals more with artificial accounting inputs (dollars, personnel slots, buildings, etc.) than with defense outputs (mission capabilities or strategic goals). The inputs are easier to count and to control, and unlike defense mission capabilities they permit comparisons to other programs across the entire Federal Government.

A report to the Senate Armed Services Committee described how the budget request needed to fulfill a particular defense mission-developing the capability to deploy 10 combat divisions to Europe within

[43] Defense Science Board, op. cit., footnote 1, pp. 63-64.

[44] Defense Systems Management College, "Congressional Involvement and Relations: A Guide for Department of Defense Program Managers," November 1986, p. 60.

[45] Judith Reppy and Franklin A. Long, "The Decision-Making Role of Congress," in Franklin Long and Judith Reppy, op. cit., footnote 28, p. 185.

10 days of mobilization-was divided by accounting categories into separate pieces parcelled out among the committee's subcommittees. Although each different piece—storage site construction, spare part supply, updating airlift capability, transporting materials to Europe, etc.-was part of an integrated whole, each was treated as an independent item. Each subcommittee compared the items in its jurisdiction to similar ones wholly unrelated to the mobilization mission. "In a short time, the emphasis on policy implementation of a major defense commitment was lost among thousands of minor decisions on accounting inputs."[46]

Although many have recommended that Congress serve as a board of directors for DoD as a whole, its present budget process tends to push the examination to a much lower level. Moreover, Congress has difficulty entering into a dialog with the Defense Department on strategic objectives because there is no clearly identifiable counterpart within DoD with whom such a discussion can be conducted:

> There is no appropriate forum at the OSD [Office of the Secretary of Defense] level in which strategy, policy, and operational concepts and capabilities are fully debated and translated into specific acquisition programs. The thrust of the current process is to concentrate on procurement, management, and allocation of resources for individual systems rather than on the overarching rationale and purposes that define the need for and the operational capabilities of those systems. . . . Ideally, the Joint Chiefs of Staff (as a collective body) and the Secretary of Defense could furnish this longer perspective, but they are hampered by process, schedule, and organization from dwelling on many of these broad operational considerations.[47]

It might be added that much of the "process" keeping these officials from taking a broad view consists of responding to numerous congressional inquiries and directives.

Additional factors complicating congressional review of the DoD budget are major procedural changes that have been introduced over the last 15 years. In 1974, the Congressional Budget and Impoundment Control Act established a new budgetary process within Congress. Prior to that act, the two-stage process of authorization and appropriation dealt with Federal agencies and programs individually. There was no mechanism whereby revenues and expenditures could be examined across the entire Federal Government. The 1974 Act prefaced a third "budgeting" stage in which Congress establishes income and expenditure targets for the Federal budget as a whole and specifies spending targets in each of 15 mission areas. These targets are supposed to guide, but not formally bind, the authorizing committees. Later in the budgetary cycle, the budget guidelines are reviewed and new targets are specified that are binding upon the appropriations committees.

Under this new process, review and appropriation of the DoD budget takes significantly longer. Final decisions for the defense budget are made by congressional conference committees as (or, in many recent cases, after) the new fiscal year starts, late in the executive branch's budget-formulation process for the following fiscal year. Last-minute changes in the appropriated funding levels require last-minute changes to next year's request and influence planning estimates for the following fiscal year. The Packard Commission found that the timing and scope of changes introduced late in the appropriations process "prevent the DoD from making coherent linkages among the three defense budgets that it manages at any one time—the budget being executed, the budget under review by Congress. and the budget that DoD is developing for the upcoming fiscal year."[48]

The Balanced Budget and Emergency Deficit Control Act of 1985 (Public Law 99-177, more commonly known as the Gramm-Rudman-Hollings Act) placed further constraints on congressional budgetary process. Besides reinforcing the "zero-sum" nature of the Federal budget, the major impact of this legislation was its emphasis on Federal "outlays," or money actually spent, during a fiscal year. The appropriations process prior to Gramm-Rudman-Hollings dealt not so much with actual

[46]Senate Armed Services Committee Staff Report, op. cit., footnote 23, p. 584-585.

[47]"U.S. Defense Acquisition: A Process in Trouble—the CSIS Defense Acquisition Study," op. cit., footnote 5, p. 26.

[48]President's Blue Ribbon Commission on Defense Management, "A Quest for Excellence: Final Report to the President," June 1986, p. 22.

spending but with "budget authority," or permission to enter into contracts that obligate the Federal Government to future expenditures.

Deficits are created not by budget authority but by actual expenditures. Since funds appropriated for different purposes are spent at very different rates, the relation between budget authority and outlays depends on the purposes for which the funds are to be used. Salaries, for example, are essentially spent entirely within the year for which they are appropriated; cutting one dollar of budget authority for salaries will reduce that year's outlays by a dollar. Funds for building ships, on the other hand, can be spent more than a decade after their appropriation; cutting a dollar off a ship procurement appropriation trims as little as two cents off that year's outlays.

Due to this variation in outlays versus budget authority, Gramm-Rudman-Hollings outlay controls make it even harder to review the defense budget. Increasing appropriations in one area may require far greater cuts in another to keep outlays from changing.

As a final point concerning the role of congressional "micromanagement," the prospects for changing the relationship between Congress and DoD to one of greater strategic oversight were damaged by the years of tension and confrontation that existed between Congress and DoD in the early 1980s.

Department of Defense

Actions within the DoD contribute as much to program variability as do those by Congress. Although congressional line item changes certainly complicate program management, changes generated within the many layers of DoD management add significantly to the problem. The cuts that are passed down are due to DoD's inability to forecast program costs accurately, to defer new starts until sufficient funding to cover the actual (rather than the originally estimated) costs is available, or to eliminate programs-rather than stretch them out—in the event of funding shortfalls.

In 1981, then-Deputy Secretary of Defense Frank Carlucci offered 32 management initiatives to improve the defense acquisition process, with number 4 being to "increase program stability in the acquisition process." Program stability was also one of six areas cited for high-level management attention in 1983. Nevertheless, a General Accounting Office (GAO) review of the Defense Acquisition Improvement Program in 1986 found that "despite large budget increases, DOD has reported essentially no progress in stabilizing major weapon programs."[49] GAO found that although the impact of underfunding programs is "well-recognized and documented, a workable and effective method for matching DoD's needs with budgetary constraints has not been developed."[50] The Office of the Secretary of Defense, according to GAO, "has reported that the inability to cancel low priority programs continues to be a fundamental obstacle to improving program stability."[51]

Limiting the number of new programs and terminating low priority ones will be required in order to prevent the remaining programs from being underfunded. Although DoD has claimed progress in limiting the number of "major new programs,'" GAO found this reduction to be due in part to a doubling of the minimum cost threshold that defines a major system. "Consequently, fewer new starts are considered major under the revised higher thresholds."[52] These funding issues are discussed further in the "Affordability" section of chapter 8 of the main report.

Too often, desire for "funding stability" wanes when the possibility of funding growth presents itself. According to the Comptroller General of the United States. the boom and bust cycle that the DoD budget experiences "encourages managers to procure as much as possible when funding is relatively plentiful and not attempt to develop a stable and

[49]General Accounting Office, "Acquisition: Status of the Defense Acquisition Improvement Program's 33 Initiatives," GAO/NSIAD-86-178BR, September 1986, p. 10. The 33rd initiative was added in 1984.

[50]General Accounting Office, "Major Acquisitions: Summary of Recurring Problems and Systemic Issues: 1960-1987," GAO/NSIAD-88-135BR, September 1988, p. 10.

[51]General Accounting Office, Acquisition: "DoD's Defense Acquisition Improvement Program: A Status Report," GAO/NSIAD-86-148, p. 10.

[52]Ibid.

realistic procurement plan."[53] Although he doubted that "defense budgets will ever be as stable as DoD managers would like," the Comptroller General nevertheless argued that steps could still be taken within DoD and Congress to "create as much stability as possible in an environment which will always be uncertain to some degree."[54]

Personnel Turnover

Another contributor to program variability is turnover in acquisition personnel. Although typical defense programs have lifetimes measured in decades, the average tenure of program managers surveyed by GAO in 1986 was less than 2 1/2 years. Such short tenures make it difficult to increase the authority of program managers because they hinder any attempt to assign accountability. Moreover, they can generate pressures to sacrifice long-term quality for short- term results.

The contribution of high turnover rates to program variability is only one of the many issues concerning the acquisition workforce. Additional issues are discussed in the section on "Acquisition Personnel," below.

Reducing Program Variability

Analysts disagree as to which of two management failures is the more serious in the light of unexpected change: failure to plan and budget flexibly, or failure to hold to a fixed schedule in the light of performance and budgetary uncertainties. Writing for the CSIS Defense Acquisition Study, Leonard Sullivan notes that acquisition plans during the Reagan Administration "have gone through a boom and bust cycle that totally defies rational planning." "These gyrations . . . make fixed planning for 'stable acquisition' an unachievable ideal." His conclusion is that "inescapable fluctuations in White House and Congressional budget expectations and tactics demand the development of an acquisition system that responds resiliently to the inevitable changes in long-range projects in America's short-range political environment."[55]

On the other hand, participants in the DSB summer study on Practical Performance Functional Requirements believed that every effort must be made to hold to a fixed schedule in the event of unexpected changes. "Upon commencement of FSED [Full Scale Engineering Development], schedule should be considered as the dominant program driver and the program contracted and funded accordingly . . . In the event that technological opportunities or operational requirements warrant change, block upgrades [deferring a set of changes for a later production series rather than redesigning and/or retrofitting changes into the entire production run] should be the primary solution to avoid schedule delays."[56] If a block upgrade is not acceptable, "it's probably better to terminate the program and begin the process over again."[57]

Several techniques have been proposed to lessen program variability and/or plan in the face of uncertainty, among them baselining, multiyear budgeting, and increasing management flexibility.

Baselining-The Defense Acquisition Improvement Act of 1986 (Public Law 99-661) mandated baselining for major acquisition programs-a requirement incorporated in DoD Regulation 5000.1 as of September 1987. The Act also requires each military Service to designate selected high priority. major acquisition programs as "Defense Enterprise programs" having streamlined reporting procedures for program managers. For these programs. congress may authorize funding for the full-scale development or production stages "in a single amount sufficient to carry out that stage, but not for a period in excess of five years . . ."[58] Such multiyear authorizations would eliminate annual congressional reviews for these programs, at least by the Armed

[53] Statement of Charles A. Bowsher, Comptroller General of the United States, before the Senate Committee on Armed Services, GAO/T-NSIAD-88-18, Mar. 14, 1988, p. 10.

[54] Ibid.

[55] Sullivan, Leonard, Jr., op. cit., footnote 16, pp. 33-35.

[56] Defense Science Board, op. cit., footnote 7, p. 2.

[57] Ibid., p. 74.

[58] 10 U.S.C. 2437 (c), as added by Public Law 99-661, Section 906. Quoted in Andrew C. Mayer, "The Defense Acquisition Improvement Act of 1986: An Analysis of Key Provisions," Congressional Research Service Report 87-733F, Aug. 28, 1987, p. 9.

Services Committees. Four programs-the Army's Multiple Subscriber Equipment (MSE) and Advanced Tactical Missile System (ATACMS) programs and the Navy's Trident II missile and T-45 Trainer System programs-have been given Milestone Authorization status by Congress. However, Congress has neither received nor approved the actual authorizations for these programs.

Multiyear Budgeting-Multiyear budgeting goes beyond multiyear authorizations for selected programs to provide authorization and appropriation of the entire Department of Defense budget for periods longer than one year. With a longer planning horizon and less frequent congressional review, the hope is that programs can enjoy greater stability, with congressional oversight directed more towards strategic guidance and away from individual line items. Following the Packard Commission's strong recommendation, the Department of Defense submitted a 2-year 1988-89 budget to Congress early in 1987.

Biennial budgeting has not been readily accepted by Congress. One reason is obvious—one of the purposes behind biennial budgeting is to lessen congressional influence. The matter is not that simple, however, since Gramm-Rudman-Hollings plays a role. Facing fixed deficit targets for future years, Congress is reluctant to commit itself to future outlays when it has no firm idea of what the corresponding revenues will be. Estimating revenues for the ongoing fiscal year is difficult enough, given their dependence on economic conditions that cannot be predicted in detail. Doing the same thing for future fiscal years becomes highly problematic.

The CSIS Defense Acquisition study points out a number of other practical disadvantages and complications of the biennial defense budget.[59] Unless implemented government-wide, it would give DoD a preferential status within the executive branch. Government policies and procedures-especially with regard to personnel—emphasize uniformity across the board. If the 2-year cycle enabled the Defense Department to resist budget cuts, it could come under strong political attack.[60]

Second, while a 2-year budget reduces opportunities for congressional micromanagement. it also restricts DoD's flexibility. A supplemental appropriation adjusting the second-year amounts would restore some of this flexibility, but it would therefore also reintroduce opportunities for congressional intervention.

The CSIS study goes on to describe timing difficulties that the 2-year terms of members of the House of Representatives and the 4-year term of the President present when coupled with a biennial budget. If the 2-year budget were submitted and approved during a presidential election year, the incoming President would not be able to execute his or her own defense budget for 20 months after taking office. If the budget were submitted and approved in odd-numbered years, Members of Congress running for reelection would be doing so on the basis of defense budget votes made more than a year ago. The CSIS study believed that Members would not want to put themselves in this position. However, the report does not make clear why a Member of Congress would find it much harder to justify a defense budget decision made the previous year on the basis of conditions at the time, than it would be to defend any other decision made during the first year of a 2-year term.

The CSIS study does not discuss the root cause **of** these timing problems, which is that absolute program stability is fundamentally incompatible with holding elected officials accountable at periodic intervals for their actions. Every time an elected official is replaced, there is—and must be—the opportunity for the new official to change the way things have been done.

There are two ways to handle the timing problem. One is to permit a new President to make significant changes in a previously submitted 2-year budget,

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59"U.S. Defense Acquisition: A Process in Trouble—The CSIS Defense Acquisition Study," op. cit., footnote 5, pp. 83-84.

60A later study conducted jointly by CSIS and the Johns Hopkins Foreign Policy Institute argued that even if biennial budgeting were not extended government-wide, "defense expenditures are sufficiently different from the balance of federal expenditures to warrant such special treatment." DoD manages a large capital plant and spends half its budget on the development, maintenance, and manufacture of goods, therefore requiring a longer view than other Federal agencies. See "Making Defense Reform Work: The Project on Monitoring Defense Reorganization," Harold Brown and James Schlesinger, co-chairmen, a joint project of the Johns Hopkins Foreign Policy Institute and the Center for Strategic and International Studies, Washington DC, November 1988, p. 20.

thereby vitiating the advantages of long-term budgeting. The other is for the new President to leave essentially intact the budget he inherits upon assuming office, concentrating instead on the budgets that he will submit This latter approach, of course, counts on the new President's successor to respect those future budgets when they extend into a subsequent Administration.

For whatever reason, the first submission of a biennial budget in 1987 for fiscal years 1988 and 1989 did not go far. Neither the House nor the Senate Armed Services Committees authorized very much of the DoD 1989 request. More significantly, the 1988 authorization act specified that "authorizations of appropriations and of personnel strength levels in this Act for fiscal year 1989 are effective only with respect to appropriations made during the first session of the One Hundredth Congress' '-i.e., appropriations made that year. The appropriations committees of the House and Senate, even less enthusiastic about multiyear budgeting than the Armed Services Committees, did not appropriate any 1989 funds.

Although no funds were appropriated for 1989 during the 1988 budget cycle, one effect that the 2-year submission did have was to make DoD's out-year plans more visible to Congress than they had been before. Although some might fear that this visibility just gives Congress that much more opportunity to meddle, it is also plausible that improved communication between Congress and DoD might give Congress the confidence in DoD planning it needs to relax its level of "micro-management. " Good communication extends the planning horizon, enabling both parties to take a longer view.

Management Flexibility—A further way to reduce the variability of DoD programs is to increase the ability of the DoD to adjust to changing circumstances without having to come back to Congress. Such techniques-which would make DoD management easier just as they would lessen congressional influence-include increasing DoD's ability to transfer money from one program to another (i.e., reprogramming); using funds in one appropriation type (e.g., procurement) for another purpose (e.g., research and development); and including unspecified management reserves in program budgets.

Box B—Multiyear Budgeting and the U.S. Constitution

Multiyear budgeting for the Department of Defense is, to some extent, restricted by the United States Constitution. Article I, Section 8 of the Constitution gives to the Congress the power "To raise and support Armies, but no Appropriation of Money to that Use shall be for a longer Term than two Years."[1] According to the debate surrounding the ratification of the Constitution, this provision reflected the desire of the founding fathers to keep close tabs on the standing military.

The very next paragraph of the Constitution, however, gives Congress the power "To provide and maintain a Navy"[2] without specifying any time limit for appropriated funds. Presumably this reflects the fact that shipbuilding—even in the 18th century, before the growth of a massive Defense Department procurement bureaucracy—took longer than 2 years.

None of this language would have any effect on a biennial budget cycle. Neither does it affect the authorization process, which is not specifically discussed in the Constitution. Should budget cycles longer than 2 years be desirable, constitutional lawyers would have to answer questions such as how multiyear appropriations for procurement, personnel, research and development, and construction would be affected by these clauses.

[1] Article I, Section 8, Paragraph 12.
[2] Article I, Section 8, Paragraph 13.

Congress now grants DoD the ability to make some such changes without prior notification of or approval by Congress. However, in other cases. either notification or prior approval of the Appropriations and/or the Armed Services Committees is required.[61] Furthermore, each fiscal year's budget has associated with it a maximum amount of transfer authority. If the sum total of all reprogrammings subject to the transfer authority limit reaches the maximum, no further reprogrammings can be made.

These requirements, along with the emphasis in DoD budgeting on specific program elements, restrict DoD's ability to respond to changing circumstances. The DSB Acquisition Cycle Task Force pointed out several DoD needs that do not neatly fall within existing line items and that therefore require additional funding flexibility to address:

- Getting started with technology and system experiments in areas that DoD has already decided to submit to Congress in the following year's budget. (This problem would be aggravated by a biennial budget cycle.)
- Purchasing good ideas from the losing bidders in competitions.
- Providing extra support to programs performing better than expected.

The Task Force recognized the belief within Congress that too many reprogrammings were already being used to evade congressional intent. "Negotiating new and higher thresholds will thus require a restoration of DoD's credibility with the Congress."[62]

The decomposition of the defense budget into different accounting categories restricts DoD flexibility. It also can impede efficient program management objectives such as maintaining a smooth transition from development to production. A DSB Task Force concluded in 1983 that "the Design to Production transition is a process and not a fixed event," and that DoD funding rules prohibiting the use of R&D funds for production make it "very difficult to apply resources [during full-scale development] to producibility, manufacturing planning, tooling and test equipment and other actions leading to production.'"[63]

A Final barrier to sound program management, and the biggest obstacle towards giving program managers greater authority over their own programs, is the lack of management reserves. Although the funds required to fix unexpected problems obviously cannot be estimated for any particular program, they can be determined statistically in the aggregate. Supervisors who oversaw several program managers, if provided with these reserves and the authority to allocate them, would be able to address problems as they arose. According to the Acquisition Cycle Task Force,

> ,.. the important thing to keep in mind is that this is not "contingency" money that is simply budgeted "in case something happens." It is a necessary management resource that should be provided because it is well known, and experience amply demonstrates, that something *will* happen and it must be fixed quickly if the program is to remain on schedule and within "planned for" costs.[64]

However, the intense competition for funds within DoD, as well as the degree of scrutiny applied to defense budgets by Congress, both mitigate against providing such reserves. In an environment where there are already far more claims on defense dollars than available funds, there is every incentive to underestimate the costs of programs when Service budgets are prepared. Even if contingency reserves are initially provided for, they are one of the first items to be trimmed.

Were management reserves somehow to survive DoD's internal budget preparation process, they

[61] "Below threshold" reprogrammings can be done by DoD without congressional notification or approval. "Notification reprogrammings" require that the Appropriations and/or Armed Services Committees of both houses be notified in advance; such reprogrammings are considered approved if the notified committees do not object within 15 days. A "prior approval" reprogramming, on the other hand, must be approved by all the relevant committees and is considered rejected if no response is made.

Whether a reprogramming can be approved internally to DoD or whether it requires the notification or the prior approval of Congress depends on factors such as the particular appropriation accounts involved, the size of the requested transfer, and whether any of the affected accounts have been designated as being of "Special Interest" to the congressional committees. Similar factors govern whether only the Appropriations Committees are involved or whether the Armed Services Committees are involved as well.

[62] Defense Science Board, op. cit., footnote 1, p. 93.

[63] Defense Science Board Task Force, "Transition of Weapons Systems From Development to Production," report prepared for the Office of the Under Secretary of Defense for Research and Engineering, August 1983, pp. 40, 42.

[64] Defense Science Board, op. cit., footnote 1, p. 78.

would probably not fare well on Capitol Hill. According to Leonard Sullivan,

> Reserve funding wedges, if identified in the budget so that congressional staffers can find them, end up spotlighted, renamed "slush funds," to protect the taxpayer from waste, fraud+ and abuse.[65]

Requirements Generation and the Resource Allocation Process

Description of the Problems

In 1985, a DSB summer study examined the process by which requirements for new military systems are generated. The task force concluded that "although promising efforts are underway in all of the Services to improve their requirements processes, deficiencies in this process are still likely to be significant contributors to continuing increases in both the cost and the length of time required to field new defense systems."[66] The report identified three problems in particular:

- Users are not involved directly and continuously in determining and ranking their military needs.
- Requirements are expected to be observed too rigidly.
- Acquiring organizations do not go over their requirements often enough with their suppliers, before making them formal.

The study proposed emulating the organizational structure of successful commercial programs to streamline DoD acquisition, a proposal which formed the basis of the Packard Commission's recommendations regarding acquisition organizations.

According to the DSB report, deciding what to acquire in the commercial world—at least for the highest priority, "bet-your-company" programs examined by the study panel—is essentially a one-step operation. Balancing requests from users against technological opportunities and available resources, the program manager advances realistic proposals from which the company's chief executive officer (CEO) can select.

> The PM [Program Manager] is motivated to be realistic about performance, cost and schedule, both because he will have to carry out the program if it is approved and because his job is dependent on the merits of the proposal and not simply on whether it is accepted.[67]

The DoD, on the other hand, decides what to buy in two stages. First, a highly political competition for funds involves the military Service, the OSD, OMB, and Congress. After funds are reserved. as denoted in the milestone process by a DRB decision to initiate a new program, a second stage of competition selects the actual supplier.

> There are great pressures to overpromise in order to survive the [funding] competition. Since the decisions are made by political processes among a large and diverse group of people, there is little pressure to discipline the process and to enforce realism. Clear-cut designs to meet the requirements are not allowed because they would interfere with the next step—competitive source selection. The result is a firm over-stated requirement which too frequently can neither be met nor changed.[68]

Leonard Sullivan describes a little more bluntly some additional factors within DoD that lead to overstated requirements:

> The twin siren songs of "nothing is too good for our boys" (sung by the Services) and "nothing is impossible" (crooned by the technological community) have produced a deeply embedded American defense culture and guarantee the perpetuation of a military force that is at or beyond the leading edge of technology in the factory, and at or behind the trailing edge of any realistic sustainable warfighting capability.[69]

"Another myth popular among amateur 'requirements' generators," Sullivan adds, "is that since the desired system is going to be expensive anyway, the marginal costs of adding a few more capabilities will

[65] Leonard Sullivan, Jr., op cit., footnote 16, p. 50.
[66] Defense Science Board, op. cit., footnote 7, p. 1.
[67] Ibid., p. 91.
[68] Ibid., pp. 93-94.
[69] Leonard Sullivan, Jr., op. cit., footnote 16, p. 17.

be small . . . [However, these] add-ens become 'the straw that breaks the camel's back' in terns of design complexity, {development scheduling, and production costs."[70]

Sullivan, the DSB panel, and the Packard Commission all attribute much of the pressure for overstated requirements to insufficient interaction between those who know what is needed and those who know how to provide it. According to the Packard report, "Generally, users do not have sufficient technical knowledge and program experience, and acquisition teams do not have sufficient experience with or insight into operational problems.'[71]

The DSB panel recommended that the Commanders in Chief [CINCs] of the operating forces be given a more significant role in requirements generation.[72] The CINCs "do not participate with the services in making requirements tradeoffs even though they may be the most qualified to judge the true operational value of a particular requirement."[73] The Packard Commission agreed that much greater emphasis should be placed on "an informed trade-off between user requirements, on the one hand, and schedule and cost on the other."[74] The DSARC process. according to the Packard Commission, was unable to strike this balance. Although DSARC was able to determine whether proposed new systems would meet the requirements set for them, it "lacks a viable mechanism for *challenging* those requirements."[75]

The 1985 DSB panel on requirements that recommended the CINCs play a greater role in generating requirements also called for them to be more involved in-or at least, more aware of—the subsequent development process. Admiral W.J. Crowe—at the time of the DSB study the Commander in Chief of the U.S. Pacific Command-believed that his input into the requirements process was sufficient until the system entered development. "From that point, however, I have little influence over the process because feedback on affordability, priorities, and any tradeoffs made by the developing Service is almost non-existent. I do not want the capability to design or build systems, but I do need sufficient involvement in the development process to be able to point out major design changes of omission or commission which would affect my capabilities and/or strategy."[76]

According to the DSB, even the program managers who are immediately responsible for developing major systems do not have sufficient ability or desire to reexamine requirements once development has started. Should meeting a particular requirement prove more difficult than expected, leading to cost growth or schedule slippage, program managers all too often fail to reconsider the need for it. Moreover, since program offices are established after the requirements have been ratified, managers generally arrive too late to affect requirements at ail.

Improving the Requirements Process

Changes in the requirements process can come in two different areas. One is in the process by which the Services first establish requirements for new systems or upgrades. The existing two-stage process is a recipe for producing the wrong system too late and at too high a cost. Moreover, Services may not fully evaluate non-traditional means of meeting their requirements, especially if they involve changing the respective roles and missions of the Services.

[70]Ibid., p. 77.

[71]The President's Blue Ribbon Commission on Defense Management, op. cit., footnote 4, p. 21.

[72]The military Services (the Army, the Navy and Marine Corps, and the Air Force) are responsible for training and equipping military forces, but not for commanding them operationally. For operational purposes, the Armed Forces are organized into military commands that report through the Secretary of Defense to the President. Although the Commanders in Chief (CINCs) of these military commands individually are members of one of the military Services, they do not report directly to the Chiefs of Staff or Secretaries of their respective military services for operational matters.

The CINCs—not the Services—have responsibility for commanding troops in time of war. They often have a different perspective on military needs than that put forth by the Service leadership.

[73]Defense Science Board, op. cit., footnote 7, p. 54.

[74]The President's Blue Ribbon Commission on Defense Management, op. cit., p. 21.

[75]Ibid., emphasis in original.

[76]Defense Science Board, op. cit., footnote 7, p. 48.

Improvements to the initial requirements generation process involve strengthening the role of the USD(A) in these early stages, ensuring an objective evaluation, and preserving a role for Defense Advanced Research Projects Agency (DARPA) to explore nontraditional solutions outside of Service processes.

The report of the Project on Monitoring Defense Reorganization, charged with reviewing the implementation of the Packard Commission's *recom*mendations, concluded that "although the Packard Commission's objectives pertaining to 'requirements' are far from fulfilled, there has been material progress."[77] Most important, according to the study, was the establishment of the Joint Requirements Oversight Council (JROC) under the newly created post of Vice Chairman of the Joint Chiefs of Staff. This council is charged with reviewing all programs that are candidates for joint development because they can be used by, or affect the operation of, more than military Service. JROC has also served to increase the role of the CINCs in decisions on weapon characteristics, according to the study.

With respect to the Packard Commission's recommendation that requirements be better balanced against cost and schedule and that affordability be taken more seriously, the implementation study found that "the organizations and procedures that could make possible such a change have been set up," but "their effective operation will require continued high-level attention."[78]

The requirements process can also be improved at the point where program managers review them with the ultimate users: the CINCs and others serving in operational capacities. Here, managers can bring considerations of cost. schedules, and technical developments into play to change those requirements.

Bureaucratic Paralysis

"When I took over procurement responsibility for General Motors, the guidelines for running the acquisition activities was 154 pages. I gave them a target of 10. We ended up with 13 pages to run all General Motors acquisition efforts.

"I was interviewing a General from the Air Force for a job and he said, 'You cannot run an organization with only 13 pages. ' I said, 'We are. He said, '1 have 3,650 pages,' and I said, 'General, you cannot run an organization with 3,650 pages. "

—Robert Costello, Under Secretary of Defense for Acquisition[79]

Documentation

Perhaps the most discussed problem with defense acquisition is the bureaucratic burden that individuals and companies involved in defense acquisition must carry to do their jobs. On the way to a DAB milestone review, a program manager may have to make as many as 100 briefings. Attention must be paid to thousands of regulations, specifications, and standards. As the Packard Commission described,

> The program manager finds that, far from being the manager of the program, he is merely one of the participants who can influence it. An army of advocates for special interests descends on the program to ensure that it complies with various standards for military specifications. reliability, maintainability, operability, small and minority business utilization, and competition, to name a few. Each of these advocates can demand that the program manager take or refrain from taking some action, but none of them has any responsibility for the ultimate cost, schedule, or performance of the program.[80]

Increasing complications in the job of the program manager have been accompanied by lengthening the time needed to complete contracting actions and increased regulation, oversight, and auditing of defense contractors.

[77]"Making Defense Reform Work: The Project on Monitoring Defense Reorganization," op. cit., footnote 60, p. 48. This study argued that use of the term "requirements" itself introduces inflexibility into acquisition because it implies a minimum performance level below which a system would not be acceptable. "Meeting any military need or filling any deficiency," rather than "establishing a requirement," describes the desired process more accurately.

[78]Ibid., p. 49.

[79]"Reauthorization of the Office of Federal Procurement Policy," Hearing before the Committee on Governmental Affairs, U.S. Senate, Mar. 25, 1988, S. Hrg. 100-694, p. 18.

[80]President's Blue Ribbon Commission on Defense Management, op. cit., footnote 49, p. 46.

A recent RAND Corporation study tried to quantify both the increased regulatory activity in recent years and the effects of those regulations on cost, schedule, and performance.[81] They found near unanimity among those who work in acquisition that complying with regulations, management review, audits, etc. is much more difficult now than in the past. However, the indicators RAND chose to measure that difficulty-growth in staff sizes, requests for DoD testimony, numbers of DoD regulations, numbers of GAO reports, etc.-did not clearly confirm the increase.

Of the indicators sought to identify the *effects* of the regulatory burden-cost, schedule, and performance-RAND found that cost shows the clearest effects:

> We conclude, on the basis of the sparse data available, that the sum of all incremental costs which can reasonably be charged to regulatory controls probably amounts to between five and ten percent of total program costs.[82]

These numbers are lower than some that have been cited by defense contractors, possibly because they address only the incremental effects of recent regulation and not the cumulative effects. One contractor in a dual-use (military and commercial) business told OTA that the constraints imposed by doing business with the DoD are responsible for 20 to 50 percent of the total price of the defense product. Other estimates go even higher. The president of Grumman Corporation has stated that "only about a third of the time and money spent in developing new weapons systems has anything to do with design, development, and testing. The rest of it is the cost of review and oversight.[83]

This estimate is almost certainly high, since Grumman Corporation would surely conduct some review and oversight activities for its own use even if DoD did not mandate them. In fact, according to a senior executive at another aerospace corporation, DoD imposes no administrative burden above what the company would want to do anyway. According to Albert D. Wheelon, for 16 years the head of satellite production at Hughes Corporation,

> Our experience is that *similar* spacecraft cost about the same, whether they are bought under military or commercial arrangements . . . Complying with DoD systems for cost and schedule control, contract management and quality control was not particularly burdensome. In fact, we used their procedures in our commercial programs by choice. In essence, DoD asked us to do no more for its programs than we would want to do for our commercial customers and ourselves.[84]

Even if cost penalties can be unambiguously attributed to regulation, it is hard to consider them as measures of government waste. As the RAND report makes clear,

> . . . to sustain an interpretation that all, or even most, of these costs are "wasted" money would require demonstrating that no benefits derive from the reporting and oversight activities that account for the bulk of the cost.[85]

For reasons discussed earlier in this chapter, defense acquisition is clearly not managed solely to minimize cost and maximize efficiency. Congress, the Services, the OSD, and the regulatory agencies apparently have found the value of their respective involvement in defense acquisition to be worth the additional cost.

Analysis

Whether or not red tape can be quantitatively shown to affect defense procurement, and regardless of the degree to which it has increased over the years, it is unambiguously greater in government than in the private sector. The RAND study noted that:

> Military program managers are frequently separated from the senior OSD-level acquisition execu-

[81] G.K. Smith, J.A. Drenzer, W.C. Martel, J.J. Milanese, W. Mooz, and E.C. River, "A Preliminary Perspective on Regulatory Activities and Effects in Weapons Acquisition," RAND/R-3578-ACQ, prepared for the Under Secretary of Defense for Acquisition, March 1988.

[82] Ibid., p. 17.

[83] Speech by John O'Brien, President and Chief Executive Officer, Grumman Corporation, before the Society of Automotive Engineers, Annapolis, MD, Apr. 19, 1988.

[84] Albert D. Wheelon, "Dual Use Technologies: Satellites," talk given to the Harvard Kennedy School of Government Study on Dual Use Technologies, October 1988, p. 10. Emphasis in original.

[85] G.K. Smith et al., op. cit., footnote 81, p. 46.

> tive by five or six administrative layers. Each layer demands a right to review all progress reports and major program change proposals. Not so apparent from the literature is that some of those layers have an extensive horizontal structure, so that the views of several different offices must be accommodated in order to pass through a particular layer or "gate.'[86]

Not only do program managers devote much of 'their time towards preparing for these reviews, but the regulations-and their increasingly strict interpretation, a point not amenable to RAND's analysis-have the effect of limiting the initiative and discretion that program managers are allowed to exercise.

Note, however, that if the present hierarchy requires five or six management layers between a program office and the senior Defense Acquisition Executive, any compression of the command chain will be accompanied by increasing the burden on those at the top-unless the total number of acquisition programs is cut proportionally. Bringing any one program to the attention of the most senior management will ensure that it moves rapidly ahead. Bringing every program to that level. without some way of ranking them to determine which ones truly deserve the attention, will create grid lock.

The 1985 DSB Summer Study on Practical Functional Performance Requirements devoted a considerable amount of analysis to the differences between the organizational environment of a DoD program manager and that of an equivalent position in non-defense-related private industry. Successful commercial programs examined during the summer study shared a number of features:[87]

- A Program Manager (PM) who has continuity, authority, flexibility, accountability for decisions, and direct access to the key decision maker (CEO).
- A powerful executive (sometimes the CEO) who has authority to make unchallengeable decisions, settle disputes, and allocate additional resources. The CEO can directly support the Program Manager and insulate him or her from external pressures as critical needs arise.
- Active user involvement. The commercial user, not committed to a single supplier, is free to purchase from other producers. Therefore, the Program Manager has a strong incentive to involve the user throughout product development, and emphasizes adherence to schedule (e.g., by modifying requirements with user concurrence) in the event of difficulties.

There are many "minor players" in this commercial model, including inside staffs, government regulators, consumer groups, etc., but "one of the major advantages of the Commercial Model is that the minor players play a minor role."[88]

In its planning stage, according to the DSB summer study, the commercial model is essentially a one-step procedure. The Program Manager, balancing user needs, foreseeable resources, and available technology, prepares a realistic proposal for the CEO to consider. The CEO, weighing this proposal against other alternatives such as having the proposal revised or rejecting it in favor of other uses for corporate resources, makes the decision to go ahead. "His future depends on whether programs he approves are ultimately successful, not on whether or not he goes ahead with them."[89]

The plan's execution is marked by a close, direct working relationship between the PM and the CEO:

> The CEO must be kept informed and the PM must be able to get help rapidly and reliably if he needs it. The principle is one of a joint activity towards a common goal. A program failure is a failure of both CEO and PM.
>
> The staffs and inspectors, test groups and "ilities" [reliability, maintainability, supportability, etc.], groups exist, but are insulated from the PM by the CEO. The staffs can talk to the PM and comment and advise but cannot direct the PM without going through the CEO. Only the PM and the CEO can make decisions; they have the responsibility and therefore the authority.[90]

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[86] Ibid., p. 15.

[87] Defense Science Board, op. cit., footnote 7, p. 2.

[88] Ibid., p. 89.

[89] Ibid., p. 91.

[90] Ibid., pp. 92-93.

The summer study sought to emulate these practices within DoD acquisition programs. Specifically, they recommended that DoD establish what they called "surrogate CEOs''—individuals who have been delegated authority and responsibility to serve as the ultimate decisionmakers for one or a few programs. To implement this recommendation, the Military Departments would have to reduce the number of people involved in the decision processes, reduce the number of layers through which the program manager reports, and reaffirm program manager responsibility for all phases of program execution. They would also have to provide program managers with access to those senior managers (the surrogate CEOs) who would have the authority and resources sufficient to "make and enforce decisions regarding tradeoffs between performance, schedule, and cost. "

The Packard Commission cited this DSB study as the basis for its recommendations to streamline the acquisition process. In particular, the Commission called for "unambiguous authority for overall acquisition policy, clear accountability for acquisition execution, and plain lines of command for those with program management responsibilities."[91] At the top of the acquisition structure recommended by the Packard Commission would be a new position, the Under Secretary of Defense for Acquisition (USD(A)) who would serve as the Defense Acquisition Executive. Reporting to the USD(A) would be comparable to Service Acquisition Executives (SAEs) in the Army, Navy, and Air Force and equivalent positions in the defense agencies. Each SAE would appoint and oversee a number of Program Executive Officers (PEOs), who in turn would oversee Program Managers. The PEOs, "like group general managers in industry, should be responsible for a reasonable and defined number of acquisition programs. Program managers for these programs should be responsible directly to their respective PEO and, on program matters, report *only* to him."[92] It would be the responsibility of the Under Secretary for Acquisition to ensure that "no additional layers are inserted into this program chain of command."

Through the Defense Reorganization. Act of 1986 and concomitant Executive Orders and DoD Directives and Instructions, the organizational structure recommended by the Packard Commission was established. However, *the new structure supplemented-and did not replace—any existing chains of authority and command.* According to a study of the implementation of the Packard Commission recommendations and associated legislation,

> ,., the purposes of the legislation have not been met. Our sense is that the new positions were simply superimposed on top of the existing structure.[93]

The new acquisition chain is at present a communications link, and does not control funds. Figure A-4 shows the new acquisition lines of authority along with the existing organizations for command and budget.

Regardless of how effectively the implementation of the Packard Commission recommendations within DoD captured the intent of those recommendations, it is clear that the actions taken to date do not address the original concerns of the DSB summer study.

Nor is it clear that they could. At the same time that it recommended changing DoD practices to put them more in line with commercial ones, the DSB summer study also acknowledged that:

> There are inherent and basic differences between the DoD and non-DoD processes which certainly inhibit and may even prevent the direct mapping of lessons learned [from the commercial examples] into the DoD requirements process. For example, there is no counterpart to the role of Congress in industry, nor are there any unifying quantitative measures of success in DoD corresponding to profit or [return on investment]. Furthermore, some personnel constraints in DoD have no counterpart in industry. Finally, DoD does not operate in a free market as buyer or seller, and can only imperfectly approximate free market competitive conditions.[94]

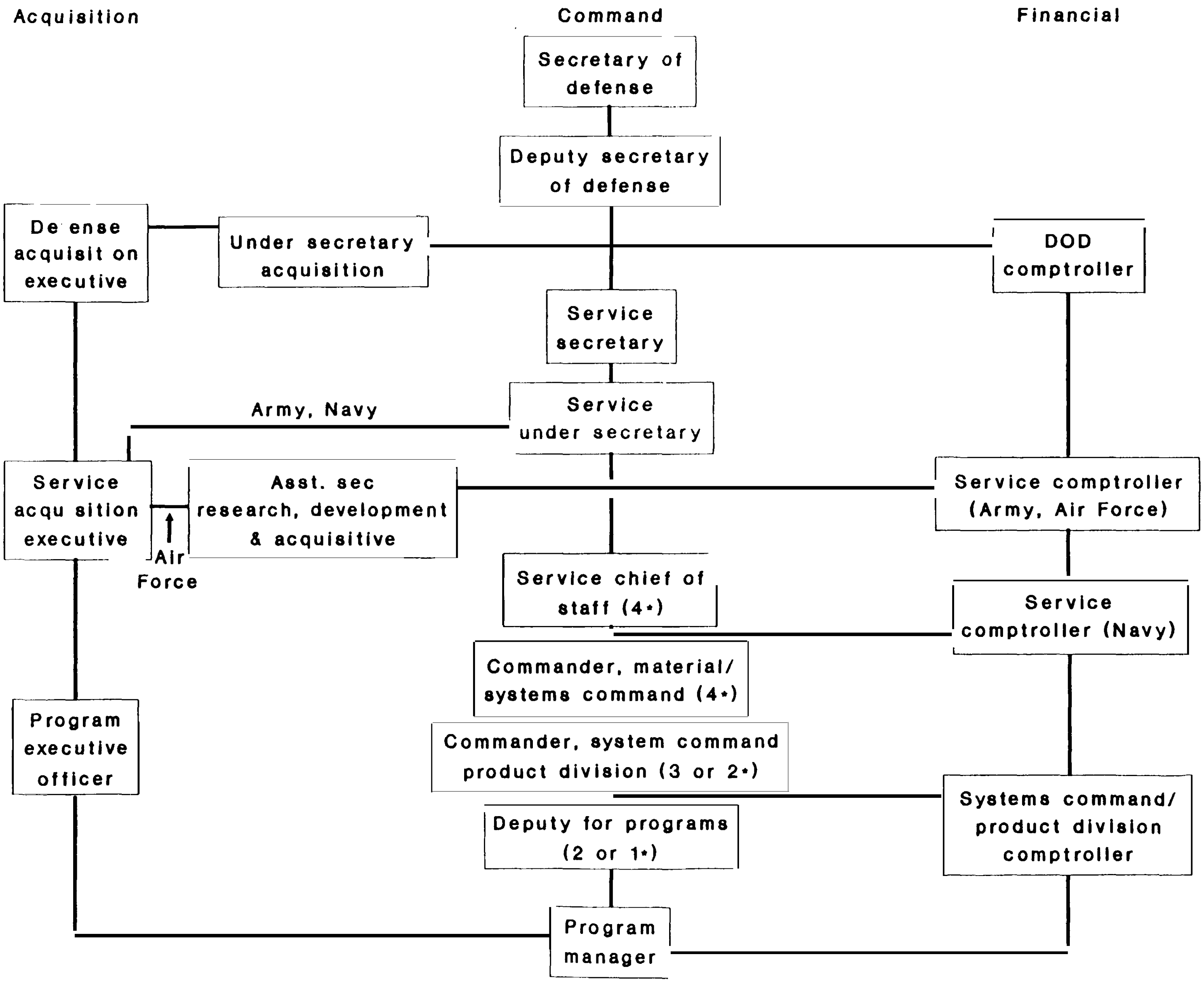
[91] President's Blue Ribbon Commission on Defense Management, op. cit., footnote 49, p. 53.

[92] Ibid., p. 54.

[93] "Making Defense Reform Work: The Project on Monitoring Defense Reorganization," op. cit., footnote 60, p. 50.

[94] Defense Science Board, op. cit., footnote 7, p. 28.

Figure A-4—Chains of Authority



SOURCE: Defense Systems Management College, unpublished materials.

Neglecting the inherent and essential involvement of the political process, in particular, will lead to inappropriate solutions. Edwin Deagle's analysis, cited in the previous section of this appendix on "Program Variability," is particularly relevant to discussion of the acquisition (or, more accurately, the military R&D) process:

> . . . organizational and procedural designs are unusually important. . . since they determine the structure within which massive managerial and political control problems intersect." Moreover, there can be conflict between organizational strategy designed to produce efficient political decision processes and managerial strategy designed to achieve coherent control of weapon system development. Yet the organization for control of military R&D inevitably is a mixture of both purposes. It is argued here that the failure to cope explicitly and well with this paradox is the central public policy problem of military R&D.[95]

The DSB summer study acknowledges the importance, but not the inevitability, of political influences within DoD in a passage on DoD decision- ' making that could equally well describe Congress:

> No one person has the authority to make firm decisions. Decisions are made by a large, diffuse group that acts something like an extended committee and that lacks clear-cut responsibility and accountability. The DoD itself exists in a political environment that further smears out the decision making process. As a result, decision- making is lengthy and uncertain. The players change and the decisions tend to change with them. The program Manager is separated from the top level of the DoD by many intermediate layers, all of whom must be dealt with, none of whom can say yes, but most of whom can say no. Decisions are late, inconsistent and untrustworthy.[96]

And in an earlier passage,

> Although the DoD is nominally a hierarchical authoritative organization, it is very difficult in a democracy for anyone to make a controversial decision stick.[97]

The key to the direct decisionmaking processes and lines of authority in the DSB summer study's commercial model is the close and direct link between the program manager and the CEO. However, the commercial programs analyzed by the summer study—the ESS-4 automated electronic switching system for long-distance communication developed by Bell Labs, the Boeing 767 airliner, a Satellite Business Systems communication satellite system, the IBM System 360 computer series, and the Federal Aerobatics Administration national air traffic control system-were not run-of-the-mill activities. They . . .

> were of great importance to the companies involved and therefore to the CEO. There is hardly any single program in DoD of equivalent importance to Service Secretaries, let alone to the Secretary of Defense. DoD has too many important programs for such officials to keep track of them in detail.[98]
>
> ***
>
> Increasing the authority of the PM alone will not solve the problem. Attempts to streamline the process and to connect the PM more directly to the top of the DoD have not been successful except in extraordinary cases. There are too many programs for the top level to understand in detail. They must rely on their staffs and authority rediffuses in the bureaucracy.[99]

This was to be the role of the "surrogate CEOs" which the DSB summer study called for establishing within DoD. The success of the Surrogate CEO . . .

> will depend on how much authority he really has to adjust performance and schedule, provide additional resources if needed, make or approve tradeoffs.[100]

It was this recommendation that led the Packard Commission to call for the establishment of Program Executive Officers. However, since the acquisition chain of authority established by the military Services in response to the commission's recommenda-

95 Edwin A. Deagle, op. cit., footnote 28, p. 161.

96 Defense Science Board, op. cit., footnote 7, p. 98.

97 Ibid., p. 94.

98 Ibid., p. 94.

99 Ibid., p. 99.

100 Ibid., p. 99.

tion has no real control over resources, it is questionable how well it fulfills the Commission's intent. In the Navy and the Air Force, the Commander of the System Command product division to whom a program manager reports has been designated as his Program Executive Officer—despite the conclusion of the DSB summer study that:

> A supervisor or commander in the current DoD structure is not equivalent to a Surrogate CEO because he does not have the necessary delegated authority . . . He does not have any more authority over performance, cost, and schedule of his programs than his PMs do. He cannot transfer funds among programs and he has almost no discretionary money under his control. His control of staff and monitoring groups is minimal. He is overcommitted and has almost no flexibility.[101]

In the Army, PEO offices have been established separate from the commanders of the System Commands within Army Materiel Command, but even these offices have no real control over resources.

Truly implementing the recommendations of the DSB summer study and the Packard Commission would require drastic changes in the operation of DoD. Given the inherent involvement of the political process within defense acquisition, true implementation may not be possible at all. The essence of the Surrogate CEO/Program Executive Officer concept lies not in rearranging who reports to whom, but in concentrating real authority in an individual positioned to make decisions about a program and see that they are implemented. However,

> The law of conservation of authority says that this delegated authority must come from somewhere and it must come, in fact, from the Surrogate CEO's superiors and from the staffs and regulatory bodies in the government. These people, in the manner of all human beings, will resist giving up authority even when they understand that their previous activities have been harmful rather than helpful. If the most senior people will really delegate their authority and insist that it be further delegated to Surrogate CEOs, there is a chance the idea will succeed. There will still be plenty of other things for the senior people to do.[102]

"Successful" DoD Models

Certain programs within the Department of Defense—in particular, highly classified "special access" or "black" programs,[103] and high-priority strategic programs such as the Minuteman missile, the Air-Launched Cruise Missile, and the Navy's Strategic Systems Program Office that developed the Trident system-have been held out as models that have successfully conquered DoD bureaucracy. Special access programs, due to extreme security requirements, bypass much of the review and approval process that ordinary, "white" programs must contend with. Exempt from normal procurement and oversight operations, they are significantly less encumbered with bureaucracy.[104]

According to Bernard McMahon, former Executive Director for the Director of Central Intelligence (responsible for reviewing all intelligence programs and operations) and subsequently staff director for

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[101] Ibid., p. 100.

[102] Ibid., p. 101.

[103] Technically DoD does not use the term "black" program. A "special access program" is one in which additional restrictions beyond those available through the normal Confidential/Secret/Top Secret classification system are deemed necessary. The budgets and existence of these programs may or may not be classified. "Black" programs generally refer to those whose existence is kept secret.

[104] Although the decision to operate a program on a special access basis is supposed to be made only on security grounds, many suspect that the reduced visibility and the freedom from procurement bureaucracy that special access programs enjoy also play a role. The phenomenal growth of special access programs over recent years, which is difficult to correlate with an equivalent growth in security requirements, lends support to this argument. However, official numbers documenting this growth are obviously difficult to come by. David Morrison, writing in the *National Journal*, uses what he calls conservative estimates to conclude that the "black" budget has nearly quintupled in recent years, from an estimated $5.5 billion in fiscal year 1981 to $24.3 billion in the fiscal 1988 request. *National Journal*, Apr. 11, 1987, p. 867.

The chairman and ranking minority member of the House Armed Services, who are certainly in a position to know, said in 1986 that "the amount of money in the "black" part of the defense budget has grown eight-fold in the last five years." They did not disclose the absolute size of this budget, but stated that "fully 70 percent of all the funds that are now obscured under the "black" umbrella could be listed publicly in the budget without causing any harm to national security." House Armed Services Committee News Release, for release May 12, 1986.

The growth in budget does not represent an equivalent growth in program numbers. Part of the black budget increase represents the growth in cost of major programs such as the B-2 Stealth bomber as they proceed into more costly stages of development.

the Senate Intelligence Committee, special access programs do have a number of advantages:[105]

- speed of deployment-equipment is generally developed and deployed faster than in normal programs;
- exceptional stability, both in personnel and in concept and
- better program managers and personnel than normal programs of the same cost have.

Many senior officials with experience in both special access and ordinary program management report that the streamlined management approaches and freedom from bureaucracy that characterize special access programs make possible the speed with which these programs can field hardware. Others, however, argue that the advantages possessed by black programs are not necessarily due to bureaucratic shortcuts. McMahon argues that since management and oversight of these programs are tightly restricted, those who perform these functions tend to be the most senior management of the military Services:

> Because special access programs are reviewed only by top management-their review boards are composed of flag officers and senior DoD civilian executives-they tend to get "special status" when funding priorities are established. Top managers tend to view the programs as their own, sponsor them, defend them, protect them in the competition for dollars with regular programs, and favor them in setting priorities. Seldom are they terminated, reduced, or stretched out nor is the economic rate of production considered.[106]

The exceptional stability enjoyed by these programs is therefore due, at least in part, to their high priority and the high level at which they are reviewed. "Management obstacles are cleared for special programs in ways normal program managers never experience."[107] Similarly, their advantages in personnel are partly due to their priority. Admittedly, managers also have the advantage of being able to spend more of their time managing and less handling bureaucratic overhead and advocacy.

The advantages enjoyed by special access programs also come at a price. Procedures used in special access programs "significantly increase the risk of failure, both of program hardware and of accomplishing what we paid the money to do."[108] Part of the increased risk reflects the fact that special access programs tend to be technically riskier. However, risk is further increased by eliminating reviews and by short-circuiting the political process in which normal DoD programs operate:

> The short cuts taken in the special access programs , . . are dangerous. In the special access world one hears horror stories of equipment that was too expensive, did not meet design expectations, was not supported, was unreliable, and duplicated other capabilities.[109]

Those who attribute some of the successes of special access programs to their management approaches argue that these approaches should be extended to other DoD procurements. McMahon, however, argues that the model offered by black programs should not be extrapolated to the rest of defense procurement.

> We simply cannot conduct a defense wide procurement system using special access program procedures. Top management does not have time to review all programs with the degree of oversight it must give to special access programs. Programs that have succeeded have done so because they were small and few in number. . . .Efficiency alone is not sufficient. In rare, important cases we may choose to take risks and skip important steps; it should not become general defense practice.[110]

The strategic systems also held out as examples of successful management share some of the same

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[105]Bernard McMahon, "Special Access Programs: A Model for Reform?," a paper presented at the Center for Strategic and International Studies Conference on U.S. Defense Acquisition, November 1986, Washington, DC, pp. 8-9. (Commissioned for "U.S. Defense Acquisition: A Process in Trouble," The CSIS Defense Acquisition Study.) Used by permission of the author.

[106]Ibid., pp. 5-6.

[107]Ibid., p. 9.

[108]Ibid., p. 6.

[109]Ibid., p. 9.

[110]Ibid., pp. 10-11.

characteristics of successful special access programs: viz., high priority and high visibility to senior management. According to a critique of the Packard Commission report by an ad hoc committee of the American Defense Preparedness Association, these strategic programs use "high quality but rather large staff"—as opposed to the Packard Commission's recommendation for small, streamlined staffs—and the programs have "established sufficient priority to avoid the normal budget drills and priority-setting disruptions." The committee's critique "questions the feasibility of achieving these objectives on all programs."[111] In other words, given a long line of claimants, those at the head of the line move faster. This does not mean everyone should be at the head of the line.

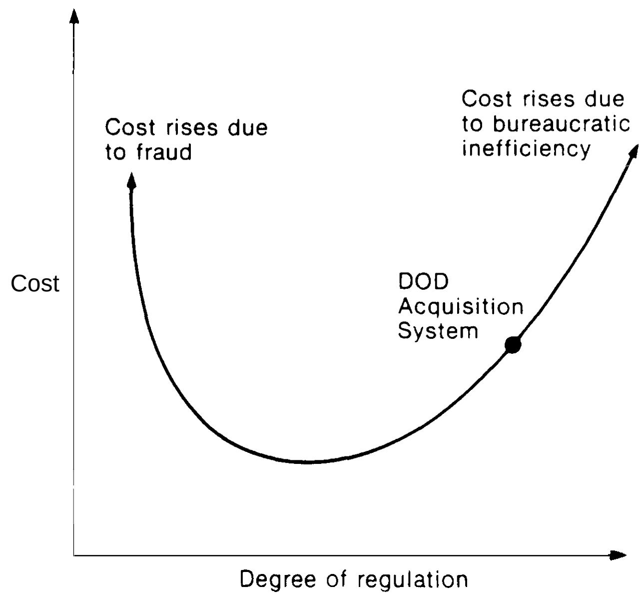
Overregulation and Public Opinion

Those who decry the inefficiencies imposed by regulation, audit, and oversight must realize that these penalties may be intentional; taxpayers place stringent requirements on expenditure of public funds. Figure A-5 illustrates the cost of doing business as a function of regulatory scrutiny. With minimal regulation or oversight, the government is dependent on the goodwill of contractors and public officials. Honest officials and corporations could operate very efficiently in this region, but dishonest ones would take advantage of the lack of oversight to defraud the government.

At the other end of the spectrum, tight regulatory controls deter or detect those defrauding the govenrment, but they also drive up the cost of doing business for everyone else. As was noted earlier, analyses by the RAND Corporation and others imply that the existing regulatory regime imposes additional costs of between 10 to 50 percent on the cost of doing business with the Department of Defense. How much fraud this regulation deters is impossible to estimate, but it must certainly be less than the $15 billion to $75 billion represented by 10 to 50 percent of the procurement budget.

Most likely, the current regulatory regime is considerably more stringent than that which, according *to* strict economic considerations, would result in minimal cost. It may be the case that the public would not demand such stringent controls if it fully understood the costs. If so, making the costs of overregulation clearer could lead to a relaxation of unnecessary constraints. It may be possible, however, that the American taxpayer prefers to pay the "tax" that overregulation imposes rather than permit those in positions of public trust to misappropriate lesser amounts. If public demands for overregulation constitute avoidable waste, then perhaps waste must be considered the price of curbing fraud and abuse.

Figure A-5-Cost v. Regulatory Intensity



SOURCE: Office of Technology Assessment, 1989.

Reducing Paperwork and Bureaucracy

Arbitrary measures to cut red tape or streamline the bureaucracy will fail unless they take into account the reasons for establishing a bureaucracy in the first place. For one thing, regulations area means of preserving institutional memory in an environment where presidential appointees have a median length of service of just over 2 years[112] and where military personnel are regularly rotated. They incorporate the political oversight and review procedures

[111] "Quick Reaction Assessment of the President Blue Ribbon Commission on Defense Management," an ad hoc Study conducted under the auspices of the Undersea Warfare Systems Division of the American Defense Preparedness Association, October 1986.

[112] "Leadership in Jeopardy," National Academy of Public Administration, November 1985, p. 4. This figure applies to the entire Federal Government.

that come with the expenditure of public funds. They codify management procedures for large and unwieldy organizations. Finally, they further important policy objectives that may be in the Nation's or DoD% collective best interest even though they might interfere with the most efficient execution of individual programs. As has been stated before, the government has many goals-environmental protection, occupational health and safety, fair labor practices, equal opportunity, etc.-that may conflict with any individual program manager's ability to run a program. Just because a program manager does not believe his or her program is the appropriate vehicle to implement national policy does not mean that that policy should be ignored. Although regulations have been criticized as attempts to solve yesterday's problem by impeding today's progress, those problems are certain to be repeated in the absence of some way of institutionalizing the lessons learned.

A number of different approaches can be taken to reduce bureaucracy and regulation within DoD. Implementing any of them, however, presumes an atmosphere of trust among the DoD, the rest of the executive branch, and Congress. Our political system guarantees that the executive and legislative branches will compete for power and influence. However, this competition can be carried out in more or less confrontational terms. The relationship between DoD and Congress in the early 1980s was one of confrontation, substantially aggravating the level of mistrust.

In such an atmosphere, Congress chooses to legislate rather than persuade because it has no assurance that persuasion will have any effect. The DoD prefers to err on the side of strictness, for fear of incurring a congressional investigation and still stricter legislation.

Major Legislative and Administrative Reform— One approach would be to replace the existing statutory and administrative framework in which fraud and abuse are deterred by extensive reporting and auditing requirements with one in which greater responsibility is placed on voluntary compliance coupled with vigorous enforcement and severe punishment for those who get caught. Enacting such a system would involve a major overhaul of the existing defense acquisition system and the environment in which it is conducted. Moreover, it would require (and also follow from) reducing what many in government and industry see to be the existing adversarial relationship between the two.

Bottom-Up Review-Since regulations (or at least guidelines) are inevitable in so bureaucratic an institution as DoD, one approach to alleviating the regulatory burden might be a bottom-up review of all regulations to ensure that only absolutely necessary ones are retained. However, the definition of "absolutely necessary" is highly subjective, and different groups or factions within the Department of Defense, the executive branch, and Congress are unlikely to agree. Every DoD regulation was originally instituted for what seemed to someone to be a worthy purpose. This point is acknowledged by the Packard Commission in describing the "army of advocates" for various special interests that beleaguer program managers:

> None of the purposes they advocate is undesirable in itself. In the aggregate, however, they leave the program manager no room to balance their many demands, some of which are in conflict with each other and most of which are in conflict with the program's cost and schedule objectives. Even more importantly, they produce a diffusion of management responsibility, in which everyone is responsible, and no one is responsible.[113]

Before any of these advocates or excess regulations are eliminated, those who instituted them will have to be satisfied that the goals they advocate will be preserved. Moreover, those with the time to review the regulations would most likely not be the ones adversely affected by them, and it is unlikely that this approach would effect significant change.

Evolutionary Review—The DoD is testing an evolutionary process to relax unnecessary bureaucratic requirements. Pursuant to the Defense Acquisition Improvement Act of 1986, DoD has designated selected high-priority, major acquisition programs to be "Defense Enterprise Programs" having streamlined reporting procedures (table A-1).

[113]President's Blue Ribbon Commission on Defense Management, op. cit., footnote 48, p. 47.

Each Enterprise program is being reviewed to see what regulatory relief would be useful. As soon as these reviews are completed, it is expected that the Services will request waivers of certain regulations from the USD(A). Complicating these reviews, however, is the scale of the problem. Program officials can find it more trouble to petition for waiver of the numerous regulations that are thought to be inappropriate, inapplicable, or obsolete than it is simply to ignore them and see if anybody notices or cares.

Evaluating the success of these programs may be difficult because some of them are already among their Service's highest priorities. At least one (the C-17) was the Air Force's model program for a previous initiative on Acquisition Streamlining, and has therefore already received special attention towards streamlining.

The same approach of setting up a structure by which waivers to particularly obnoxious regulations can be solicited and acted on is used in two other DoD efforts, the Model Installations Program (MIP) and the Pilot Contracting Activities Program (PCAP). In each of these-one aimed at DoD bases and installations and the other at organizations engaged in significant amounts of contracting—requests for waivers are forwarded to the individuals who can approve them, and if appropriate they are granted on an experimental basis. If the experiment shows that the waiver should be extended in time or to a wider audience, proposals recommending the appropriate change are prepared.

Note that none of these processes has the power to remove constraints originating outside DoD-such as legislation—because nobody within DoD has the authority to waive those constraints. However, in cases where outside constraints are identified, DoD can request relief from the outside agency or from Congress. Waivers to such outside constraints are encouraged so that the ones most limiting DoD activities can be identified.

Shifting the "Burden of Proof"—Another possibility, more along the lines of the Packard Commission and the DSB summer study recommendations, is to shift the "burden of proof" from the program manager to those who wish to overrule the program manager. In this approach, most regulations would be made advisory, rather than mandatory. Program managers would be free to decide which ones could be overridden in their particular circumstances. The "special interests" and "advocates" would still exist and would still be free to make recommendations to the program manager. However. the program manager would be free to disregard their advice—unless they could persuade the program manager's superior.

Table A-l-Defense Enterprise Programs

Army	Multiple Subscriber Equipment (MSE) communications system
	TOW II missile
	● ATACMS missile
Navy	Trident II missile
	T-45 trainer system
	SSN-21 submarine
Air Force	Medium Launch Vehicle
	C-1 7 Transport
	SRAM II missile
	Titan IV booster

•The program has also been granted Milestone Authorization status by Congress. See preceding discussion of "Baselining," beginnlng on pg. 21 of the appendix.

SOURCE: Office of the Secretary of Defense.

This system could only work if program managers and their superiors were evaluated not only on how well individual programs fared but also on how well the programs on balance supported the intent of the regulations—which, after all, serve to incorporate DoD and national policies that senior policy makers have decided are important. Program managers would have to realize that their goal is not simply development and deployment of a weapon system but furthering national policy as well.

It is not clear that this approach could be pulled off successfully. First of all, it requires a stable and highly professional work force. Government by fiat and decree removes individual initiative. and for that reason can compensate to some extent for an untrained work force. The requirement for restoring initiative is having people capable of exercising it.

Another, more intractable, problem is deciding on the irreducible core of regulations that would remain mandatory. Discretion cannot be permitted in areas affecting safety, for example, or in regard to matters that are specified by law.[114] It is not clear that deciding on an irreducible set of minimum, absolute regulations would be any easier or more effective than the "bottom up" review of all regulations discussed above.

Any implementation of a program of this sort would have to be flexible. As time progressed, feedback as to which mandatory regulations needed revisiting or which advisory guidelines were being systematically ignored would be used to make adjustments. Every level of authority would have to support the program and cooperate to make it work. In an environment where tensions exist between Congress and the executive branch, between DoD and industry, between the military Services and the OSD, and within the Services, that maybe too much to ask for.

Reducing Delays

Many of the delays built into the acquisition process follow from the implementation of regulations and the operation of the bureaucracy as described above. No particular delay can be addressed in isolation. However, two problems in particular seem to be mentioned frequently. They are singled out for discussion below.

Reducing the Delays in Contracting-Much of the time and complexity of the contracting process stem from requirements and regulations that serve to enhance competition, to ensure that all potential bidders capable of doing the work are given an opportunity to bid on it, and to support socioeconomic goals. The last two of these items-fairness and socioeconomic goals-are policy goals that Congress has found worth pursuing even if they impede defense acquisition. Like any other political decisions, these judgments could be reversed if Congress were to find that the benefits of pursuing these goals did not justify their cost to the acquisition system.

The first factor, however, stems not so much from a political judgment that competition is inherently good as from the fact that competition-at least in a commercial market-is the mechanism that provides the buyer better quality at a lower price. Competitive purchasing in defense procurement is often misinterpreted to mean competition on the basis of price alone. While this might have been true in the days of "formal advertising" or sealed bids that used to characterize government procurement. passage of the Competition in Contracting Act of 1984 extended the concept of competition to include non-price factors. Some argue that price is still too heavily weighted, but it is clearly not the only factor that can be considered.

The debate concerning competition in defense procurement concerns how well the concept can be extended from the free market-where it clearly makes sense—to the highly regulated defense industry, which is characterized by few sellers, a single buyer, and the requirement to create new systems that press the state of the art.

The Packard Commission very strongly endorsed the concept of competition:

> Commercial procurement competition simultaneously pursues several related objectives: attracting the best qualified suppliers, validating product performance and quality, and securing the best price . . . we believe that DoD should greatly increase its use of truly effective competition, using as a model the competitive buying practices of major corporations and their suppliers.[115]

However, 2 years later, Commission chairman David Packard appeared to have changed his mind—at least as far as competing major acquisition programs is concerned—when he said, "One could do as good a job awarding major contracts by throwing darts at the names of qualified bidders.''[116]

The contracting and bid award process has come under increasing scrutiny recently amid allegations of serious improprieties in bid preparation and selection. This area will certainly be looked into further. However, nobody has yet come up with a mechanism by which all the benefits of competing

[114] Note that this statement does not imply that all existing laws should necessarily be retained under this approach. Indeed, to alter the present regulatory regime, substantial legislative change would be required. Nevertheless, those laws that remain in force cannot be waived at the discretion of a DoD official.

[115] President's Blue Ribbon Commission on Defense Management, op. cit., footnote 48, pp. 64-65.

[116] Quoted in James Flanagan, "Competition in Defense Buying Costly to U.S.," *Los Angeles Times,* July 31, 1988.

major acquisitions can be preserved in a less cumbersome process.

Contracting mechanics should pose less of a problem in procuring research than in procuring systems. The Competition in Contracting Act exempts "research" form many of its provisions, and DoD had previously taken this exemption to apply only to budget category 6.1. However, a letter from Members of Congress to the Secretary of Defense made clear that this exemption applies to technology base activities-research and exploratory development—in general.[117]

***Reducing** the Delays* in Review-Considerable time is taken in preparing for oversight reviews by the DAB or Service equivalents. With poor planning, activities of the program under review grind to a halt while the necessary documentation is prepared and analyzed. Appropriate planning should provide for delay, using the span between submission of documentation (3 months prior to the DAB meeting) and the review's outcome for work that does not commit large sums of money to anticipated outcomes of the review.

These reviews almost never lead to program cancellation, so in practically every case, program officials can foresee activities to be conducted after the board review no matter what the review outcome is. Obviously, major full-scale development contracts should not be let pending the decision to proceed to full-scale development. However, many activities that would facilitate the FSD process-or that might occur during full-scale development but do not involve commitment to a major FSD contract—could be conducted while awaiting an FSD go-ahead.

Some funds might be jeopardized because managers conducted activities judged inappropriate in the light of subsequent oversight board decisions. However, these expenses would almost certainly be outweighed by the savings made possible by permitting large development teams to do useful work, rather than wait idly by, during the period pending an oversight review.

Organization

> ... ***good*** organizational design alone will not exorcise all the demons in the weapon system acquisition process, but the lack of it is almost sure to keep them there.
>
> —Edwin A. Deagle[118]

So far this appendix has discussed acquisition procedures within the existing DoD organization. However, there are other organizational models, some of which were proposed in various pieces of legislation introduced in the 100th Congress. These bills run the gamut of acquisition structures from those similar to current practice to substantial departures from it:

- *H.R. .3898* (Kasich): Gives the USC(A) precedence over the Service secretaries. This precedence is asserted by DoD regulation in acquisition matters, but regulations do not make clear whether the Service Acquisition Executives report directly to the Under Secretary of Defense for Acquisition through the Service Secretaries.
- S. 2621 (Dixon): Centralizes procurement authority under the USD(A) but permits it to be delegated back to the Services.
- S. 2732 (Roth) and *H.R. 4950* (Hertel): Establishes under the USD(A) a Defense Acquisition Agency or Corps that receives requirements from the Services and then completes the acquisition process, giving the USD(A) final authority over procurements. Terminates the procurement authority of the Service Secretaries and prohibits delegation of certain USD(A) authority back to the Services.
- *H.R. 5048* (Boxer): Establishes an Independent Procurement Corps outside the Department of Defense to research. develop. and produce major weapon systems for DoD.

Not included in this list—yet—are even more far-ranging ideas such as regulating the defense industry as a public utility, or even nationalizing it.

[117]G.K. Smith et al., op. cit., footnote 81, p. 22. The letter referred to, dated Apr. 15, 1986, was addressed to Secretary of Defense Weinberger and signed by the Chairmen—and in some cases the ranking minority members—of the House Government Operations Committee, the House Science and Technology Committee, the House Armed Services Committee, and the Senate Armed Services Committee.

[118]Edwin A. Deagle, op. cit., footnote 28, p. 176.

The approach suggested under the third of these: alternatives—consolidating all procurement activity under the USD(A)-was considered but rejected by the Packard Commission.

> . . . such centralization would not serve the cause of reducing the bureaucracy, because it would tend to separate further the acquisition staff from the military user. We believe that it is important to maintain the Services' traditional role in managing new weapons systems.[119]

The program manager, argued the Commission, must understand the operational uses to which the system will be put and the environment in which it will operate.

However, some analysts share the viewpoint of Leonard Sullivan, a civilian writing for the CSIS Defense Acquisition study, who argues that military involvement in acquisition is far too extensive:

> The U.S. acquisition system is laced with users . . . they are almost anyone in uniform except the equipment operators in the field. And they have done a poor job keeping the acquisition process on the straight and narrow.
>
> A military person's judgment about technical feasibility, costing and budgeting, quantitative analysis, affordability, and supportability is no better than, and may be worse than, that of a professional civilian . . . The role of user is a convenient myth perpetuated by the military to increase its presence and by civilians to rationalize dubious decisions.[120]

Proponents of a centralized civilian acquisition agency argue that only such a mechanism can foster the professional, stable, qualified work force needed to implement true reform.

Taking acquisition away from the Services and turning it over to a civilian agency would represent a radical change. Most individuals involved in defense procurement-within DoD and in industry, military and civilian-do not favor such a sweeping change at present. Most studies of the issue have, like the Packard Commission, recommended against it. One major exception is the President's Private Sector Survey on Cost Control, or Grace Commission. The Grace Commission recommended that "consolidation of the management of the acquisition process within the Office of the Secretary of Defense (OSD) would improve efficiency and provide opportunity for significant cost savings."[121]

A somewhat more tenuous endorsement of the idea was provided by the Project on Monitoring Defense Reorganization, a study of the implementation of the Packard Commission recommendations. This study stated a preference for leaving acquisition authority with the Services, but recommended consideration of an independent organization under the USD(A) in the event that the Services refused to create specialized "acquisition corps." The study concluded that "radical steps, such as the establishment of a single procurement organization within the department [of defense], should not permanently be ruled out.'' [122]

The GAO found that the prevailing opinion it encountered in a study of centralized acquisition lay against establishing such an agency.[123] Some of the advantages to such an agency cited by GAO were

- reducing Service parochialism and fostering more common/joint system development;
- improving the quality and continuity of the acquisition work force; and
- reducing the size of the work force and eliminating administrative layers by consolidating duplicate acquisition functions.

Some of the more significant disadvantages were:

- Inability to address acquisition problems that were not organizationally related. Many problems with the existing system were thought to be in this category, such as those involving

[119] President's Blue Ribbon Commission on Defense Management, op. cit., footnote 48, p. 54.

[120] Leonard Sullivan, Jr., op. cit., footnote 16, pp. 56-57.

[121] U.S. President's Private Sector Survey on Cost Control (Grace Commission), "President's Private Sector Survey on Cost Control—Report on the Office of the Secretary of Defense," Sept. 15, 1983. Quoted in David E. Lockwood, "U.S. Weapons Procurement: Should a Civilian Agency Be In Charge?" Congressional Research Service, Report 84-61F, June 13, 1984, p. 31.

[122] "Making Defense Reform Work: The Project on Monitoring Defense Reorganization," op. cit., footnote 60, p. 59.

[123] General Accounting Office, "Defense Organization: Advantages and Disadvantages of a Centralized Civilian Acquisition Agency," GAO/NSIAD-87-36, November 1986, p. 1.

identifying what weapons to buy and trading off military requirements against cost.

- Possible disregard of military operational experience that could support claims that the new equipment is operationally suitable and effective for military use.
- Adding an additional layer of bureaucracy.
- The potential large size of such an agency, which could render it unmanageable.

If a centralized acquisition agency were formed, GAO recommended that it remain within the DoD. GAO reported the "overwhelming opinion" of those with whom it spoke that the Secretary of Defense should be accountable for all resources dedicated to defense.

A RAND Corporation study concluded that there is no reason to believe a centralized acquisition agency would operate more effectively than the existing system. Inputs from military users "probably receive insufficient attention even today, and it is difficult to believe that the interests of the users would be better represented by a more civilianized management."[124] The study recommended changes in the acquisition process, rather than the acquisition organization.

Although study of European nations that use centralized procurement systems might illuminate the successes or failures of such a plan, factors besides their centralized procurement systems make such analyses difficult. One important difference is that their defense programs are small compared to that of the United States. Other differences, as presented in a recent study of European weapons acquisition practices by The Analytic Sciences Corporation,[125] are that:

- European military Services do not dominate acquisition.
- Multiyear defense plans dominate fiscal planning in Europe and make it impossible to obtain program funds not in the multiyear plan.
- The annual defense procurement budget is approved by the legislature with minimal changes.
- The government imposes minimal "how-to" requirements on the defense industry.
- Industrial policy is a major consideration in defense contracting.

According to this study, the U.S. approach to acquisition, when compared to the European one, results in considerably more sophisticated and capable weapons developed over a shorter period at higher cost, but with lower cost per unit performance. The advantages of the European model-early analysis of cost v. performance, adherence to long-range fiscal plans, and concern for affordability--do not require a centralized acquisition agency to achieve. Moreover, if U.S. acquisition activities were centralized in a single agency, that agency would have about 15 times the staff and budget of the largest European acquisition agency.

Personnel

> There has always been an implicit assumption within the Defense Department that people with little or no advanced training and experience in the management of large industrial programs could function effectively at any management level. This assumption has been a key factor leading to the disappointing results of virtual] y every improvement program in the last twenty years.
>
> —J. Ronald Fox, with James L. Field[126]

Documentation

Successful implementation of many recommendations for improving defense acquisition-several of which have been cited in previous sections—requires a high-quality, stable, and well-trained acquisition work force. In a letter to President Reagan one year after the publication of the Packard Commission report, David Packard stated that:

> Personnel policy is the keystone of virtually all of these reforms. With able people operating them, even second-rate organizational structures and pro-

[124] Michael Rich and Edmund Dews, "Improving the Military Acquisition Process: Lessons From RAND Research," R-3373-AF/RC, February 1986, p. 51.

[125] Jacques Gansler, Charles Henning, and John Serlemitsos, "European Weapon Acquisition Practices: Implications for the U.S.," The Analytic Sciences Corporation, TR-5341-1, prepared for the Ford Foundation, February 1988.

[126] J. Ronald Fox with James L. Field, *The Defense Management Challenge: Weapons Acquisition* (Boston, MA: Harvard Business School Press, 1988), pp. 311-312.

cedures can be made to work; and without able people, even first-rate ones will fail.[127]

Improvements recommended by the Packard Commission included reducing the barriers to recruiting senior-level executive branch personnel,[128] attracting qualified new personnel, improving the training and motivation of existing personnel at the middle management levels, and continuing the recent improvements in defining military career paths in acquisition.

The Commission thought that civilian acquisition personnel needed much more attention than military, and cited many of the deficiencies of the federal Civil Service system that are described in the context of national laboratory personnel in chapter 5 of the main report. Recommendations particular to the acquisition work force included enhancing the status of the contract specialist job classification. At present, this classification is an "administrative" series position, prohibiting establishment of any business education requirement; the Commission recommended moving this position to the "professional" series. The Office of Personnel Management, which classifies Civil Service positions, has resisted this change on the grounds that DoD is free to require a business-related college degree for any particular contract specialist position, but that requiring such a degree for *all* such jobs is arbitrary and unnecessary.

In a major study of defense acquisition, Professor J. Ronald Fox of the Harvard Business School distinguished between two prevailing attitudes towards the government's role. Those holding what he terms the *liaison manager* view believe the government program manager seines primarily to promote a program, prepare progress reports, negotiate with various parties within DoD, and resolve conflicts between these parties and the contractor. Cost control is solely the responsibility of the contractor, and there is no need for the program manager to have extensive training or experience with industrial management and cost control methods. Program management is therefore a reasonable rotation for military officers between operational assignments. Those holding the liaison manager view, according to Fox, are widespread in both government and industry. They see the present acquisition process as essentially well managed, with few problems.

Fox himself believes very strongly in an alternative that he terms the *active manager* view. In this formulation, the program manager's role is one of planning, rigorous oversight, negotiation with, and control over the contractors. Responsibility for cost control is shared between government managers and the contractor; by establishing and implementing incentives, both formal and informal, the program manager has significant opportunity to reduce costs throughout the life of the program. The existing system of staffing and training military program managers cannot produce individuals capable of taking this role:

> As in industry, the development of highly qualified program managers requires focused career paths, progressing from technical work to assignments at laboratories, program offices, and plant repersentative offices, to full program management responsibility for small programs, and ultimately for large programs. There is no time left to become expert in a military operational specialty as well.[129]

Civil Service personnel share few similarities with military officers in acquisition assignments, according to Fox. Whereas the short tenure of officers in acquisition rotations severely impedes their ability to match their industrial counterparts, many civil servants "remain for so long that they resist innovation and change."[130] Fox recommends reforming civil service regulations to establish higher standards and permit removal of mediocre performers. Absent these changes. "defense acquisition programs will appeal primarily to those satisfied with the present low level of responsibility. "

The DSB 1987 Summer Study on Technology Base Management recommended establishing a trial "Senior Scientific, Technical, and Acquisition Exec -

[127] David Packard, letter to the President of the United States, July 10, 1987; cited by J. Ronald Fox with James L. Field, ibid., p. 315.

[128] Among those specified were simplifying financial disclosure forms and allowing appointees to defer capital gains tax liability incurred in divesting themselves of assets to satisfy conflict-of-interest provisions.

[129] J. Ronald Fox with James L. Field, op. cit., footnote 126, p. 312.

[130] Ibid., p. 314.

utive Initiative" to investigate means of improving the quality of personnel involved in defense acquisition and DoD technology base program execution and management. This program would provide up to 100 non-tenured positions for senior managers serving 3-year, renewable terms. One of the key features of this program would be to provide compensation comparable to equivalent positions in academia or industry through a special mechanism that would be outside conventional Civil Service regulations and limits. Poor performers would not be renewed. The summer study saw conflict of interest regulations, which restrict interchange of senior personnel between government and industry (the "revolving door"), as the most serious impediment to instituting such a program. "Some form of conflict of interest waiver-requiring legislative action—will be required to make the demonstration truly effective. "[131]

Analysis

All proposals for reforming personnel policies run into conflicts between competing objectives. Significantly increasing the tenure of military personnel in acquisition assignments, and weighing those assignments more heavily in promotion reviews, would probably improve acquisition. However, those actions would require making significant changes to what senior military officers now consider to be requirements for successful military careers.

Making fundamental reforms to Civil Service procedures— or even exempting groups from them—would also pose substantial political difficulties. Federal employees already feel as if they have 240 million supervisors, and it sometimes seems—at least while reading "Letters to the Editor" columns when civilian pay raises are debated in Congress-that there is nothing so despised as a civil servant. proposals that would increase compensation or other benefits of Federal employment in an effort to attract more senior and more highly qualified employees would be seen by others as adding slots to the Federal trough.

Conflict-of-interest regulations provide a case in point. Some argue, as did a panel of senior industry officials advising the Senate Armed Services Committee, that:

> There can be no question about the need to attract competent industry-trained men and women into vital upper-middle level appointee positions in the Pentagon. "Revolving Door" legislation, however well intended, defeats this need. The stigma of evil associated with the "revolving door" issue is most unfortunate and largely unwarranted. [132]

Contrast that attitude with the following:

> Weapons makers and weapons buyers should have different perspectives, and therefore *different skills.* Thus. there should be no tendency to share the same labor pool . . . Whether or not these people [who go back and forth between government and industry] are bribed, or promised future employment, they will be caught up in a loyalty to the project(s) they work on. They have lost their consumer's perspective.[133]

It will be difficult, if not impossible. to reconcile these two points of view. Those insisting on strict "revolving door" legislation to prevent officials from consciously misusing their public office for private gain might be satisfied that extraordinarily severe penalties could deter blatant conflict of interest violations. However, those more concerned about the "loss of perspective' '-the suspicion that the interests of government and those of industry should not be so closely aligned that individuals would be able to work just as effectively in one as in the other-would probably not agree that tougher penalties for violations of law would help clarify this more ambiguous situation.

131 U.S. Department of Defense, "Report of the Defense Science Board 1987 Summer Study on Technology Base Management," prepared for the Office of the Under Secretary of Defense for Acquisition, December 1987, p. 21.

132 "Report to the Subcommittee on Defense Industry and Technology, Senate Armed Services Committee," by the Ad Hoc Defense Industry Advisory Group (13 senior defense industry officials), p. A-1.

133 Project on Military Procurement, "Defense Procurement Papers: Campaign 88," September 1988, p. 75.

Appendix B

Studies of Acquisition Times

Contents

Figures

Appendix B
Studies of Acquisition Times

This appendix summarizes three studies of acquisition cycle times for in aerospace sector. The issue is difficult to address quantitatively because program milestones are hard to identify and compare in programs undertaken in different decades under different organizational structures. Moreover, the data are widely scattered and not plentiful. Comparisons restricted to similar systems acquired at different times (tactical fighter aircraft, for example) do not provide many different data points, so it is difficult to obtain statistically significant results. If a broader range of systems are lumped together (say, missiles and aircraft together), there is a risk that the differences between programs will be too great to permit meaningful comparisons. On the other hand, a broader base of comparison may permit differences due to factors other than time to be averaged out.

Defense Science Board 1977 Study on the Acquisition Cycle[1]

This study concluded that the "frontend" of the acquisition cycle—the time between conception of a system and approval to enter full-scale development (FSD)-increased from about 2 years in length in the 1950s to about 5 years by the early 1970s (figure B-l). However, the particular programs or sources of data represented in this figure are not specified. Establishing a time for a program's "initial conception" can be difficult, especially for those initiated before the present system of formal program reviews was initiated in 1969. A RAND analysis (see following section) has noted that "the structured DSARC review approach to initial development may make the process appear to take longer [today]: early design efforts that were once not assigned to any mission are now recorded as part of an incipient mission which later evolves into a weapon system."[2]

Looking primarily at Air Force tactical aviation programs, the DSB study also found that the time needed for full-scale development itself had not changed significantly over the same period, but that the length of the production cycle (from production go-ahead until the delivery of an initial operational capability) had grown longer and longer. This growth appeared to be due not to the inability to produce systems more rapidly but rather to the inability to pay for them.

Air Force Affordable Acquisition Approach (A^3) Study[3]

Completed in 1983, the A^3 study examined 109 Air Force programs representing space systems (boosters and satellites), air-to-air and air-to-ground missiles, ground-to-ground missiles, aircraft, radars, and command/control systems. Development intervals (total development time[4] and duration of the full-scale development phase) were analyzed as a function of the time required to start FSD. Only four categories-space systems (satellites plus boosters), fighter aircraft, surface radars, and command/control systems—provided enough data for statistical analysis.

Of the four, space systems showed the strongest and the most statistically significant increase in development time as a function of calendar date. Between the 1950s and the 1970s, total development time for space systems increased at a rate of over 4 months per year; this increase over time explained more than half the total variance in development time from system to system over that period.

Fighter aircraft showed a statistically significant increase in development time as well, growing by a little over 1 month per year. Essentially all the increase occurred in the pre-FSD period; the A^3 study (agreeing with the 1977 Defense Science Board analysis) showed no significant increase in

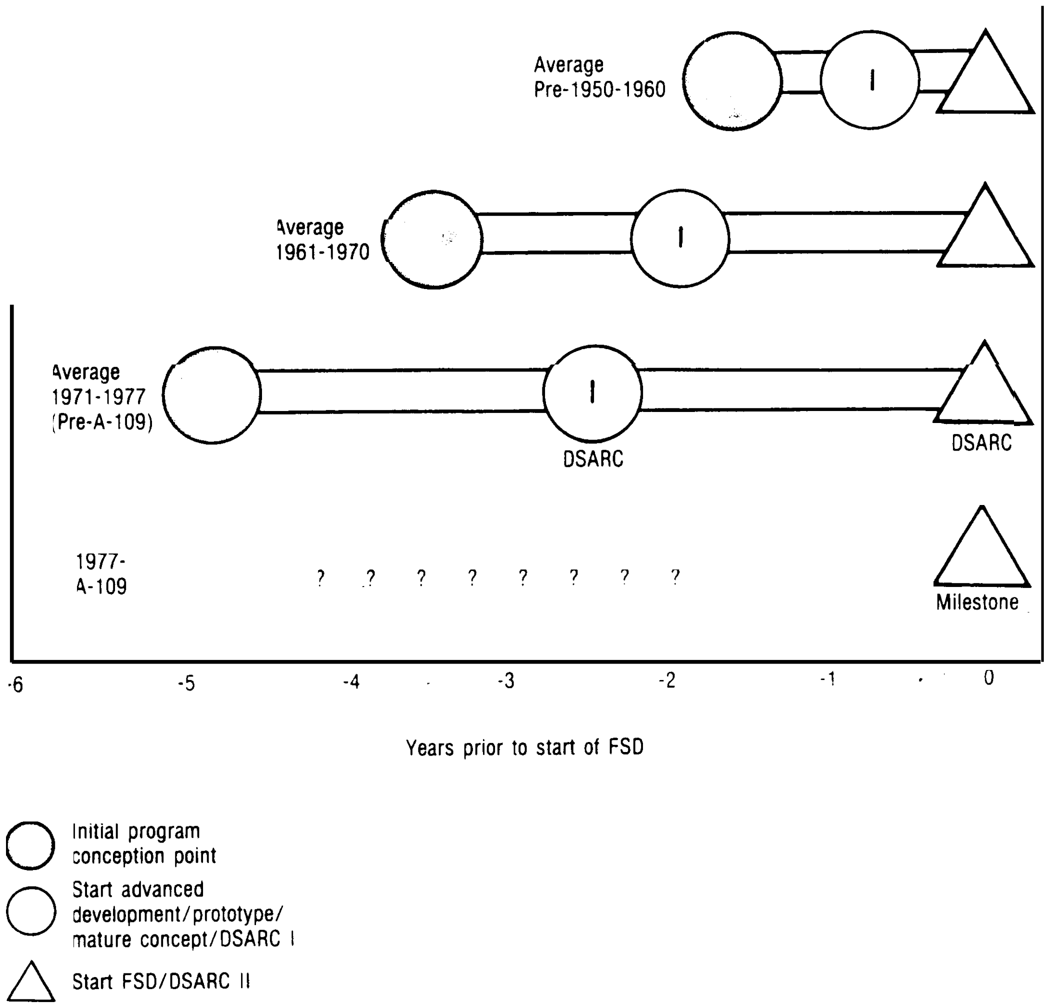
[1]Defense Science Board, "Report of the Acquisition Cycle Task Force 1977 Summer Study," prepared for the Office of the Under Secretary for Research and Engineering, Mar. 15, 1978.

[2]M. B. Rothman, "Aerospace Weapon System Acquisition Milestones: A Data Base," prepared by RAND's National Defense Research Institute for the Under Secretary of Defense for Acquisition, N-2599-ACQ, October 1987, p. 4.

[3]Air Force Systems Command, "Affordable Acquisition Approach Data Handbook, Vol. 1," Andrews Air Force Base, Nov. 15, 1982.

[4]Defined as the time between the start of any activity directly attributable to the program and the delivery of the first production article.

Figure B-1—Increase in Pre-FSD Development Times From the 1950s to the 1970s



SOURCE: Defense Science Board, "Report of the Acquisition Cycle Task Force 1977 Summer Study," prepared for the Office of the Under Secretary for Research and Engineering, Mar. 15, 1978.

the period needed for full-scale development itself. Although data for both radars and command/control systems also showed increases in total development time, these increases were not statistically significant: the program-to-program variation could not be substantially attributed to the date at which the programs entered FSD. Missile and aircraft programs that were ongoing at the time this study was completed had development times substantially exceeding the averages for those programs between 1950 and 1970.

The A^3 study also examined production rates of those systems still in production. For aircraft, production rates have declined significantly over time. This slowdown is to be expected if—as has been the case—the unit cost of weapons systems has increased faster than their annual production budgets. For several types of missile, actual or projected production rates had increased over the study interval; these increases were attributed to the projected increasing Air Force role in anti-armor warfare and depended heavily on holding to future Air Force funding projections.

RAND Corp. Studies

In 1980, the RAND Corp. published its analysis of the acquisition periods of about five dozen aircraft, helicopters, and missiles—"the only kinds of systems that have been developed in significant numbers more or less continuously over several postwar decades and that have been subject to the full panoply of decision review and ratification processes."[5] Agreeing with the DSB 1977 summer study and the Air Force A[3] study's conclusions for tactical aviation, RAND concluded that "the central phase of the acquisition cycle [full-scale development] has remained fairly unchanged and the early and late phases have been lengthening.'[6] The study went on to conclude that increases in the pre-FSD phase "should not automatically be considered undesirable," since these increases were consistently accompanied in the study data by reductions in cost growth, schedule slippage, and performance shortfall.

RAND found strong evidence that the portion of the pre-FSD phase constituting formal "planning" (excluding the earliest period of concept formulation that is difficult to define for the earliest systems) had increased in duration at an average rate of 6 to 10 months per decade. In the 1970s, this phase averaged from 50 to 80 percent longer than it had in the 1950s. However, the greatest part of this increase took place in the 1960s, with only a modest addition in the 1970s.

The RAND work was updated in 1987, extending it to "the vast majority of aircraft and a solid majority of the missiles and helicopters developed since 1945."[7] Analysis of the updated data had not been completed when the update was published, but its initial conclusions-that the data provide "some tenuous support" for increases in the pre-FSD period-appear weaker than those of the original study. The strongest correlations between development time and year of program start showed up in missile programs. Even for these, however, the correlation was not strong, with less than 15 percent of the program-to-program variance explained by date of program start. For all programs taken together, the update concludes that "calendar date alone explains little of the program-to-program variance," a point that figures B-2 and B-3 make clear. Figure B-4 shows the total time from program start to first delivery for aircraft, missiles, and helicopter, with an apparent growth in acquisition time of about 15 percent per decade.

Given the scatter in the data in figure B-4, interpretations could vary. The best-fit trend line shows a modest but steady growth. However, one might be persuaded that a "U'' -shaped curve, with a minimum somewhere around 1955-1960, better fits the points. The rationalization for such a fit would be that immediately after World War II, urgency relaxed and acquisition slowed down. However, the Korean War and the Cold War increased the urgency for acquisition, speeding up the system. During the 1960s, McNamara procurement policies, the cost of the Vietnam War, and regulation and micromanagement began to take an increasing toll. By this reading, the situation now is considerably worse than would be indicated by the steady but modestly increasing trend. The data to date do not indicate which of these models is better, but a continuation of this analysis through the 1980s and beyond could indicate whether either one provides a valid explanation.

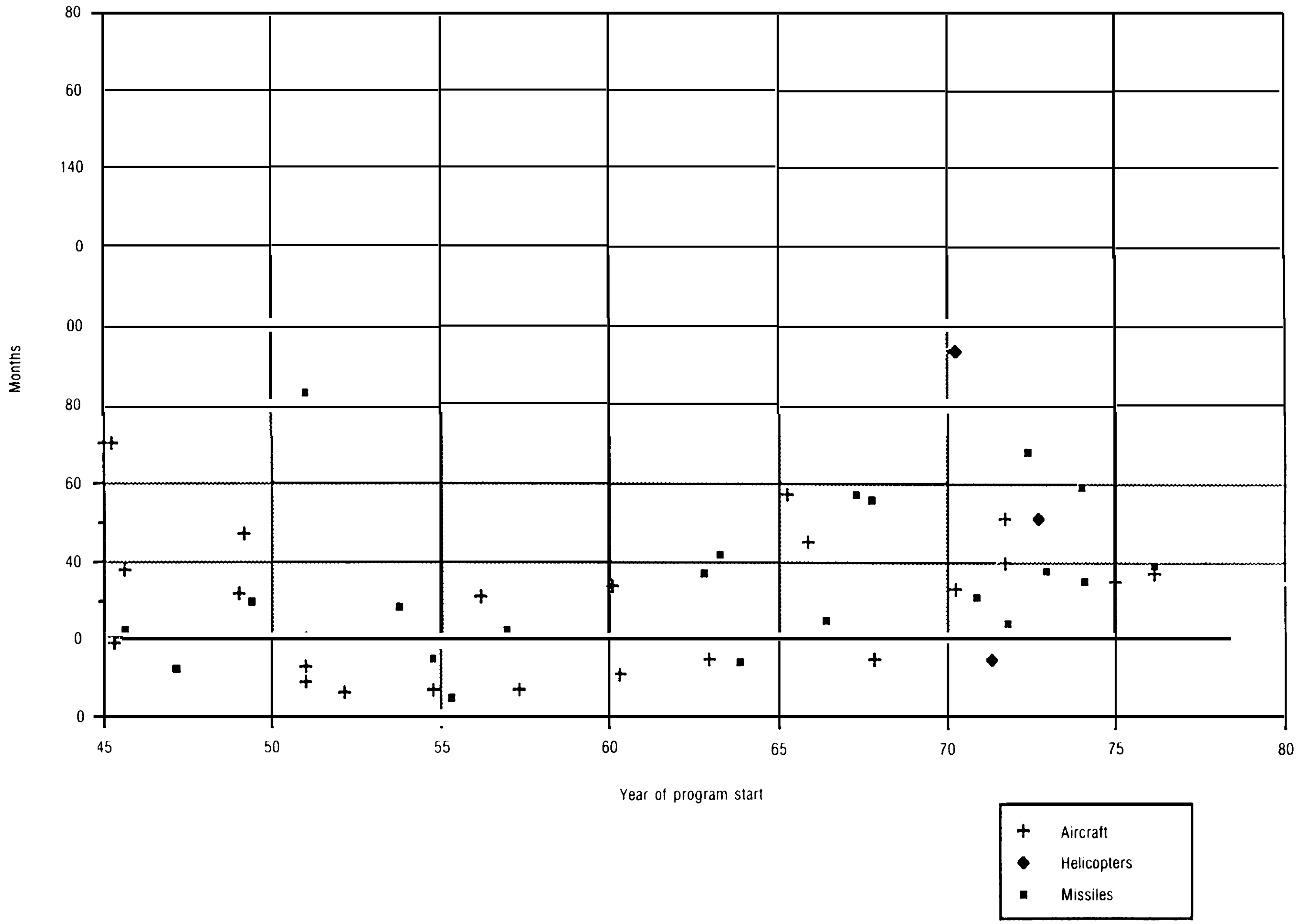
Differences between the RAND study and the Air Force A[3] study, which found a stronger correlation between year of development and development time, may be due to RAND's larger database. RAND found that data for aircraft entering FSD before 1950 prevented them from establishing a relationship between development pace and calendar date; these earlier planes were not included in the Air Force study. Moreover, RAND considered data from bombers and cargo planes along with fighters, whereas the A[3] study examined fighters alone. This aggregation makes little difference in the analysis, according to RAND. The variations in development time among systems within a single aircraft type mask out any obvious difference from one type to another, even if there were significant differences between subcategories, the small size of each subcategory would prevented RAND from analyzing the data at that fine a level.

5G.K. Smith and E.T. Friedman, "Analysis of Weapon System Acquisition Intervals, Past and Present," the RAND Corp., R-2605 -DR&E/AF, November 1980, p. v. This study was a follow-on to earlier RAND work that had addressed acquisition intends but had not analyzed them in depth: Edmund Dews, Giles K. Smith, Allen Barbour, Elwyn Harris, and Michael Hesse, *Acquisition Policy Effectiveness: Department of Defense Experience in the 1970s*, the RAND Corporation, R-2516- DR&E, report prepared for the Office of the Under Secretary of Defense for Research and Engineering, October 1979.

6G. K. Smith and E. T. Friedman, op. cit., footnote 5, p. v.

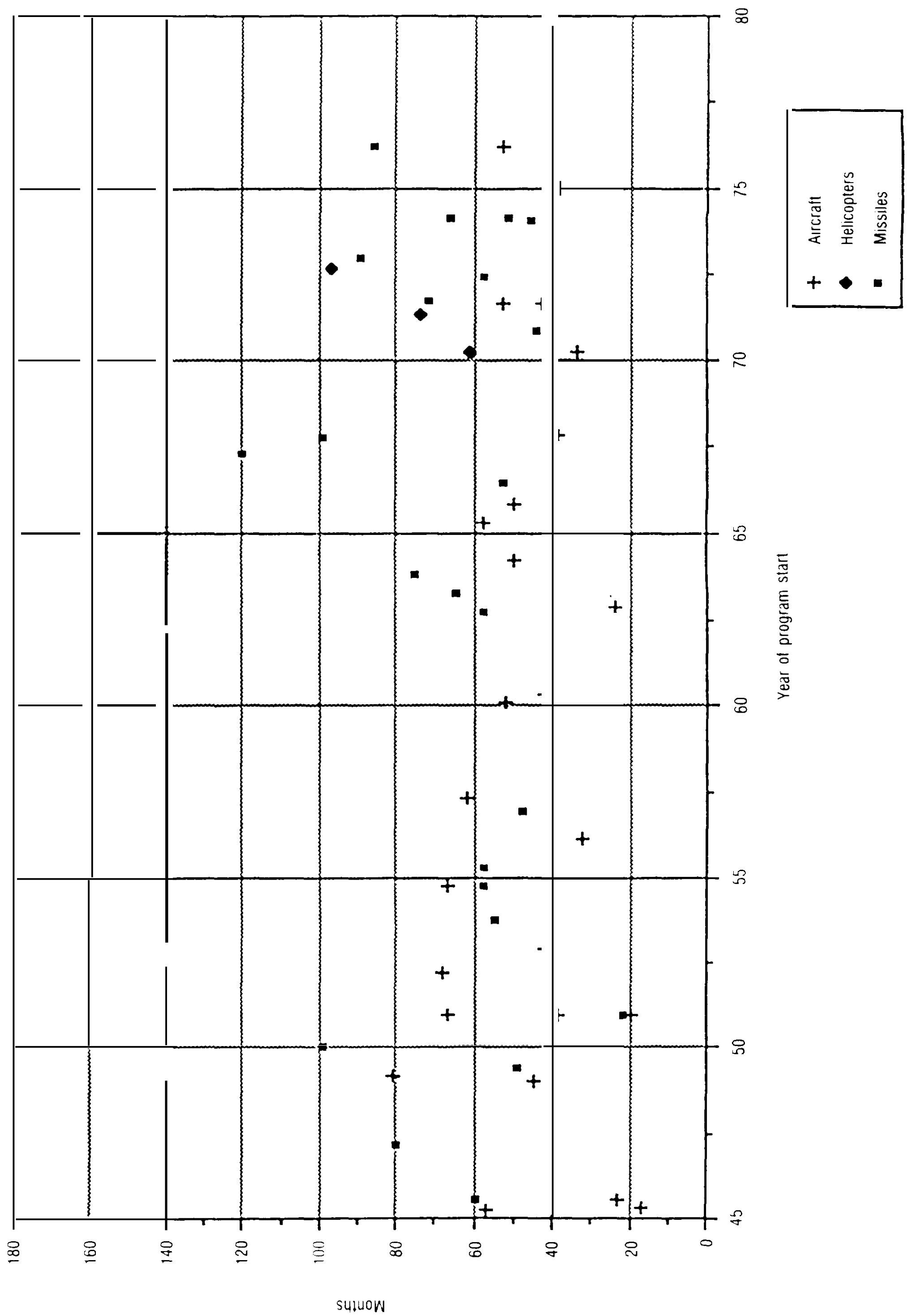
7M. B. Rothman, "Aerospace Weapon System Acquisition Milestones: A Data Base," prepared for the Office of the Under Secretary of Defense for Aquisition, the RAND Corp., N-2599-ACQ, October 1987, p. 3.

Figure B-2—Time From Program Start to FSD Start



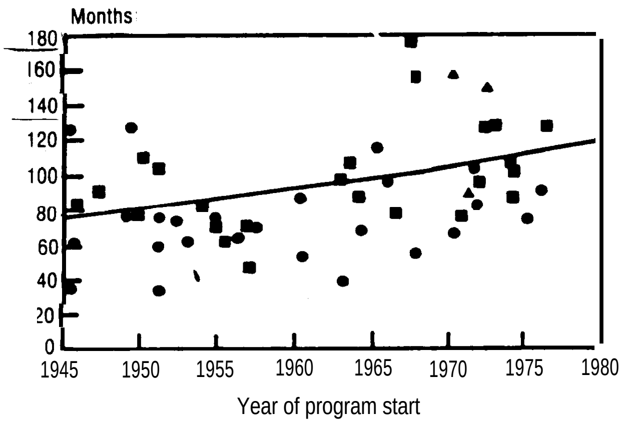
SOURCE: RAND 1987 Update, figure 5, p. 19.

Figure B-3—Time From FSD Start to First Delivery



SOURCE: *RAND* 1987 Update, figure 6, p. 20.

Figure B4-Time From Program Start to First Delivery, Along With Exponential Best Fit



Year of program start

o Aircraft

● Helicopters

• Missiles

SOURCE: G.K. Smith, J.A. Drenzer, W.C. Martel, J.J. Milanese, W. Mooz, and E.C. River, *A Preliminary Perspective on Regulatory Activities and Effects* in Weapons Acquisition, R-3578-ACQ, prepared for the Office of the Under Secretary of Defense for Acquisition, March 1988, figure 2, p. 19. This figure uses data from the RAND 1987 report on Acquisition Milestones.

Appendix C

Acquisition Milestones and Phases

Appendix C
Acquisition Milestones and Phases

The acquisition process described below is diagrammed in figure A-3 in appendix A.

Milestone O: Mission Needs Determination— Milestone O approves the initiation and authority to budget for a new program. It marks the point at which the mission analyses and technology base activities conducted by the Services on an ongoing basis first become focused through identification of a requirement for a system that might plausibly be developed.

A mission need may result either from a deficiency in existing agency capabilities or from the decision to establish new capabilities in response to a technologically feasible opportunity. Prior to initiation of a program, a military Service conducts analyses of projected threats and possible new missions, given the performance of its current systems. If this process identifies a deficiency, if plausible solutions can be envisioned, and if the Service considers those solutions to have a high enough priority to justify a claim on future resources, it prepares a Mission Needs Statement to initiate the acquisition process. Office of Management and Budget (OMB) Circular A-109 specifies that mission needs should be defined in functional terms, "independent of any particular system or technological solution."

Establishing priority within the Service for solving a mission need generates what can become an intense competition within the Service's budget preparation process. If the mission need survives this internal competition, the Service reserves funding for meeting the need in its long-range financial plan and its Program Planning and Budgeting System (PPBS) budget submission. Reviewing the Services' overall submissions, the Defense Resources Board decides whether or not to approve new programs. If approved, the program is assigned a program element number and is submitted to Congress as part of the Department of Defense (DoD) budget.

Primary considerations for Milestone O approval are: adequacy of the mission area analysis; affordability; ability to acquire or modify existing U.S. or Allied systems to provide the needed capability; and projected operational utility of the proposed solution.

Concept Exploration/Definition Phase— Approval of the mission need grants the authority to explore alternative system designs for new systems. It does not automatically mean that a new system will eventually be acquired. Other means of satisfying the need, such as changes in doctrine or training or increases in personnel, may prove to be the best solution. During the concept exploration/definition phase, the program office is established and a Program Manager (PM) is selected. One of the PM's first tasks is to develop an acquisition strategy, a major part of which is structuring an industrial competition to create, explore, and evaluate alternative designs. This phase typically takes from 0 to 2 years.

Milestone I: Concept *Selection-Results* of the concept exploration/definition stage are summarized in a System Concept Paper, which describes the acquisition strategy; identifies the best concepts to be carried into the demonstration phase; explains why other concepts were eliminated; and establishes broad cost schedule, effectiveness, and sustainability goals to be reviewed at subsequent milestones. Upon Milestone I approval, these goals become the program "baseline" within which the PM is free to operate-provide the resources are indeed made available.

The primary considerations evaluated by the Defense Acquisition Board at Milestone I include tradeoffs between various alternatives; trade-offs between performance, cost, and schedule; the need for development of a new system versus buying or modifying existing systems, whether military or commercial; appropriateness of the acquisition strategy; the need to prototype systems or components; affordability, including life-cycle costs; and plans for test, evaluation, logistics, and support.

Concept Demonstration/Validation Phase— Concept demonstrations are intended to verify that the chosen concepts will operate in a realistic environment and are technically sound. This phase, typically lasting 2 to 3 years, must provide sufficient information to permit decisions to proceed to full-scale development (FSD) to be made with confidence. Prototypes are built and evaluated during this phase, providing the eventual users with their first opportunity to see a realization of a system that can meet their needs-some 5 years after their original request.

Funds spent during this phase are generally in budget category 6.3B, system-specific advanced development. Designs and decisions made before approval for FSD will determine most of the future system's total life-cycle cost, with the great majority of that cost actually spent following the FSD decision.

Milestone II: Full-Scale Development Approval—Defense Acquisition Board (DAB) approval at Milestone 11 not only permits the start of FSD, but also implies approval for production upon successful completion of FSD. Consequently, production of certain long-lead-time items may be authorized, and low-rate initial production of selected components and complete systems may be approved as well to verify producibility and provide test articles.

In its Milestone II review, the DAB considers a number of factors including: affordability (in terms of cost versus value); technical risk; producibility; results of prototyping and demonstration/validation; manpower, training, and safety assessment: procurement strategy; logistics support; and additional requirements for command, control, communications, and intelligence. The Decision Coordinating Paper that summarizes the results of the demonstration/validation phase must "show [that] all significant risk areas have been resolved" and discuss "the extent to which technology is in-hand and only engineering (rather than experimental) efforts remain.'" More specific program cost, schedule, and performance thresholds are established, becoming the baseline governing both program development and reporting to Congress.

Since successful completion of FSD implies that production will be approved, the Defense Science Board 1977 Summer Study recommended that "FSD should be limited to those programs that are intended to be, and can be afforded to be, procured within the total defense budget (on the basis of realistic and credible cost estimates)."[2] At the time of the study, far more programs were in FSD than could be produced within any reasonable budget. The same situation is true today. The consequences of this finding shortfall are discussed under "Affordability" in chapter 8 of the main report.

Full-scale Development Phase-During full-scale development, typically lasting 3 to 6 years, the system is fully developed and engineered for production, and initial models are fabricated for developmental and operational testing. Developmental **testing and evaluation** (DT&E) helps the developer complete the design and engineering of the system and verifies that technical specifications are met. **Operational** testing and evaluation (OT&E) determines the suitability or effectiveness of the system when operated by typical military users in an operational environment.

During FSD, engineering and design changes are inevitable. If not appropriately anticipated, these changes increase the cost and length of the FSD phase. Although some of these changes may be necessitated by changes in the threat that the system is intended to address, according to one analyst, the impact of changes due to "improper, inadequate, or unrealistic definition of operational requirements and insufficiently critical evaluation of candidate system concepts" is often greater. Such changes late in" the development cycle, he claims, are likely "the largest single source of delays and cost overruns encountered in advanced and full-scale system development."[3]

Milestone III: Full-rate Production Approval— Upon review of the results of FSD, approval is given to proceed to fill-rate production. In cases where the Milestone II thresholds have not been exceeded, approval authority is typically delegated to the military Services. By statute, production approval cannot be given until the Director of the DoD Office of Operational Testing and Evaluation has certified that the results of operational testing are acceptable. If the interval between low-rate and full rate production is long enough, an additional Milestone IIIA decision for low-rate production maybe broken out from the full-rate production decision.

[1] DoD Directive 5000.2, "Defense Acquisition Program Procedures," Sept. 1, 1987, pp. 4-2.

[2] Defense Science Board, "Report of the Acquisition Cycle Task Force 1977 Summer Study," prepared for the Office of the Under Secretary for Research and Engineering, Mar. 15, 1978, pp. 3.

[3] Alexander Kossiakoff, "Conception of New Defense Systems and the Role of Government R&D Centers," in Franklin Long and Judith Reppy, eds., *The Genesis of New Weapons: Decision Making for Military R&D* (Elmsford, NY: Pergamon Press, 1980), p. 81.

Full-rate Production Phase-The production phase of a system can last for many years. The system first enters service when the user judges that enough have been produced to provide an initial operational capability, a point typically reached after 3 to 5 years of production. Several additional years of production may be needed before the system reaches full operational capability.

In the past, production has been undertaken concurrently with FSD in the hope of saving time. The risks and benefits of this approach are discussed in the box on "Concurrency" in appendix A.

Milestone IV: Logistics Readiness and Support Review-DoD Instruction 5000.2 specifies that the DAB review the logistics and support requirements of the new system 1 to 2 years after initial deployment. However, no such review has ever yet taken place.

Deployment and Operations Phase-Deployment of a major new defense system typically occurs 10 to 15 years after initiation of the program. Systems can remain operational-albeit with upgrades-for decades. The lifetime of major systems, from the beginning of FSD until the retirement of the last model from National Guard/Reserve inventories, can easily last 40 years. Deploying, operating, and supporting the system over its lifetime can have a cost comparable to the cost of developing and producing it.

Milestone V: Major Upgrade or System Replacement Review-Five to ten years post-deployment, according to Instruction 5000.2, DAB is to review the system's current operational effectiveness, suitability, and readiness. This review should determine whether major upgrades are needed or whether deficiencies warrant system replacement. However, as in the case of Milestone IV, no Milestone V review has yet taken place.

Appendix D

Case Study: The Fiber Optics Industry

CONTENTS

Appendix D
Case Study: The Fiber Optics Industry

Note: This case study, along with those in Appendixes E and F, was presented in condensed form in chapter 9 of the main report, Holding the Edge.

INTRODUCTION

Not until *1963* did Corning Glass Works, Bell Laboratories, and Standard Telecommunications Laboratories recognize the possibility that glass fibers could be used to transmit information from one place to another. In that year, all three groups initiated research on guided-wave optical communications.[1] In 1970, Corning demonstrated the necessary breakthrough by achieving a radiation loss of 20 dB/km, using a vapor deposition process.[2] It was not until 1977 that the state of the art had advanced sufficiently for AT&T and GTE to install the first commercial fiber optics systems. Since then, fiber optics technology and the extensive international industrial structure that supports it have matured at a dizzying pace, causing one of its early inventors to observe that "fiber optics went much faster from research to use than any big project ever before."[3] By 1988, the U.S. fiber optics and optoelectronic industries included about 700 firms and had reached an annual volume of sales in fiber optics systems of approximately $568 million.[4]

Fiber optics has realized exponential growth, not only in production and sales, but also in the potential scope of the technology itself. It has been defined, broadened, and redefined variously over the past several years. A recent study by the National Research Council included fiber optics as a subset of a larger field called photonics. That report described photonics as a "critical, emerging technology . . . [that] has been building a technological armamentarium of proven science and advanced technology throughout the past three decades." It focused broadly on telecommunications, information processing, optical storage and display, and optical sensors-four "technical areas where the overall worldwide market for equipment approaches $400 billion per year."[5]

This perspective echoes the assessment of independent analysts who believe that fiber optics and related optical disciplines will eventually exert an impact on the world economy comparable to that of electronics in the 1970s and 1980s. They expect intense international competition, with governments designating the new technologies as necessary national assets. This may well involve strategies for economic defense of photonics-related industries, similar to those that Japan and some European Community member states have already installed for optical fiber and optoelectronic devices.

OTA is examining fiber optics as a dual-use technology, from the perspective of its contribution to defense needs in the United States. It is important to note, however, that fiber optics technology is far more widely used in the civilian sector than it is in the military. While significant research is taking place in the military sector, few fiber optic systems have been fielded to date. The rule of thumb is that fiber and optoelectronic devices are installed only when no other adequate solution to a problem exists.

Fiber optics is a vital technology that has strong implications for national security, as well as for economic competitiveness. A primary purpose of this case study is to assess the availability of fiber

[1]This initial corporate interest in fiber optics was sparked by the path-breaking work of Elias Snitzer, first published in 1961. Trudy E. Bell, *IEEE Spectrum*, Special Issue, vol. 25, No. 11, pp. 97-98.

[2]F.P. Kapron, D.B. Keck, and R.D. Maurer, "Radiation Loss in Glass Optical Waveguide," *Applied Physics Letter*, Vol. 17, 1970, pp. 423.

[3]Bell, op. cit., footnote 1, p. 102.

[4]U.S. Department of Commerce, "U.S. Industrial Outlook 1988—Communications Equipment," 1988, pp. 31-36. It is important to note, however, that the U.S. optical fiber industry is extremely concentrated, with two firms—Corning Glass Works and AT&T—accounting for over 80 percent of fiber production. See, for example, U.S. International Trade Commission, "U.S. Global Competitiveness: Optical Fibers, Technology and Equipment," USITC publication 2054, January 1988, p. xii.

[5]National Research Council, *Photonics: Maintaining Competitiveness in the Information Era* (Washington, DC: National Academy Press, 1988), pp. vii, 1.

optics technology developed in the civilian sector for military use. For this reason, this appendix focuses on commercially available optical technologies for which there is demonstrated military need. It concentrates on fiber optic communications systems, including the fiber itself, cables, and related optoelectronic devices (transmitters, connectors, switches, repeaters, and receivers). Because of their many military applications, fiber optic sensors are also discussed.

This case study is designed to address three central questions: First are the civilian fiber optics and optoelectronics industries—especially those that are critical to the military-eroding in the United States? Second, do military applications of fiber optics technologies diverge significantly from their dual-use counterparts in the civilian sector of the economy? And third, what are the principal barriers, both technical and institutional, that inhibit military access to civilian fiber optics technology and vice versa? Each of these areas is addressed in a separate section below. The last section concludes ‘with a summary of policy problems specific to fiber optics technology.

GLOBAL FIBER OPTICS MARKETS AND THE HEALTH OF THE U.S. INDUSTRY

The first major boost to the fiber market came in the late 1970s when the regional Bell Telephone operating companies ran into problems pulling more copper wire through already established conduits. Because of this congestion, they had to choose between building more ducts or substituting fiber for copper. Thus, interoffice trunking became the first large market for fiber optics in the United States. A second big boost for fiber extended from 1983 through 1986, as long haul fiber trunks were installed across the United States. With deregulation of the telecommunications industry and competition for long distance carriage, demand for fiber increased by 100 percent per year and its cost dropped precipitously. By 1985, U.S. telephone companies had installed more than 2 million kilometers of fiber. Between 1986 and 1988, the price of fiber cable decreased 70 percent. The completion of these large-scale projects caused worldwide sales of fiber optics to stabilize, and has encouraged major fiber makers to look for new markets for their products.

The U.S. market for fiber optics is the largest and most open in the world, accounting for over 50 percent of world consumption in 1984.[6] Over the past four years, however, the relative size of the U.S. market has decreased; it is forecast to drop to between 35 and 40 percent of the world market by 1989. Near-term installation of fiberoptic systems in Japan and Western Europe is expected to exceed that of North America. At the same time, overall world consumption of fiber optic systems is expected to increase by a factor of four by the year 2000.[7] The major market for fiber optics has been, and continues to be, the supply of fiber and optoelectronic devices for telecommunications systems. Although flat, this market could expand dramatically if financial and regulatory barriers to bringing fiber to the home are removed. While potentially substantial, military markets are not expected to mature until the middle 1990s—and even then, DoD technology planners and the U.S. Congress would have to designate and support fiber optics as a critical military technology. This scenario is by no means assured, given the imperative to reduce budget deficits and the continued strong competition within the Department of Defense (DoD) for a decreasing pool of funds.

Telecommunications applications now account for as much as 90 percent of the world market for fiber optic components and cables by some estimates. The U.S. consumed about 1.6 million kilometers of fiber in 1987, while the world market reached approximately 3 million kilometers. Europe comprises about a third of the market, with Japan and Korea accounting for about 16 percent. The overall international market for fiber grew about 20 percent in 1987,8 North America and the Far East are net exporters of optical fiber, while Europe is a net importer. The difference between production and consumption of fiber is not large in any region.

Since the end of the long haul market boom, the worldwide fiber optic industry has been characterized by overcapacity and intense competition, with

[6] U.S. Department of Commerce, International Trade Administration, “A Competitive Assessment of the U.S. Fiber Optics Industry,” September 1984, p. 32.

[7] U.S. Department of Commerce, International Trade Administration, “International Competitiveness Study: The Fiber Optics Industry,” September, 1988, pp. 24.

[8] Figures provided by Corning Glass Works.

most Organization for Economic Cooperation and Development (OECD) countries designating fiber optics as an essential national capability. By 1980, a pattern had begun to emerge in the way that OECD member governments and their corresponding industries would respond to the strong growth potential of the fiber optics markets. In the United States, large, vertically integrated firms like ITT and AT&T began to invest heavily in fiberoptic R&D. Corning Glass Works, which held many of the important patents in the field, established an early lead in fiber development. Major cable companies became takeover targets by firms that had not been principally associated with the telecommunications industry, and that now sought to position themselves for future fiber optics business.[9]

In Japan, NTT, MITI, and KDD (the Japanese international communications agency) initiated a carefully orchestrated campaign. NTT (then an official government agency) led the effort, conducting and promoting fiber optics and optoelectronics research. At the same time, KDD initiated a long-term program to develop all aspects of technology necessary for submarine fiber optic systems. And MITI[10] initiated two substantial research projects, the Hi-OVIS program and the Optical Measurement and Control System R&D program.[11] Most European countries generally appeared to take a middle ground, with the national PTTs (state-run public telecommunications monopolies) establishing R&D programs (such as BIGFON in West Germany) and actively seeking to promote the interests of their domestic industries. In Sweden and the Netherlands, the private sector appears to have taken a stronger role.[12] The differences in the development of fiber optics industrial structure and markets in the three regions require further explanation.

In Europe, most European Community (EC) member states have designated fiber optics as a critically important technology, and the national PTTs have tended to favor a few domestic suppliers of equipment and cable. More importantly, because the PTTs provide centralized planning and control of the telephone networks, they can (and do) support the introduction of new technology into those networks by arranging for trials and demonstration projects. This has resulted in highly fragmented national markets. Nevertheless, Corning Glass Works, an American firm, has been able to penetrate European markets by entering into joint ventures and licensing agreements-usually with cable manufactures, who then sell to the PTT monopoly buyer. Other companies, including the Japanese, participate in joint ventures with European firms to establish a presence in a changing market environment,

Concern over the anticompetitive aspects of centrally planned and regulated domestic markets has led EC officials to create programs designed to help European industry keep pace with innovative U.S. and Japanese industries. They believe that the eventual merging of communication and information technologies will require dynamic changes in the structure of the independent and isolated national industries and markets. With an eye to Europe's 1992 unification. they have instituted such programs as RACE (Research in Advanced Communication in Europe) and ESPRIT (European Strategic Plan for Research and Development in Information Technologies).[13] While representatives of large U.S. fiber optics companies believe that European markets are essentially open to all, they are concerned about the possible consequences of a pan-European policy.

In fiber optics and optoelectronics, the Japanese government has pursued a strategy of sponsoring a domestic industry, insulating home markets from foreign competition, building up a highly capable, vertically integrated industry with significant overcapacity, and encouraging export of quality systems to Europe and the United States. By the late 1970s, Coming and AT&T had established strong positions in world markets, due to the advanced state of the U.S. technology and to Corning's ownership of the major fiber optics patents. At that time, MITI identified optoelectronics as a key technology for Japan, and was very active in focusing the industry and getting development started. Specifically, NTT was tasked with designating industrial partners and

[9]Organization for Economic Co-Operation and Development, *Telecommunications: Pressures and Policies for Change* (Paris: OECD, 1983), pp. 117-118.

[10]Nippon Telephone and Telegraph, Ministry of International Trade and Industry, and Kokusai Denshin Denwa.

[11]OECD, op. cit., footnote 9, p. 120.

[12]Ibid., p. 124.

[13]U.S. International Trade Commission, op. cit., footnote 4, pp. 10.2-10.5.

forming a consortium to conduct the R&D work necessary to develop a domestic optoelectronics industry.[14]

In close consultation with MITI officials, NTT selected three major companies, Sumitomo, Furukawa, and Fujikura, essentially picking winners from among a larger pool.[15] While NTT provided some R&D funds, the most significant funding was invested by the companies themselves. What NTT did was to guarantee that it would purchase the fiber that was produced at over twice the world market price, and in proportion to the investment that each company made.[16] By guaranteeing a market, and by discriminating against companies like Coming and Siecor,[17] NTT effectively eliminated risk for the three companies as well as for the financial institutions that backed them. By the middle 1980s, the Japanese optoelectronics companies had developed technology on a par with the best in the world. and had established a major position in world markets for fiber optic systems.[18] Indeed, their ability to produce total fiber optic systems has led some analysts to suggest that they will soon achieve a strong-and perhaps dominant-position when fiber reaches into the local area network and into the home.

One pervasive effect of these differences in policy and approach is that U.S. firms must face stiff competition at home, while they are effectively breed from substantial penetration of some foreign markets. Nevertheless, U.S. fiber makers believe that they lead the world competition across a number of vital areas. Product performance for U.S. fiber makers is presently superior to that of Japan and the major EC member states (including France, Great Britain, and the FRG), and is superior to that of Korea and ether producers such as Australia. American fiber companies assert that for fiber, the U.S. leads the world in R&D and innovation, and that major new advances are in the offing. The cost to manufacture fiber is lowest in the U. S., but Japanese and some European producers are narrowing the gap hem. Many representatives of American fiber and optoelectronic companies believe that the U.S. presently maintains a technological lead in virtually every area of fiber optics, but that this lead is eroding.[19] The American position was established and is still based on intense competition for sales to American telephone companies. Many believe that the industry is robust, and that for this reason, official Washington should stay on the sidelines and allow market forces to favor an industry in which the U.S. has already proven itself to be particularly sturdy and capable.

Others are less sanguine about the future competitive status of the fiber optics and optoelectronics industries in the United States. A 1984 Commerce Department assessment predicted that although the U.S. fiber optics industry "urrently enjoys a significant competitive advantage, the limited access of U.S. firms to markets in Japan and Western Europe will adversely affect the performance of these firms in the future"[20] Four years later, a second Commerce Department report provided a somewhat more so-

[14]NTT has played a similar role in telecommunications as well as, in electronics: "In essence, NTT's industrial policy role has enabled favored Japanese telecommunications-computer-semiconductor companies to develop and commercialize new technologies in a protected and subsidized, risk-minimized way. The resulting equipment has been procured in high volume at premium prices until quality and cost have reached world levels, enabling rapid competitive penetrations of world markets by major Japanese firms". Michael Borrus et al., "How Government Policies Shape High Technology Trade," BRIE Working Paper #3, October 1984, pp. 68-69.

[15]Each of the "winners" knew that NTT officials expected first-rate performance, and that they were prepared to pick other players in the event that the three companies did not deliver. This posture on the part of Japanese government officials helped to generate intense competition, not only between the three winners, but also with a larger group of second-tier companies working with optoelectronic technologies.

[16]Clyde V. Prestowitz, Jr., *Trading Places: How We Allowed Japan to Take the* Lead (New York, NY: Basic Books, 1988), pp. 131-135.

[17]For reasons that are difficult to pin down, Corning's patent applications in Japan were not processed for 6 years on average. The Japanese patent office took 11 years to grant exclusive rights for Corning's basic patent, retarding the initial stages of that company's market development in Japan. In addition, the system of Japanese standards promulgated by NTT effectively excluded much of the foreign competition, even though the U.S. companies were able to offer NTT superior products at a much lower price than the three Japanese companies.

[18]When Sumitomo attempted to enter the U.S. market, however, Corning challenged them in court for patent infringement and won, closing Sumitomo's American production facility. It is likely, however, that Japanese industry will renew its efforts to produce in the U.S., as Corning's patents expire over the next several years.

[19]This view was not reflected in the finding of the U.S. International Trade Commission: "Japan is generally regarded as the leader in applied research and product development of certain optoelectronic components and systems that drive optical fiber lightwave systems . . . .Japanese producers have also gained more experience than U.S. or Western European firms in the mass production and commercialization of certain optoelectronic devices. Included in these are compact disk systems that many industry experts believe will be transferable in the near future to optical fiber transmission systems, especially those used in local area networks and subscriber links to the home". U.S. International Trade Commission, op. cit., footnote 4, p. xvi.

[20]U.S Department of Commerce, International Trade Administration, op. cit., footnote 6, p. ix.

bering view. It concluded that the future competitiveness of the U.S. fiber optics industry is by no means assured, but instead will hinge on a variety of critical factors, a view strongly endorsed by the U.S. International Trade Commission in a recent report.[21] An OTA workshop held in Washington on July 25, 1988 reflected these, as well as other, concerns, the most important of which are summarized below.[22]

The future health of the U.S. fiber optics industry depends largely on its ability to sell fiber and optoelectronic devices to the telecommunications companies, and this in turn depends on the development of a fiber-to-the-home market in the U.S. Legislators and regulators have tended to shift responsibility for the development of the national telecommunications infrastructure to market forces and the courts. And the courts have established a regulatory regime that effectively separates telephone and television delivery systems and inhibits the spread of telematic (online) services. The Bell operating companies are limited to providing local exchange communications and to permitting access to long-distance (or interexchange) companies. They may not provide additional information services or manufacture telecommunications equipment.[23] While AT&T and the other long-distance carriers are not restricted in manufacturing, they depend on the local Bell networks to access individual homes. Accordingly, there is little economic incentive for either the local Bell operating companies or for the long distance carrier/manufacturers to invest in fiber-to-the-home networks. This situation may retard the development of the optoelectronics industry in the United States. At the same time, large Japanese and European firms are gaining experience in the development, production, and commercialization of overall fiber optic systems in their home markets.

Many analysts expect that the future demand will be for fiber optic systems, not for fiber or isolated devices. Some believe that firms that sell systems may be willing to give away the fiber in order to obtain the contract. They believe that such a demand structure would tend to favor companies that are vertically integrated.[24] At present the only U.S. firm that can produce whole systems is AT&T. As many as six Japanese firms are thought to have this capability. Unless the structure of the industry is dramatically altered, U.S. companies will have to cooperate with other suppliers to be able to construct entire systems. Some foreign firms-which lead in an overall systems approach—have even developed large-scale integration through government-supported demonstration projects, moving farther "down the learning curve" in integrating their products into functioning systems. When North American markets for local area networks and subscriber loops do open in the 1990s, it is likely that vertically integrated foreign firms will have significant experience and a comparative advantage as suppliers.

A second area of concern focuses on the lack of international standards for fiber optic systems and associated optoelectronic devices. While international standards are developing, especially for integrated system digital networks (ISDN), progress in this area is very slow and cumbersome in an industry that is innovating quickly. Different countries have tended to adopt different standards, and standards have sometimes been used as non-tariff barriers to protect home markets for developing industries. Some industry representatives believe that Japan and the European nations are more advanced in setting standards than the United States, and that this will give them a developmental advantage. They believe that U.S. firms are reluctant to make extensive capital investments in optoelectronic devices that may be obsolete before they can be installed. Large firms that can offer complete fiber optic systems are at a distinct advantage in this respect. With well-developed national standards, large, vertically integrated Japanese firms may be

[21]U.S. Department of Commerce, International Trade Administration, op. cit., footnote 7, pp. xiv-xv.

[22]"Workshop on the Relationship between Military and Civilian Fiber Optics," Office of Technology Assessment, Washington, DC, Jul. 25, 1988. See *Holding the Edge*, p. vi, for a list of workshop participants.

[23]These prohibitions are contained in the Modified Final Judgment. See "United States v. Western Electric Co., Inc., et al. Notice of Entry of Final Judgment," 47 Fed. Reg. 40392-40394 (Sept. 13, 1982).

[24]Globalization and vertical integration are powerful trends in the field of telecommunications equipment generally. "In the next decade or so the global telecommunications equipment market will come to be dominated by about six Western players: two in Europe, two in North America, and two in the Far East . . . .Building the next generation of optical super-switches and super-computers will require enormous concentrations of capital, talent, and sustained engineering effort. The stakes are huge, not just for individual companies but for entire nations. This is not a market that the largest players enter lightly, or that smaller players enter at all". U.S. Department of Justice, Antitrust Division, "The Geodesic Network: 1987 Report on Competition in the Telephone Industry," January 1987, p. 1.13.

able to set *de facto* world standards, thus forcing U.S. and other component makers to meet those standards if they wish to Participate.

Third, foreign markets-especially in Japan but also in some EC member states-still present significant barriers to American firms. This disadvantage to U.S. companies is compounded because future expanded demand for fiber optic systems is expected to occur first in foreign markets, where domestic manufacture are favored. At the same time, the U.S. market remains wide open to all suppliers, and U.S.-based companies face intense competition for their share. As the U.S. market for fiber optics shrinks in relation to the world market, so too will the proportionate share of world sales for U.S. firms. As the market for fiber optic systems expands in the future, foreign firms may achieve large market shares and realize economies of scale unavailable to the American competition.

Fourth, most European producer nations and the Japanese government have designated fiber optics as an essential technology of the future, and subsidize research and development in the optoelectronics field. In the U. S., government assistance has been largely confined to the military, and U.S. companies have tended to pursue such R&Don an ad hoc basis. American firms lack the subsidies, the protectionist trade policies, the experience developed from demonstration projects, and the government-led standard-setting that their foreign competitors enjoy. On the other hand, U.S. firms have benefited from early and extensive patent acquisition, superior R&D, and the largest domestic market for fiber optic products in the world. However, these advantages appear to be eroding, and some will expire shortly. For example, some of the key patents held by Coming Glass Works will expire in the next several years, threatening the American position in both the domestic and international fiber optics markets.[25] Already, a number of foreign fins-especially French and Japanese—have had considerable success in the American market. The leading American companies, AT&T and Corning Glass, face considerably greater obstacles in attempting to penetrate foreign markets.

And finally, the U.S. continues to maintain a regime of export controls for fiber optics that is more restrictive than that of its CoCom partners and non-CoCom nations such as Sweden and Finland. The result is that U.S. companies often experience unnecessary delays, and have even been barred from exporting products that can easily be obtained through the European and Asian competition. For this reason, some executives of foreign companies have instructed their managers not to include American-made parts in their systems on the basis that supply may be unreliable in the future.

CONVERGENCE/DIVERGENCE OF CIVILIAN AND MILITARY FIBER OPTICS TECHNOLOGY

Military planners recognize a number of advantages inherent in deploying fiber optic systems in a military environment. Fiber optic systems are immune to electromagnetic interference, including the electromagnetic pulse that would emanate from a nuclear blast. They are considerably more secure from eavesdropping than traditional electron-based communications systems. It is comparatively easy to determine if a listening device has been attached to a fiberoptic system, and fiber itself has no electronic signature. Communication systems that use fiber can span longer distances without repeaters than can a twisted copper wire or coaxial cable. In addition, fiber optic systems are much lighter and far less voluminous. This is of extreme importance, for example, in Army tactical communications that must be strung out over a large area in a matter of hours or minutes, and in the Navy's ships, where weight and volume are especially critical factors. Fiber optic systems can function in intense heat and are able to withstand severe vibration, shock, and other mechanical stresses. Extensive testing by all three Services indicates that under most battlefield conditions, optical fiber systems are superior. It is a technology that appears to be inherently better suited to military environments than the technologies presently employed.[26]

Shipboard application demonstrates these points well. When the *U.S.S. Stark was* struck by missiles in the Persian Gulf last year, the communications

[25] Some industry representatives argue, however, that expiration of these patents may stimulate the U.S. fiber optics industry. They maintain that a "patent umbrella" has resulted in stifling domestic competition in a critical technology and has placed enormous marketing power in the hands of two companies, AT&T and Corning. They argue that it is not in the national interest for a key technology to reside in such a limited sphere.

[26] Army briefing to OTA on fiber optics, Jun. 29, 1988.

systems were immediately disabled. The electrical wire physically melted in the ship. Wire that was run on the deck melted in place. Under these conditions, a fiber system would be far more likely to survive. Experimental data have shown that fiber will continue to transmit information when it is heated up to 1200 degrees Centigrade, a temperature at which copper or aluminum would long since have disintegrated. There are other advantages. The Navy indicates that for one of its ships, 47 copper wire cables could be replaced with one glass fiber cable, which would weigh 15 pounds as opposed to 14,000 pounds, and could be installed at a cost of $30,000 instead of $1 M, the cost to install the copper cable.[27] Despite all these advantages, it is still the case that no ship in the U.S. Navy presently employs a shipwide fiber optic communications system.

In approaching the question of the extent of divergence between military and civilian applications of fiberoptic technology, it is perhaps useful to distinguish between tactical and fixed-plant fiber optic systems. The Army has provided information that directly addresses this problem. Tactical systems require rapid mobility. Approximately 50 percent of mobile communications would be operating in place for only ten hours. Although fixed-plant systems are installed directly in the ground or in conduits, most tactical systems must be placed on the ground or strung above the ground. While there are no significant limitations on cable length for fixed systems, tactical systems must be configured so that they can be set up and retrieved quickly. In addition, cable used in tactical communications must be more flexible and durable than in fixed-plant systems because it is handled frequently and under conditions that may not be optimal. Cable and repeaters for fixed facilities are usually protected from extreme variations in climate; whereas tactical systems may have to face a temperature range of between -55 and +160 Fahrenheit. While optical splicing may be used for many fixed applications, connectors are necessary due to requirements for mobility in a tactical environment. And finally, batteries or other sources of local power are usually required to drive sources and repeaters in tactical systems.[28]

There are also some important military applications of fiber optic technologies that do not have civilian analogs. One example is the use of fiber optic guidance systems in tactical missiles. The fiber configuration must be light, strong, and able to pay out quickly even after years of storage on a coil. The Fiber Optic Guided Missile (FOG-M), now in full scale engineering development, pays out an optical fiber from a bobbin, like a fishing reel, enabling the battlefield operator to target the missile with a real-time video image emanating from a camera in the nose of the missile. This makes it possible to hit targets that are not in the operator's line of sight, while the operator is at a sheltered location.[29] It requires many special parts that are not typically produced for civilian purposes. In addition, there are a number of fiber optic sensing devices now in research and development, such as the Navy Ariadne system, for which there are no obvious civilian applications.

But do such differences in application really translate into differences in the technology itself or in the way that R&D for fiber optics must be conducted? Here, the answer is a qualified "No." For fixed-plant systems, the requirements would differ only marginally, if at all, from those used in private sector businesses or for local area subscriber networks. The need for secure lines might, in some cases, entail a requirement for special hardware to monitor the system to ensure that security was not compromised. But such measures might also be necessary to safeguard proprietary information of businesses as well as the communications of banks and other financial institutions. For a large percentage of military applications[30]—wiring the Pentagon, the DoD laboratories and R&D facilities, and the military bases-the technology is broadly available from the civilian sector. This is also true for the long distance trunk lines used to connect military facilities with one another and with commercial communications systems. In addition, fiber optic systems deployed on ships would be similar to local area

[27] Navy briefing to OTA on fiber optics, Jun. 23, 1988.

[28] Army briefing to OTA on fiber optics, Jun. 29, 1988.

[29] Although the current military market for fiber is small, if this weapon system were put into full-scale production, the military demand for fiber optic cable would increase dramatically.

[30] Of principal fiber optics programs in the Army, for example, seven were categorized as fixed plant, two as tactical, and one was the FOG-M missile. (Army briefing to OTA on fiber optics, Jun. 29, 1988).

networks now undergoing trials in the private sector in Japan and the United States.

In both sectors of the economy, sensors have enormous potential in a wide range of applications. Many of the major sensors used by the military are analogous to those used in the civilian sector. Radar and sonar probably diverge the most from civilian products, but sonar is used to locate and harvest fish in the open sea as well as in logging and oil exploration operations. The oil industry employs a cable that is inserted into wells, using optical gyros, which is subjected to more severe environments than would be encountered in a military context, and which is used over and over again. For this reason, it is not accurate to say that fiber optic sensor technologies that are employed for military purposes diverge significantly from those used in the civilian sector. Nevertheless, some sensors are absolutely unique to combat environments.

One fiber optics group in the Navy has designated 54 different types of sensors that could be applied to a wide variety of military systems. Most would be benign and passive in all the environments for which they are designed. The group has tested a great many sensors developed for civilian purposes and found that most of them did not perform adequately in a military context. Their conclusion, however, was not that the civilian sensors should be discarded and replaced by sensors built to military specification. (After all, most such specifications do not yet exist, and the process of writing them and getting them approved will take years.) Instead, the group took the approach of addressing military requirements by attempting to modify commercial products so that they are suitable for the particular military needs.

The group's objective is to use the technology that is out there-technology which, they believe, is far more capable than the Services are currently capable of employing. Industry already has endoscopic devices used to look into machinery and into places where electronics cannot be inserted. None of these things is new or radical; each represents basic technology with different applications. In this view, the job at DoD is to figure out how to take the technology that is available-not a radical departure from it—and adapt it to a military setting. This synergistic approach is especially interesting, because sensing technology is probably the only area of fiber optics technology where the military leads the civilian sector.

Despite the decidedly military character of the FOG-M missile, its designers indicate that the Army has been able, for the most part, to use optical fiber that can be produced on modified commercial manufacturing equipment. The fiber companies have entered into earnest discussion with the FOG-M program because they anticipate a run of fiber that might reach 2 million kilometers. There are differences in the way that the fiber is wound on the spool. in the cladding that must surround it, and in the materials that are used to attach the fiber to the spool. But these do not translate into large technical differences, nor do they require large differences in the way that R&D is carried out. What is needed is the civilian industry and technology base to develop the modification.

BARRIERS TO MILITARY ACCESS TO CIVILIAN FIBER OPTICS TECHNOLOGY AND VICE VERSA

The issue of using civilian products for military purposes is not new. It is at least as old as the recognition that the costs for the military to develop its own technologies are extensive and, in some cases, prohibitive. The Packard Commission recommendations addressed the question of commercial versus developmental items in strong language: "Rather than relying on excessively rigid military specifications, DoD should make much greater use of components, systems, and services available 'off-the-shelf. ' It should develop new or custom-made items only when it has been established that those readily available are clearly inadequate to meet military requirements."[31]

The Commission's statement builds on a long line of legislative provisions, presidential directives, and cabinet-level memoranda since 1972 that have suggested a preference for commercially available products in government procurement. Nevertheless, the substitution of civilian products for military standard items remains the exception rather that the rule, and nothing less than a "specific and enforceable statutory directive [from Congress] in favor of the acquisition of commercial products" is likely to

[31] *An Interim Report to the President by the President's Blue Ribbon Commission on Defense Management*, Feb. 28, 1986. p. 17.

make a difference.[32] The wisdom or unwisdom of such a mandate is a matter of heated debate; but there is, nevertheless, considerable consensus that much excellent technology exists in the civilian sector, and that the military must surmount enormous barriers to acquire it.

Perhaps the greatest structural impediment that the military faces in drawing on the civilian technology base is that the business practices of the government diverge so radically from those of the private sector.[33] Like other industries, fiber optics companies have found it necessary to create a separate corporate division in order to do any substantial amount of business with the Department of Defense. In *order* to meet government regulations and specifications, fiber optics businesses must organize many of their principal functions differently-including accounting, personnel, auditing, R&D, production, advertising, marketing, and management information systems.

They must also adjust their business psychology and profit orientation. Successful fiber optics and optoelectronics companies invest heavily in research, develop a superior product, realize large profits, and plow their earnings back into the R&D effort. This business environment contrasts sharply with government-subsidized research and regulated profit margins. While all firms that seek defense contracts must face these facts, it is particularly difficult for high technology companies whose products and technologies were born in the civilian sector. In many cases, fiber optics and optoelectronics companies are unable or unwilling to make the required investments and adjustments.

The Problem of Specifiations and Standards

The question of how to specify fiber optic systems and devices for the military poses what amounts to a paradox, both for the industry and for the government. The problem is that optoelectronic and fiber optic technologies are changing so rapidly that no one can agree on standards. Part of the reluctance to adopt worldwide standards is based on the competitive postures of different national industries. If a company or group of companies could set standards *de facto,* forcing the rest of the industry go along, the originators would enjoy a strong comparative advantage. But equally important, there are some fields in which settling on a particular set of standards is not possible because the technology never stabilizes. Fiber optics has been such a field. and standards officials expect that it will remain in flux for the foreseeable future. Faced with such volatility, DoD has been unable, thus far, to write specifications for fiber optics fast enough to enable it to procure many of the items that it needs.

DoD is confronted with the problem that, by picking a standard, it may lock itself into an obsolete technology or an application that no one in the civilian sector is willing to build at a reasonable cost. This is because the military wants to nail down prescriptive standards[34] in a field that is changing from month to month. The alternative is to adopt performance standards specifying, in a general way. the characteristics that a part or component must meet, and then leave it to industry to figure out the specifics. Performance standards may make more sense for fiber optics technology in the present situation, but they raise problems of enforcement and lack of uniformity among testing measurements. Nevertheless, the rate of technological change in the industry makes prescriptive standards virtually impossible to use.[35]

Industry executives suggest that, in general. the military does not recognize the capabilities of the commercial sector. From the industrial perspective this is due to "the momentum factor" and "cultural

32"A Quest for Excellence: Final Report to the Presdent," by the President's Blue Ribbon Commission on Defense Management, June 1986-Appendix H: "Expanding the Use of Commercial Products and 'Commercial-Style' Acquisition Techniques in Defense Procurement: A Proposed Legal Framework," pp. 95, 103-105.

33This was a principal conclusion of the 1986 Defense Science Board Summer Study: "'Commercial practices used to procure commercial products are sufficiently different from DoD practices (because of history, regulations, and statutes) that the expanded use of commercial products in DoD systems will be inhibited until the differences are reduced". Defense Science Board, Report of the Defense Science Board 1986 Summer Study on Use of Commercial Components in Military Equipment. prepared for the Office of the Under Secretary for Research and Engineering, January 1987, p. vii.

34In general, "prescriptive standards" specify how something is to be made or what it is to be made from. For example, a prescriptive standard might specify the material to be used for the protective jacket of an optical fiber. In contrast. "performance standards" specify only the resulting capability or performance level to be achieved. For example, a performance standard might specify the tensile stress that a jacketed fiber must withstand without damage.

35Some observers argue that DoD has been slow to develop prescriptive standards for fiber optics largely because there was no compelling advantage to adopting fiber optics for many applications. There is evidence to suggest that the Defense Department has moved to develop such standards when no non-fiber alternative was available. Examples would include underwater fiber sensing systems, fiber optic gyros and fiber guided missiles.

conservatism" in the military, two substantial barriers to the large-scale introduction of fiber optics technology. The first idea holds that the Services have committed themselves to older communications and sensing technologies, many of which are not compatible with fiber optic systems. In this view, the military is constrained to maintain an evolutionary approach, working gradually away from systems that already exist in the field. Converting the older systems over to fiber optics would introduce enormous costs that simply cannot be justified in most cases. While fiber optics technologists in the Services are anxious to retrofit ships and other platforms with fiber systems, they encounter a pervasive willingness to get along with older and less capable technology. Indeed, fiber optics technology seems to be advancing rapidly toward the field only in those applications, such as sensors, where there is a significant new capability and no existing alternative.

In addition, there are many new weapons systems in advanced development that have not been designed to take advantage of fiber optics technology. While military planners and technicians at all levels recognize the overall superiority of fiber optics, they must work against a strong and unabating cultural conservatism within the procurement system that tends to mitigate against the introduction of fiber optics. There is little incentive for program managers to seek out a new technology and put it into a weapon system, particularly if the technology is changing rapidly and proposed parts or components are not fully specified. Here, the specification would act as a buffer between the program manager and possible failure or delay associated with a new fiber optic device. Faced with possible career damage and an administrative structure that does not reward the successful introduction of a new technology, the officer in charge is likely to avoid risk and to make do with coaxial cable or a twisted copper pair and associated electronic components.

The lack of industry standards exacerbates this already difficult internal problem. From the DoD perspective there is no way that acquisition managers can make mass scale purchases from civilian industry-and this is where the technology is found-in the absence of performance, design, and testing specifications. From their perspective, such specifications are essential to the acquisition process. So there is an impasse. DoD can acquire optoelectronic technology and products only in the presence of mature specifications (or at the very least, a ruggedized civilian standard). But the technology is developing so rapidly that temporary or firm-generated standards are insufficient to meet DoD's unstated requirements.

There are also circumstances-and these may be more numerous-in which the existence of specifications creates barriers to the introduction of a new technology into the military. This problem can occur, for example, when a large civilian-sector company attempts to install a standard fiber optic telecommunications system for a military base. DoD could procure regular commercial fiber optic products because there are no special requirements. These might be systems already developed to supply businesses or subscriber networks in the civilian sector. But it is very difficult to install such a system on a base, because the company must comply with unnecessary and unreasonable specifications that are costly and unrelated to performance.

In this kind of situation, there are commercial specifications that would meet the needs of the base. In many cases, though, the military people do not pick up on the commercial standards, insisting instead on a great many complex, and sometimes contradictory, specifications that may have little to do with the way in which the telecommunications system is supposed to perform. The key obstacle here is the military specifications that are already written for the procurement of communications systems. They tend to be design-based instead of performance-based, making it difficult to substitute a newer, more capable technology for an older one.[36]

One key missing element in getting civilian technologies into the military is the lack of a commercial standard for ruggedized fiber optic cables and components. If there were a standard, the military would buy substantially more fiber. Without one, commercial technologies must be tested individually. For its part, the industry would be willing to produce to military specifications, but they do not yet exist. Military procurement officials

[36] It is, of course, still possible for DoD to acquire these systems; it is just difficult and costly. The Navy, for example, has installed a fiber optics-based communication system at its weapons testing center at China Lake, California and also plans to use fiber optics in a local area network for the U.S. Naval Academy in Annapolis, Maryland. The fiber in the backbone of this network "will be able to support future 100-megabit/sec data transmission based on the specifications being developed for fiber-distributed data interface networks". *Government Comparer News, Oct.* 24, 1988, p. 37.

reported that they are using as much civilian technology as they can, but that they need standards to promote consistency in design, facilitate procurement, assure inter-operability, ease maintenance, and reduce cost. On the other hand they recognize that the military specifications process for fiber optics should be performance-based and will have to be synchronized with the pace of technological development.[37]

Is Government an Undesirable Customer?

In general, DoD-mandated business procedures bias the system toward large prime contractors. From the military's perspective, these companies minimize the risks associated with performance, cost and scheduling. Large companies generally establish separate divisions to handle the military side of the business, a costly option that would be prohibitive for most smaller companies. In comparison to the civilian economy, the military industrial sector is extremely concentrated. A relative handful of large firms account for a large portion of the annual defense business. These circumstances have led some analysts to conjecture that the single most important capacity of the large primes is the ability to obtain and administer government contracts. The structure of these firms enables them to deal with the sometimes awesome requirements of DoD; it is a structure that simply cannot be emulated by most high technology firms operating in the civilian sector of the economy.

Industry executives and analysts cite several reasons for the difficulties some optoelectronics and fiber optics firms have experienced in selling to DoD, and why others are reluctant to do business with DoD at all.[38] Among these reasons are: (1) DoD cannot guarantee firms that funding will be available for authorized projects; (2) DoD seeks to acquire data rights that would compromise large R&D investments; and (3) to do business with DoD, a firm must fundamentally alter its corporate structure, policies, and overall intentions. Each of these problems is discussed below.

Somewhat ironically, a fiber optics company that licensed its technology from a DoD-funded university program is now unwilling to do business with the government. It is a small, highly profitable company that is limited as to the money and technology it can leverage for any given purpose. Executives must see a payoff down the road or they cannot commit in that area. They are very reluctant to take contracts with DoD because they cannot support the cost of research and gearing up for production unless there is a definite market for the product in question. Accordingly, they avoid military contracts because they are unwilling to assume the risk or even the uncertainties that go with year-to-year funding.

A related problem pertains to the turnover and reliability of government acquisition managers. In the civil sector, a company can develop long-term relationships with buyers in other firms, with a reasonable expectation that they will be around to honor their commitments. With DoD, it is less certain that the people and the program will last, and that they will end up with the final contract authority. Large defense-oriented firms undertake extensive lobbying and specialized political intelligence operations to address this problem. Fiber suppliers may also gear up for a large production run, only to have the government recompete the contract and award it to a firm submitting a lower bid-even if the firm cannot deliver the same product within the specified time.

A second major problem cited by some industry analysts is that government procurement officers and regulations do not recognize the extent to which fiber optics and optoelectronics are technologies driven by R&D. Government agents tend to demand as many data rights as they can get in a given contract, because they are under a fiduciary obligation to protect the interests of the government and get as much for the taxpayers' dollars as possible. Most fiber optics firms are unwilling to share their data because they believe that such data can be used to reveal a core of proprietary product or process information. In some cases, fiber optics companies invest tens of millions of dollars to develop a product or process. The knowledge gained is vital to the company. They know that, sooner or later, govern-

[37] There is, for example, an effort under way in the Navy to harmonize the military's proposed Safenet standards with the commercial FDDI (Fiber Data Distribution Interface) standards, but progress has been slow, since the proposed standards deal with low data rate systems which mayor may not be useful in the future.

[38] On the other hand, many technologists and procurement officers in the Services observe that civilian-sector companies are unwilling to invest their own funds to satisfy the needs of Dod. They point out that many civilian items—including fiber optic products-must be adapted, repackaged. and tested before they arc suitable for military applications.

ment may share the data, perhaps even setting a competitor up in business. They are particularly concerned that military procurement is oriented toward developing multiple sources for any given commodity, product, or process. Standard requirements in government R&D and production contracts may obligate the initial contractor to share information with another firm or firms that DoD chooses to participate in the manufacturing process down the line.

For optoelectronics and fiber optics companies, the problem of protecting proprietary rights comes at the very beginning of a decision to take a government contract or not. Fiber optics companies generally rely on quite extensive patents. That is their bread and butter in the civilian sector. If the military segment of the business is small, or if the company usually does not do military business, executives may eschew government contracts because they are expected to sign away the patent rights. Some have argued for a more versatile mechanism that would enable government agents to write a contract that defines and splits the patent and proprietary rights in a more equitable reamer. This problem was underscored for some fiber makers when DoD contracted with a Japanese competitor, enabling the competitor to continue climbing up the learning curve, even after the courts had ruled that the Japanese firm had infringed patents held by an American company.

A third major impediment between DoD and civilian sector fiber optics firms is the perception on the part of industry executives that they are simply ill-equipped to do business with DoD. This is partly a consequence of the difference in business practices in the military and civilian sectors of the economy, and partly a result of inflexibility on the government's part.[39] Many optoelectronics firms in the United States are quite small and extremely entrepreneurial. They invest heavily in research and are in the business of making and selling products at a profit. To do substantial business with the government, these firms would have to adopt DoD's standard operating procedures. They would have to learn to live with and respond to regulatory, reporting, accounting, and auditing requirements that are largely incompatible with their own systems and make no sense in the context of civilian sector business. From their perspective, managers would have to accept pervasive government oversight and regulation, including the imposition of regulated profits.

To some extent, the Small Business Innovation and Research (SBIR) program helps to alleviate this problem. It has helped some smaller "fiber optics companies enter into the initial stages of development when they might not otherwise have been able to do so. But its critics complain that by the time the product gets to production, the SBIR supports are removed and competition to ensure multiple sources comes back into play. Larger companies accustomed to doing business with DoD can easily eliminate the smaller companies from the competition.

Easing the Barriers

There are some circumstances in which the various barriers, discussed above, are diminished or have been circumvented altogether. The FOG-M missile is an important case of cooperation between government and the civilian sector in the development of military applications for fiber. Fiber optics suppliers developed new techniques for coating fiber to strengthen it. The military provided precision winding that had been developed for the TOW missile, in return receiving the fiber optic data link necessary to target the missile. The key obstacle—both for the companies and for the Army-was the rapidly changing nature of fiber optic technologies. Nevertheless, the missile, which the U.S. Army Missile Command and several fiber optics companies jointly developed, will soon enter production. This path was highly unusual, because an Army laboratory functioned as a kind of prime contractor for the project.

A second area has to do with the highly classified, special access (or so-called "black") military programs. While it is not possible to provide a specific example, DoD fiber optics officials indicated that the best thing that could happen to a program manager would be for his or her program to receive a special access classification. As such, it would be exempted from many of the regulatory, legal, and administrative requirements that usually apply when government is doing business. In addition, the program would be largely exempt from Congressional oversight as well as from inquiries from the press and public interest groups. Some analysts

[39] Several groups within the Services have stated that the procurement process is the leading barrier when DoD attempts to access technology in the civil sector.

believe that, from a security perspective, there is little that goes on in the special access programs that does not go on in less highly classified programs. But because the number of black programs has expanded by a factor of eight in the past decade, these programs now constitute a second developmental track that weapons systems can follow. In this view, the special access classification is a fast track. It indicates that a program has been given high priority by top leadership and is being pushed along outside the system for that reason. If this is true, it is a significant comment on the impediments that exist in doing business with the government.

Appendix E

Case Study: The Advanced Composites Industry

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Figures

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Appendix E

Case Study: The Advanced Composites Industry

NOTE: This study, along with those in Appendixes D and F, is presented in condensed form in chapter 9 of the main report, Holding the Edge

INTRODUCTION

Historians often classify historical eras according to the materials that societies used to build the world around them. The Bronze and Iron Ages gave way to steel and the Industrial Revolution; in the final decades of the twentieth century the world has seen a host of new and powerful engineered materials for which a new age could be named. One such material, polymer matrix composites (PMCs), constructed from two or more separate materials, provides high strength and stiffness and light weight, permitting such remarkable feats as the 'round-the-world flight of the Voyager and such advances in defense as Stealth aircraft.

The range of possible applications for PMCs is broad, including: aircraft/aerospace, automotive, marine, and biomedical applications; and products such as sporting goods, bridges, reciprocating industrial machinery, and containers for storage and transportation of corrosive materials.

Composites generally consist of strong, stiff, but brittle reinforcements (fibers, whiskers, or particulate) bound together by a surrounding material (a plastic, metal, or ceramic) called the matrix (see figure E-l). Composites are named for their matix material; thus, the composites referred to in this appendix are polymer matrix composites. The polymer matrix is an organic material, usually a thermosetting epoxy that, once formed, cannot be melted and reshaped. It is this matrix material that binds and provides toughness for the brittle fibers.

PMCs are classified according to their strength and stiffness. They can be divided into two categories: reinforced plastics and advanced composites. Reinforced plastics (or engineered plastics) have been used in large volume in corrugated sheet and pipe and in the auto and recreational boat industries. Reinforced plastics are formed using inexpensive, lower-performance glass fibers. They were used to make the composite body of the GM Fiero and the Chevrolet Corvette. These fibers may be chopped into short lengths and oriented randomly in the plastic matrix.

Fibers for advanced composites are made of materials such as boron, aramid, and carbon.[2] Advanced composites comprise only about 2 percent of the total markets for PMCs, selling primarily in the aircraft/aerospace market. Although relatively expensive per pound. they are lightweight and possess excellent strength and stiffness (see figure E-2); according to one industry spokesman, they are "pound for pound, the strongest material known." Advanced composites are comprised of continuous fibers aligned very carefully within the polymer matrix. Sixty-five to seventy percent of advanced composite structures produced worldwide are reinforced with high-strength carbon fiber.

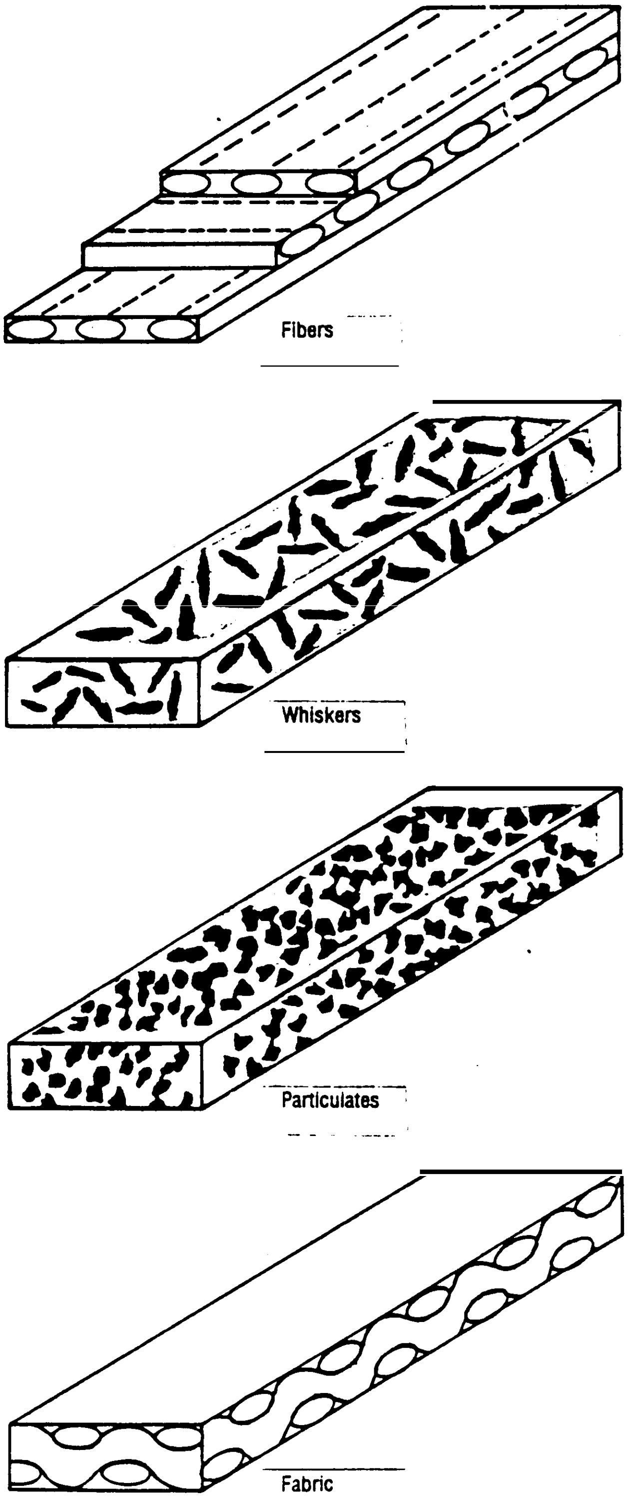
Used in commercial aircraft, advanced PMCs can currently offer commercial airline companies a savings in fuel of $70 to $100 per pound over the life of an aircraft. Used in military fighter and attack aircraft, advanced PMCs are enabling technologies for high speed and maneuverability, and can be modified for the reduction of radar signatures. This appendix will focus on advanced composites made of carbon and epoxy used in the aircraft and defense aerospace industries.

Advanced PMCs are highly specialized materials; they are not commodity materials, like metals. In contrast to production of metal parts, where material properties are fixed, PMCs used for given applications are tailored to them at the start of the design process. The material cost, and the cost of the process technology used to make an advanced

[1] This appendix draws on U.S. Congress, Office of Technology Assessment. *Advanced Materials by Design: New Structural Materials Technologies*, OTA-E351 (Springfield, VA: National Technical Information Service, June 1988).

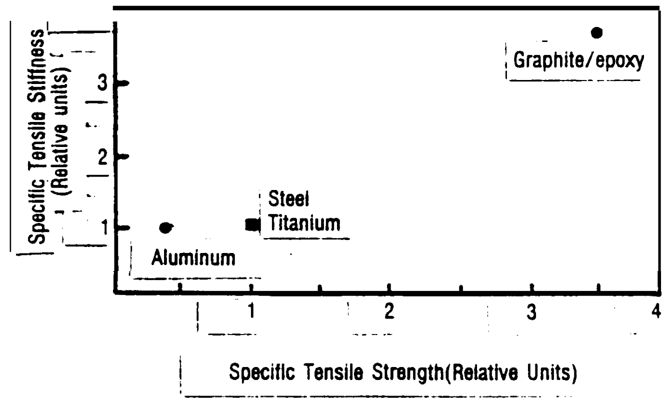
[2] The major type of graphite fiber used comes from polyacrylonitrile (PAN precursor). It is of high strength, but expensive. Many firms, particularly in Japan. have attempted with little success to produce a cheaper high-strength graphite fiber from a pitch precursor. Several Japanese companies (and certain U.S. companies) possess a noteworthy capacity for producing of pitch precursor; but the derivative fibers are not very strong.

Figure E-1—Composite Reinforcement Types



SOURCE: Carl Zweben, General Electric Co.

Figure E-2—Specific Strength and Stiffness of Graphite/epoxy Composites and Selected Metals[a,b]



SOURCE: Carl Zweben, General Electric Co.

composite, depend entirely on the end use and the market. For example, E-glass fiber used in certain automotive applications costs $0.80 per pound and can be formed by processes that produce pounds per minute. Graphite fibers used in aircraft cost $25 to $50 per pound, and are formed by processes that produce pounds per hour.

Processes for making military and commercial aircraft structures from advanced composites are extremely labor-intensive. New, more automated processes are under development at a number of airframe manufacturers. (Table E-1 describes the current range of part-forming techniques in use and under study.) Although PMCs can be competitive with certain metal structures that require complex machining or large numbers of fasteners, more economical processing methods are a key to increasing market interest in advanced PMCs.

This case study is structured to explore three questions: First are the PMC industry and its associated industries eroding in the United States? Second, do military applications of polymer matrix composite technology diverge significantly from their counterparts in the civilian sector of the economy? And third, what are the principal technical and institutional barriers that inhibit civilian access to military PMC technology and vice versa? Each of these questions is refined further and addressed in a separate section below.

Table E-1—Polymer Matrix Composites Part Forming Techniques

Technique	Characteristics	Examples
Compression Molding	Fast, fexible, 1"–2" fiber	Sheet molding compound, auto body panel
Injection Molding or Extrusion	Fast, high volume very short fibers, thermoplastics, thermosets	Gears, fan blades
Resin Transfer Molding	Fast, complex parts, good control of fiber mat orientation	Auto structural panels
Prepreg tape layup	Slow, labor-intensive, expensive, reliable, automation potential	
Pultrusion	Continuous fiber, constant cross-section parts	I-beams, columns
Filament Winding	Moderate speed, continuous fiber, hollow parts, complex geometries	Aircraft fuselage, pipes, drive shafts
Thermal forming*	Reinforced thermoplastic matrices; fast, easy repair, joining	Possibly all of the above

*Future technology

SOURCE: Office of Technology Assessment.

GLOBAL MARKETS AND THE HEALTH OF THE INDUSTRY

Global Nature of Advanced PMC Technology

Although the U.S. Department of Defense drives the development of composite materials technology (historically through its R&D funding and now through its aircraft/aerospace purchases), advanced composites are a global business conducted by companies with broad international interests. Large chemical and petroleum companies are suppliers of fibers and composite parts around the globe; these suppliers are multinationals of varied national origin. BASF, a West German multinational and one of the largest chemical companies in the world, is a supplier of fibers, "prepregs" and fabricated parts. Shell (the Netherlands) and DuPont are also located throughout the world. It has become difficult to determine what is a "U.S. firm."

The PMC industry has been worldwide from its inception. In other technologies, the typical economic scenario has become the successful application and marketing by Japan (or other global economic competitor) of a high technology product invented in the United States. Advanced PMC technology is an exception, in that carbon fiber technology was originally developed in Great Britain and Japan, as well as in the United States by Union Carbide. U.S. firms followed the development of this technology as it occurred, and developed advanced PMC technology for aerospace applications. Since then, the United States has provided the largest market, with U.S. firms having a dominant role.

Joint Ventures and Licensing Agreements

PMC technology spread globally as the Japanese, the Europeans, and the Americans participated in licensing, joint ventures, and acquisitions-a process that continues today. Japan has two main suppliers of carbon fiber, Toray and Toho, each with business and technology ties to European and U.S. companies. Historically, Japanese carbon fiber technology was licensed to U.S. firms to build U.S. production capacity: Union Carbide (facilities now owned by Amoco) and Celanese (facilities now owned by Hoechst). These license agreements are due to expire soon, and Japanese fiber suppliers can be expected to enter U.S. markets. Hercules, another major U.S. carbon fiber supplier, obtained carbon fiber technology from Courtaulds in England.

Roughly 68 percent of the U.S. carbon fiber market is supplied by U.S.-based companies, as indicated in table E-2. The balance of the U.S. market is supplied by Japanese, European, or other firms. Japanese companies are building a strong position worldwide in PMC technology.

U.S. advanced PMC carbon fiber suppliers indicate that their only success in penetrating Japanese markets has been in supplying fiber for fabricating components being built in Japan for American programs. The following discussion of offsets will show that these programs are a significant force both in the development of foreign markets and the transfer of technology to foreign firms. These

Table E-2—World Market Shares In Carbon Fiber for PNCs

Supplier	Market Share, percent: U.S.	Japan	Europe	Taiwan	Other
United States	68	5	9	3	4
Japan	21	86	68*	81	44
Europe**	8	2	21	10	45
Other	3	7	2	6	7
	100	100	100	100	100

*Via Japan and Japanese—European Joint Venture Facilities
**Non-Japanese
SOURCE: James N. Burns, "Relationship Between Military and Civilian PMC's," presentation made at an OTA workshop, September 23, 1988.

suppliers feel that it will be very difficult for the United States to participate in Japanese markets.

The Japanese also have a large share of European markets, either by shipping in fiber from Japan or through Japanese joint ventures (there are two in Europe). In Taiwan, the Japanese currently have a very large market share. Although U.S. industry leaders expect Japanese imports to decline as the Taiwanese build their own facilities, Japanese influence will remain high-since many of them will be Japanese-owned.

Offsets

Foreign production of U.S. aircraft components is growing. Manufacturing of composites for commercial aircraft has moved offshore in many cases. As table E-3 shows, a significant number of foreign companies are fabricating parts for U.S. aircraft manufacturers. This is largely the result of economic offsets that are used to secure sales of aircraft by offering portions of the aircraft fabrication to companies from the buying nation. Aircraft sales are of clear economic benefit to the United States in terms of the balance of trade, but the offset agreements associated with the sales enhance technology development and potential future economic competitiveness of foreign-owned advanced composites businesses, possibly at the expense of U.S.-owned firms.

Industry representatives generally believe that the transfer of technology to other firms is necessary and in the best interests of both aircraft manufacturers and materials supplier companies. Access to U.S. technology is provided to sell aircraft and thereby maintain the current competitiveness of the U.S. aircraft industry in international markets. On the other hand, some industry executives privately state that they would rather not use offsets, since they may generate unwanted competition later.

Airbus Industrie (a consortium of European companies) is now offsetting parts to the United States in order to encourage sales to this country. Some PMC industry representatives speculate that Airbus may be concerned that one day poilitical pressure will be applied to U.S. airline companies to avoid buying foreign-made aircraft. The more U. S.-manufactured components there are in the aircraft, the more Airbus will be able to resist that pressure. The dollar exchange rate may also make it more economical to fabricate parts in, for example, Tennessee, than in Europe today.

Besides securing aircraft sales, airframe companies use offsets to force their suppliers to bear some of the burden of inventory and work-in-progress costs of non-military programs for which there are no progress payments.

Foreign Dependence

A clause contained in the DoD Appropriations Act passed in December 1987, required carbon fiber producers to secure at least 50 percent of their raw materials (PAN precursor) from U.S. sources by 1992.[3] The legislation (H.R. 395, Section 8088) is aimed at assuring the availability of U.S. sources of defense-related carbon fibers, which are used principally to build advanced structural components for military fighters and attack aircraft. The requirement specifically applies to carbon fiber manufactured from polyacrylonitrile. Four major U.S.-based carbon fiber producers are affected by the law: Hercules (by far the major supplier of fiber made from this precursor), Amoco, BASF (West Germany), and Courtaulds-Grafil (United Kingdom).

[3] In 1985, the Assistant Secretary for Defense Acquisition and Logistics issued a statement expressing concern that there be some domestic source of *production* of PAN fiber precursor. This ultimately led to the legislation described in the text.

Table E-3—Foreign vs. U.S. Production of U.S. Aircraft Components

	Aircraft				
Supplier	767	757	737	F-16	MD-11
Foreign					
Aeritalia, Italy	X	X			X
Casa, Spain	X	X			X
Saab, Sweden	X	X	X		X
Westland, UK					X
Kawasaki, Japan	X	X	X		X
Mitsubishi, Japan					X
Fuji, Japan	X	X	X		X
Fokker, Netherlands				X	
IAI, Israel				X	
Cyclone Aviation, Israel				X	
Korean Air, Korea					X
Fleet, Canada	X				X
Embraer, Brazil					X
Short Brothers, Ireland	X	X	X		
United States					
Heath Tecna			X		X
Rohr Industries			X		X
Rockwell	X				
Grumman	X	X			
Cessna	X	X	X		

SOURCE: James N. Burns, "Relationship Between Military and Civilian PMC's" presentation made at an OTA workshop, September 23,1988.

Until 1987 there were no U.S.-based PAN precursor suppliers to the military. Hercules, the major supplier of carbon fiber for military applications, buys precursor from Japanese suppliers. Industry experts believe that DoD concern for domestic supply on this issue is tied as strongly to breaking up a single-source situation for carbon fiber supply as it is to ensuring that the one production link taking place entirely abroad be brought into the United States. Amoco produced PAN precursor in the United States but was not qualified for military programs. Since 1985 three new plants have been built in the United States, and Amoco's fiber has been qualified for some military aircraft.

Foreign-owned firms may have some difficulty qualifying their products with the DoD, and greater difficulty establishing classified facilities. Some industry analysts cite greater difficulty accessing programs at foreign-owned facilities even after qualification is achieved. However, many companies with U.S. facilities are generally treated as U.S. companies regardless of ownership, once the initial hurdles of classification have been overcome.

Industry Structure

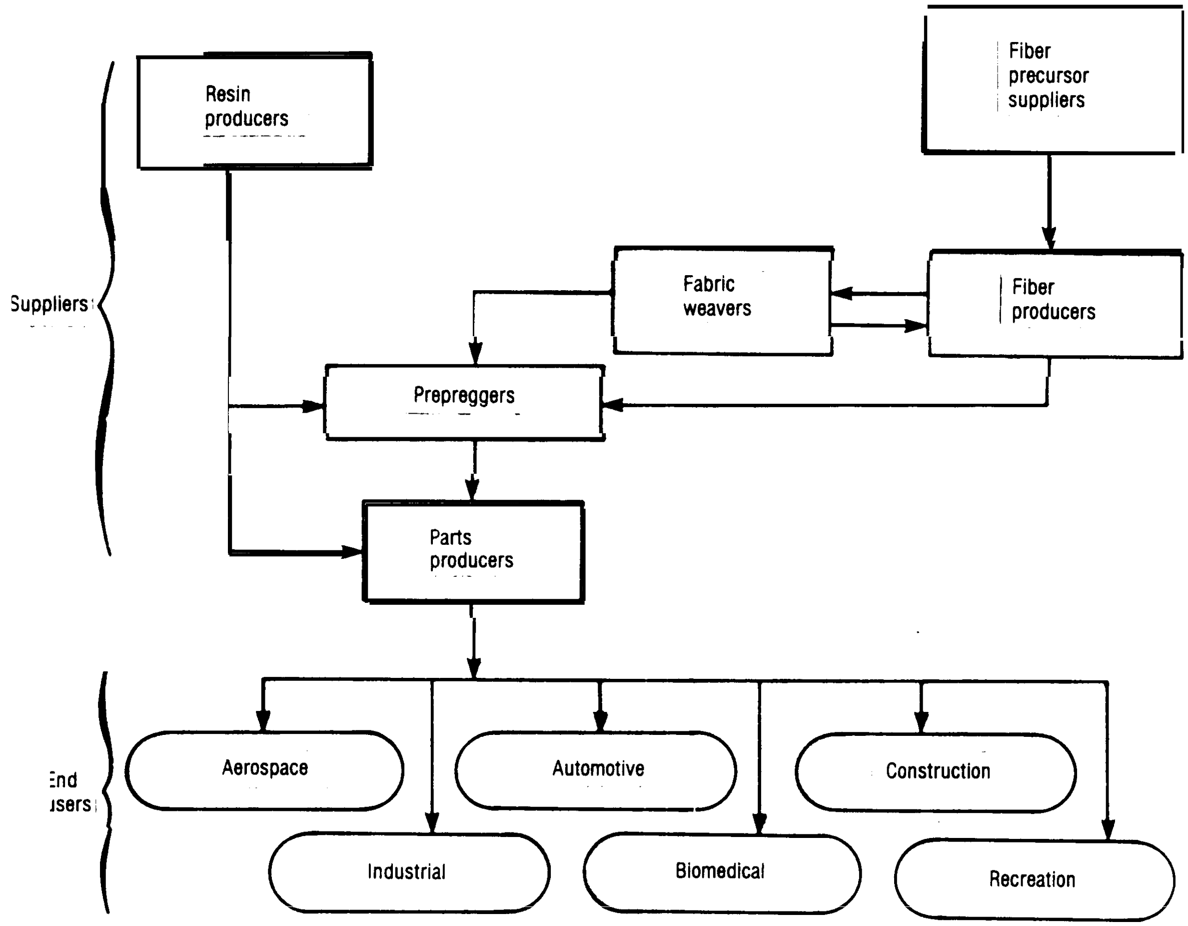
It is difficult to separate foreign and domestic interests in any review of the U.S. advanced composites industry. PMC suppliers are extremely intertwined, whether one considers corporate vertical integration, or integration with major markets, airframe producers, and multinational markets.

In order to grasp the industry's structure, one must understand the process by which PMCs are made. Advanced composites are formed in a series of stages, beginning with raw materials and ending with finished parts sold to (or made by) such end users as the airframe manufacture. Raw materials include: carbon fiber precursor, the carbon fiber made from the precursor. and the epoxy resins forming the matrix. These are used to form prepregs (impregnated woven fabric, impregnated tape, or individual fiber strands coated with epoxy). These prepregs are then formed into shapes, and cured and trimmed to become final parts (see figure E-3 for a schematic of PMC production). For purposes of the following discussion on the industry structure, it is necessary to define three distinct production phases: 1) raw materials, 2) prepregs and shapes, 3) components for end use.

Companies supplying raw materials are generally the large oil companies (Amoco, British Petroleum, Shell) and large chemical companies (BASF, Ciba-Geigy, DuPont, Hercules). There are some compa-

[4]Narmco and Celion Carbon Fiber, owned by BASF of West German y; Hitco and Standard Oil Advanced Materials, owned by British Petroleum; Fiberite, owned by ICI of the United Kingdom; and Heath Tecna Aerospace, owned by Ciba-Geigy of Switzerland.

Figure E-3--PMC Industry Structure



SOURCE: Office of Technology Assessment, 1990.

nies that are mainly fiber suppliers (Hercules, Courtaulds-Grafil, Toho Rayon, Toray), and one company that is mainly a prepreg and composite shape supplier (Hexcel). Of the 26 companies in the PMC trade association, SACMA[5], 12 are U. S.-owned, 9 are owned by Europeans, and 5 are Japanese-owned.

Corporate Integration

Most of the companies listed above are attempting to integrate vertically (the present degree of industry integration is shown in table E-4). Raw materials suppliers are moving downstream into prepregs and shaping, into more value-added products. The value added in advanced PMC structures, as opposed to commodity fibers, is large: carbon fiber is priced (near cost) at $20 to $25 per pound, prepreg sells for $40 to $55 per pound, but the final structure cost is $250 to $600 per pound.

Airframers, which had relied on shapers and prepreggers for part forming have been moving the making of parts in-house, buying only the raw materials. One company (Hercules) is integrating horizontally, expanding its production to composites other than aircraft that have military applications. Companies throughout the industry buy and sell to each other and compete with each other for business from military prime contractors.

The industry structure plays a very important role in discussions of global movements of technology, civilian versus military needs, and policy objectives.

[5]Suppliers of Advanced Composite Materials Association.

Table E4-Participation of Key Firms in the U.S. Advanced Composites Industry, 1986

Company	Advanced material products[a] Base resins	Fibers	Prepregs	Shapes
American Cyanamid			X	
Amoco Performance Products	X	X	m	m
Avco		m	m	X
BASF		X	X	m
Boeing				X
Ciba-Geigy	X		m	
Dow Chemical	X			
DuPont	X	X	m	m
Ferro			X	
Grumman				X
Hercules		X	X	X
Hexcel			X	m
HITCO		m	X	X
Hysol Grafil		m	m	
ICI	X			
ICI Fiberite			X	
Lockheed				X
LTV				X
McDonnell Douglas				X
Northrop				X
Phillips 66	X		m	m
Rohr Industries			X	
Shell Chemical	X			
United Technologies				X

[a]X = major product; m = minor product.
SOURCE: Strategic Analysis, Inc., "Strategies of Suppliers and Users of Advanced Materials," a contractor report prepared for OTA, Mar. 24, 1987.

For purposes of this chapter, two stages of integration are defined: materials suppliers (including the intermediate suppliers, the prepreggers), and end users. Fibers, and to a lesser extent prepregs, are sold more as commodity materials, in a standardized fashion; end users and part shapers develop very individually tailored structures for each application.[6] Because of this dichotomy, fiber suppliers' style of business differs markedly, from that of end users. The following discussion of global markets contrasts the market situation of the raw material suppliers with that of the major end users (U.S. airframers and Far East sporting goods manufacturers).

The Carbon Fiber Market

World demand for carbon fiber has grown from a little over 7 million pounds in 1987 to over 8 million pounds in 1988 (as indicated in table E-5) and is predicted to grow to 20 million pounds by 1995. In the United States, the market is a little over 3.5 million pounds, predicted to grow to about 12 million pounds by 1995. About 65 percent of the U.S. carbon fiber market is in aerospace (both military and commercial *aircraft)*, and the market is forecast to remain over 65 percent aerospace during the 1990s. Over half of the U.S. aerospace market for fiber is military; 25-30 percent is commercial. Military applications are projected to grow by as much as 22 percent annually in the next few years.[7]

The U.S. aerospace market is a primary target for foreign companies producing carbon fiber composites because it is the largest, most advanced, and most attractive market (see table E-5) in terms of sales and profitability. The second largest market is the Far East, where carbon fiber products are used in sporting goods (tennis rackets, golf clubs, and the like). The world sporting goods market for carbon fiber is likely to grow at 5 to 10 percent per year.

Based on the assumption that the military market will exhibit the growth projected above, the U.S. market on the whole is likely to grow faster than the world market. Although the number of U.S. military aircraft being built is declining, composites are replacing much of the metal (aluminum) on air-

[6]There arc a large number of fibers developed to meet different needs, but fibers in general are a commodity product, and will become more so as the technology matures.

[7]From the presentation of James Burns, Hercules, Inc., at the OTA workshop on polymer composite% Sept. 23, 1988, Wash., DC.

Table E-5—World Market for Carbon Fiber, 1888 (pounds, millions)

	Application			
	Aerospace	Industrial	sports	Total
United States	2.44	.90	.35	3.69
Europe	.94	.22	.38	1.54
Far East	.10	.10	2.43	2.63
Other	.10	.15	.20	.45
	3.58	1.37	3.36	8.31

SOURCE: James N. Burns, "Relationship Between Military and Civilian PMC's" prsentation made at an OTA workshop, September 23, 1988.

planes. An older plane, the F-16, has 260 pounds of composite per aircraft; the V-22, which is in the full-scale development stage, has 6,500 pounds (flyaway weight) per aircraft. This represents a tremendous growth in the use of composites. The U.S. market is projected to grow rapidly in the near future, due partly to this continuing replacement of aluminum with advanced PMCs. However, sometime in the mid-1990s this large growth due to substitution should level off, as advanced PMCs move into a high percentage of primary and secondary structures.

Given the large budget deficits with which the Congress must contend, the reluctance of the President to raise taxes, and the current perception of a diminished Soviet threat, the market projections for growth of PMCs in military aircraft may be unrealistic. Advanced composite suppliers are rightly looking toward other markets (commercial aircraft, industrial applications) to support the large production capacity developed in response to new military programs.

Although the major use of advanced composites is in the aircraft industry, carbon fiber materials also play a major role in strategic missile hardware and are forecast to move into weapon systems for all branches of the military. Large amounts of composites would be used in the heavy-lift launch vehicles required to put large payloads into space during the 1990s. A potentially large volume industrial market segment (primarily autos) is forecast for the mid-to-late 1990s.

Overcapacity of Carbon Fiber

At 16 million pounds, worldwide nameplate carbon fiber capacity is twice the current market volume.[8] Japan, with 6.9 million pounds, and the United States, with 5.8 million, have about equal capacity. Japanese companies manufacture carbon fiber precursor which is then sold to U.S.-based carbon fiber suppliers, mainly Hercules and BASF/ Celion. Hercules, in turn is the major supplier of fiber for military programs. At present. very little Japanese carbon fiber is supplied directly to U.S. military programs. Most of Japanese carbon fiber goes into U.S. commercial aircraft Japanese programs, and the Far East sporting goods market.

U.S.-based industry is continuing to add carbon fiber capacity (about one million pounds in 1988). This fact indicates that, worldwide, there is and will continue to be a great deal of excess capacity. However, while the United States has a large fiber overcapacity compared to domestic market requirements, industry opinion is that most of the worldwide excess capacity is in Japan rather than the United States. Although excessive, the U.S. carbon fiber capacity (5.8 million pounds) is still better matched to the U.S. market size (3.69 million pounds).

Worldwide prices are low mainly due to excess capacity in the Far East; Japanese-made fiber is sold to Taiwan at a loss. While the Far East sporting - goods market is as large as the U.S. aerospace market, its low profitability makes it far less attractive to fiber suppliers than the U.S. aircraft market. It is not known why the Japanese fiber

[8]Nameplate refers t. an estimate of capacity, rather than actual capacity. Carbon fiber is sold in bunches, called tows, of 3000, 6000, or 12,000 fibers per tow, Mall carbon fibers were sold in tows of 12,000 fibers (the predominant carbon fiber product sold), then nameplate capacity would be equivalent to actual capacity. Real capacity is approximately two-thirds of nameplate capacity.

suppliers are building up such excess capacity. These companies may be overoptimistic about the growth rates of their larger present markets; they may expect to enter U.S. aircraft markets as licensing agreements expire, or to be suppliers to a Japanese aircraft industry as it evolves. The companies may also be gaining production experience in an effort to lower production costs to the point where they can supply these materials in quantity to automobile manufacturers.

There are two possible reasons behind the present U.S. overcapacity. First, the U.S. fiber suppliers misread the military fiber market, adding excess capacity to respond to a military demand that never appeared. While profitable, the military market does not generate high volumes. In continuing to bring new capacity on-line, carbon fiber suppliers exhibit optimism about future use of carbon fiber in civilian and military aircraft. Since the United States is undergoing a budget squeeze, it may be that fiber suppliers are again misreading the market when adding new plant capacity. However, market projections for the carbon fiber market as a whole (including both civilian and military aircraft as well as sporting goods) predict very healthy growth over the next decade: 12 percent annually.[9] Consequently, many companies are continuing to enter the market place.

Second, overcapacity may be endemic: large military projects (like the Titan 4) encourage overcapacity by enticing too many materials suppliers to gear up production. Since the main market is military, and market forces are not allowed to work as they would in the private sector, it may be that overcapacity (which keeps material costs to the primes and the military low) is a direct result of the way that the government and military aircraft prime contractors have structured the market.[10]

Material suppliers feel that overcapacity has created such unprofitability that it is unhealthy for the industry as a whole. Airframe companies, on the other hand, benefit from chronic fiber overcapacity. Assuming that Japanese overcapacity is not affected by U.S. military needs, worldwide overcapacity is not entirely due to the military market structure. Carbon fiber also goes into the sporting goods market at very low prices-at a loss in most cases. Companies manufacturing tennis rackets are making a profit, while companies supplying material to the tennis racket manufacturers are merely dumping excess capacity .11

Intermediate Suppliers

Some material suppliers also see an excess of U.S. part fabrication capacity, with as much as 50 percent underutilization. Airframe manufacturers, though, see a shortage of qualified, economical parts fabricators. Even in the teeth of this oversupply, some airframers see it as less expensive to tool up to fabricate parts in-house than to pay the overhead required to use some of the existing parts fabrication capacity.

End Users of Advanced PMCs

While the U.S. PMC industry is healthy, it is concentrated in the defense/aerospace sector. On the strength of its military aircraft and aerospace programs in advanced PMCs, the United States leads the world in developing and using advanced PMC technology. But according to industry representatives, foreign commercial end users outside the aerospace industry are more active in experimenting with these new materials than are their U.S. counterparts. For example, Western Europe is considered to lead the world in composite medical devices.[12] The European Community (EC) also has several efforts underway to commercialize advanced PMCs in automobiles; outside of the EC in Europe, the EUREKA Carmat 2000 program proposes to spend $60 million through 1990 to develop advanced PMC automobile structures.

Looking at the aircraft industry, Western European commercial aircraft manufacturers use more composites per aircraft (specifically, the A320) than U.S. commercial airframersdo. France is by far the dominant force in advanced PMCs in Western Europe, with sales greater than all other European countries combined. West Germany, the United Kingdom, and Italy make up most of the balance.

[9] From the presentation of James Burns, Hercules, Inc., op. cit., footnote 7.

[10] The structure of the government market in the absence of private sector market forces is discussed further at the end of the appendix, in the section on teaming and second source requirements.

[11] A carbon fiber production facility needs to be operated near capacity. A fiber line operates at very high temperature, and once the line is up and stabilized, it needs to be run continuously.

[12] The regulatory environment controlling the use of new materials in the human body is currently less restricted in Europe than the U.S.

Airbus is the single largest consumer of advanced PMCs in Western Europe.

In the past few years, the increase in participation of Western European-owned companies in the U.S. advanced PMC market has been dramatic. This has occurred mainly in the form of acquisitions of U.S.-owned companies. Industry analysts indicate that U.S. carbon fiber facilities have been sold due to corporate "impatience" resulting from the need to report favorable quarterly earnings. In general, foreign corporations tend to be more patient; despite excess worldwide capacity and profitability problems, for example, the Japanese have not sold any carbon fiber facilities. Foreign companies want to participate in the U.S. market for carbon fiber, prepregs, and parts. Materials suppliers feel that the foreign interest in U.S. firms reflects a desire to enter the U.S. aerospace market and share the technology leadership that participants enjoy.

Although Japan is the largest manufacturer of carbon fiber in the world, it has been only a minor participant to date in the advanced composites business. Japanese companies have been limited by licensing agreements from participating directly in the U.S. market. Japan also does not have a domestic aircraft industry to which companies can sell advanced PMCs, although it is trying to establish one as it did with automobiles.

Foreign-Owned Firms

The U.S. PMC industry is healthy because U.S. aircraft industries are healthy. The largest, most profitable, and fastest growing market for PMCs in the world is U.S. aircraft (mostly military aircraft). U.S. overcapacity of carbon fibers exists in large part because of PMC market analyze (and general optimism) projecting strong growth in U.S. PMC production for *aircraft-civilian as well as military.*

Players in the PMC structure market must be U.S.-located for two reasons: 1) coordination of production and technology development with co-suppliers and customers, and 2) DoD regulations and Congressional legislation on domestic sourcing. However, neither of these factors requires that companies be U.S.-owned. New developments by foreign companies in PMC technology flow naturally and swiftly toward the U.S. aircraft market, end users want the latest technology regardless of source, and suppliers will go where the market is. No decapitalization is occurring; in fact, the opposite holds since foreign firms are putting long-term investment into new and acquired U.S.-based facilities. Production of fibers and resins need not even be U.S.-located, since these are commodity products: standardized, relatively high volume, and low value--added.

Like U.S.-owned plants, foreign-owned plants employ U.S. skilled and unskilled labor, and much of the research is conducted in the United States, with the attendant high-paying positions. Foreign-owned companies are as willing as U.S.-owned companies are to comply with Congressional legislation, DoD and FAA regulations, DoD policy goals, and military program requirements. Very telling is the fact that U.S.-owned PMC firms do not have the complaints against foreign-owned firms commonly heard in other industries, and industry representatives are quite comfortable with the international orientation of their industry.

What would be the possible reactions of foreign-owned companies if the U.S. aircraft industry were to become "unhealthy" in a relative sense? Although the United States is still the dominant aircraft supplier worldwide, Airbus is making significant inroads on U.S. market share. 13 Japan's pursuit of a commercial aircraft industry through offsets and joint venture arrangements with U.S. and European airframers will lead to a formidable commercial aircraft industry in Japan at some point however distant that might be. If Airbus Industrie, other European airframers, or Japanese aircraft manufacturers capture enough of the world market share for aircraft, it could profoundly affect the U.S. PMC industry.

If these trends hurt the domestic aviation industry, U.S. airframers might feel it necessary to engage in less PMC development and use as profits fall. Alternatively, they may increase use of PMCs, seeing this as away to gain a competitive advantage, particularly if rising fuel costs are a factor. Airframers might choose to move significant levels of production abroad if planes could be assembled

[13] Airbus Saks still represent a small fraction of the North American fleet, but the consortium is expanding its North American presence rapidly: 70 percent of all Airbus sales to North America over the past ten years occurred in 1987-88 and, if all options arc exercised, there will be more than 450 Airbus aircraft in service on the *Continent by* 199S. Total Airbus sales in North America for 1988 were $20 billion for 348 aircraft, according to "Canadian Orders Strengthen Airbus' Role in North America", *Aviation Week and Space Technology, Aug. 8,1988, p.68.*

more cheaply offshore, thus hurting U.S.-based PMC suppliers.

PMC manufacturers might follow the airframers by moving fiber, resin, or prepregging facilities from the United States to the countries with the largest pool of end users. This sort of movement would be attractive to both U. S.- and foreign-owned firms of large size and with currently established international interests. PMC manufacturers maintainingg the majority of their facilities in the United States (most likely U.S.-owned firms of small size) would have to choose one of several options: 1) bank on other potentially sizable markets (such as automotive applications); 2) become entirely military in orientation, while integrating further up- or down-stream; or 3) restructure (shrink) to rely on niche markets in biomedical, sporting goods, or industrial applications.

If the United States were to depend entirely on foreign-owned firms at a point when U.S. aircraft manufacturers were seriously losing market share, and if these foreign-owned firms moved offshore at this point, the U.S. military could find itself in a bind: Without the latest in PMC technology, the military would be forced to choose between buying foreign-developed aircraft or propping up a domestic aircraft industry, spending money now spent by commercial industry on PMC development, or buying significant types and amounts of strategic raw materials from foreign-based suppliers. For good reason, no industry or DoD representative has expressed so pessimistic a view, since the United States currently has the world's strongest aircraft industry—whether one considers innovations in PMC technology, new product technologies, or the use of PMCs in military aircraft. The point, though, is that Japanese and West European aircraft communities are not standing still; DoD will have to have face this issue of dependence on foreign suppliers, whether in 10 or 30 years.

CONVERGENCE/DIVERGENCE OF CIVILIAN AND MILITARY TECHNOLOGY

Military and civilian applications of advanced PMC technology both converge and diverge. It is difficult to know how much of the divergence is due to the nature of the military environments in which the technology must function, and how much to the regulations, government standards, military specifications, and contracting procedures that have accumulated over time. Most of this section considers technical and economic issues of convergence and divergence, with the remainder devoted to "artificially induced" differences between the military and commercial advanced PMC sectors.

Although military and civilian markets have different technical and cost criteria for selecting materials and process technology, both kinds of applications aim to meet the necessary performance criteria at the minimum cost. As will be seen, the particular application, not its military or commercial purchaser, is the strongest determinant of the material used. Convergence and divergence occur simultaneously in different aspects of the PMC industry and its markets.

Cost vs. Performance

Various segments of civilian and military markets place different emphases on performance and cost. In commercial aerospace, military non-aerospace, automotive, and construction markets, for instance, acquisition costs and operating expenses are the major purchase criteria, with a progressively lower premium placed on high material performance. In military aerospace, biomedical, and space markets, on the other hand, functional capabilities and performance characteristics are the primary purchase criteria.

The sales potential of advanced composites is greatest in the automobile and commercial aircraft markets. Construction materials are used in high volume, but must have a low cost; biomedical materials can have high allowable costs, but are used in very low volume.

cost

In the automotive and industrial markets, the major factor determining the value of advanced composites is the reduction of production costs, although in some cases, a performance premium may be passed on to those car buyers interested in high performance or fuel economy.

In commercial aircraft, composites have to earn their way in economic terms. Commercial airframers base the choice of advanced PMCs on the purchase criteria of the customers, the commercial airlines. Airlines weigh the balance of initial cost with the cost over the lifetime of the aircraft, including maintenance and fuel cost.

At a time of rising fuel costs, a composite empennage may have been necessary for U.S. aircraft manufacturers to compete in the commercial aircraft market. Today's relatively "stable" energy costs have minimized the value of weight savings for the present.. In 1978, one airframe manufacturer estimated that at a jet fuel cost of $2 per gallon a single pound of aircraft weight saved was worth approximately $300; today, fuel costs $.80 per gallon and weight savings is valued at roughly $70 per pound. (This measure of the importance of fuel costs is generally valid for new aircraft designs, but would not be a determining factor in changing established production of aircraft.)

Competing vs. Enabling Materials

Despite the ability of advanced composites to provide the same strength and integrity with fewer pounds as high-strength aluminum alloys, other economic benefits are needed to justify their much higher costs. Polymer composites in these markets are just one of a number of competing materials.

Although military and commercial functional requirements (low weight, high strength for primary structures, lower strength for secondary and nonstructural parts) converge, it is their stringent mission requirements that drive the use of advanced composites in military aircraft. For space applications and fighter aircraft, advanced PMCs are more than just one of many competing materials; they can be the enabling technology for mission requirements because of their high stiffness and strength-to-weight ratio.

The use of lower-cost materials (such as glass-reinforced composites) in general means more weight and lower performance (lower stiffness) in the traditional aerospace sense. Industry experts feel that to get the edge on the battlefield, weapons systems must weigh less. That is why composites, particularly carbon-reinforced composites, were attractive at their inception. Lower costs are needed in the military aerospace sector, but performance remains the major driver.

Processing

Seventy to eighty percent of the cost of a finished advanced PMC part is due to fabrication. As discussed previously, developing production technology to reduce fabrication costs is critical to commercial industrial, automotive, or marine applications. Several composite part-forming technologies are more advanced in the industrial/automotive world than in military applications. Table E-6 indicates the status of various low-cost composite material technologies in terms of meeting military application requirements.

For military and commercial aircraft, the structures made from composites (e.g., wings, fuselage, and empennage) are similarly complex to fabricate. The basic method of production of aircraft parts is also similar: coating of continuous fibers with resin, careful placement of fibers, and application of heat and pressure to form the structure. Many developments have wide applicability across both the civilian and military arenas. There is synergism between military and commercial aircraft produc-

Table E-6—Status of Emerging Low-Cost Composite Material Technologies

Process	Application/Potential Benefit	Development Status: New Techn.	Developing Techn.	Production Ready
Filament Winding (Thermosets)	Near cylindrical parts			●
	Complex shaped parts		●	
Filament Winding (Thermoplastics)	Near cylindrical parts		●	
Resin Transfer Molding	Complex thermoset parts with continuous fibers		●	
Compression Molding	Complex thermoset and thermoplastic parts with chopped fibers			●
Pultrusion (Thermosets)	Constant cross-section parts		●	
Pultrusion (Thermoplastics)	Constant cross section parts		●	
Injection Molding	High production rate process for thermosets		●	
Reaction Injection Molding	High production rate and quick cure of thermoplastics	●		
Thermal Forming	Complex thermoplastic parts with continuous fibers	●		
Superplastic Forming Of Thermoplastics	Complex parts		●	

SOURCE: McDonnell Douglas Astronautics Company, Missile and Defense Electronics Division.

tion in resins and fibers, the way materials are stitched together, and the way they are used.

However, military applications have requirements that may force a modification of the fabrication process. For example, a process called pultrusion is typically used in producing beams for industrial applications. Military applications need superior load-carrying properties, so that for military applications pultrusion must be modified to impart different properties to the fabricated part.

Lower-cost processing technologies are being evaluated in the Low Cost Composite Weapon Program (located at Eglin AFB). This program looked at three different low-cost commercial approaches for building an interdiction missile airframe:

- Compression molding (from the automotive industry),
- Pultrusion processing, and
- Resin transfer molding.

The goal of the Low Cost Composite Weapon Program is an order-of-magnitude reduction in cost lowering airframe costs to the $10,000 to $20,000 range. It was developed to examine the civilian market and assess the application to defense systems of materials and technology used in automotive and other commercial enterprises.

The initial objectives were to save weight, reduce costs, and make materials capable of traveling at higher speeds and operating at higher temperatures. In actuality, the fret-round demonstration of the application of commercial technology and materials sacrificed performance to achieve lower cost. The final design did not include carbon fiber advanced composites; low-cost materials (viz., glass fiber) were required to meet the program cost goals.

Production Volumes

Put simply, the military community often demands custom-made hardware, while commercial industries seek off-the-shelf products combining low cost and high quality. Many military and space hardware applications are very specialized and require low production volumes. The automotive industry, on the other hand, is driven by low costs and high production rates. Between the aerospace and automotive advanced PMC markets, a variety of other market applications (including the non-aerospace military market) have production rates higher than military aerospace, cost objectives similar to automotive applications, and moderate performance requirements.

Structural aircraft components may initially cost $1,000 per pound and fall to $230 per pound after production of 500 units. The DoD fiscal year 1989 budget forecast procurement of only four aircraft at these volume levels for fiscal years 1989-93:

Aircraft	*6-year total*	*Average production*
UH-60A helicopters	432 units	72 units/year
AH-64A helicopters	432 units	72 units/year
F/A-18A	504 units	84 unit/year
F-16 fighters	930 units	155 unit/year

Typical commercial production rates range from 130 per year (MD-80s) to 300-400 per year for Boeing commercial aircraft (all models).

Material quantities required for small missiles are significantly greater. Thousands of missiles such as the Stinger (6,750 units in fiscal year 1989) and the laser Hellfire (5,000 units in fiscal year 1989) are built annually. For these and similar weapon systems, materials requirements for casings and fins approach automotive composite part production levels. In the automotive industry, production of 100,000 structurally identical vehicles *is* not unusual, although special units may be built at "low" production levels of 20,000 units. (Composites have a cost advantage over steel for these specialty low volume automotive applications, mainly because composite tooling costs are lower.)

Specific Technical Performance Criteria

Military and commercial aircraft experience some similar environmental conditions, and because of this require similar lightning protection, corrosion resistance, fatigue resistance, and material toughness. While the technical requirements for PMCs in commercial aircraft are comparable to those for fighter aircraft, the major differences include:

- Military fighter aircraft are designed to technical criteria based on peak g-loading and maneuverability, while commercial aircraft are designed to meet high duty cycle and fatigue stress.
- Repair strategies for military aircraft emphasize rapid turnaround, while repair strategies for commercial aircraft emphasize lifetime durability.

- Military aircraft design and material selection must consider battlefield issues; stealth, repair of battle damage, and radiation hardening have no relevance in the commercial sector.
- Design temperatures for very high speed military aircraft are more severe than for commercial subsonic aircraft

Maintenance

Military and commercial aircraft have inherently different duty cycles. Military aircraft are on the ground a significant amount of the time, while commercial airplanes spend much more time in the air. Commercial aircraft designers are concerned with structural fatigue and takeoff-and-landing duty cycles. The dominant factors for maintenance of military aircraft are ground temperature, corrosion, and exposure.

Quality Assurance

Before a material can be used in a military or FAA-certified system, it must be "qualified" for use. Advanced composite materials are produced in the same facilities for both the military and commercial aerospace markets. For example, the same composite material is used in the production of components for the military C-17 and the civilian MD-1 1 aircraft by McDonnell Douglas; in fact, both aircraft use the same material specification. While the costs may be the same for FAA and military qualification of a material, the military can pay more to qualify a material. The entire cost of qualifying a material for a civilian aircraft is borne by the airframer and passed onto the customer; for a military aircraft the government is the customer. For any man-rated (e.g., piloted or passenger-carrying) application at least, materials will need to be qualified for use in either sector.

In the aircraft industry, material property databases are continually being developed to qualify new materials and combinations of materials. Each airframer, military or civilian, must conduct extensive tests on potentially useful materials to avoid any possibility of structural failure; thus, a certain amount of overtesting between materials supplier and user will always be necessary because of this issue of liability.

It can cost up to $10 million apiece to develop databases on individual new materials, and doing so can involve up to 3,000 individual tests by the prime contractor and a similar number by the material supplier. Much of the materials qualification expense for a military aircraft is borne by the Federal Government, either in the form of independent research and development (IR&D) overhead, or through specific program/contract charges paid to the prime contractor. Each prime contractor maintains expensive test facilities in order to develop its materials databases. Airframers consider these databases proprietary information.

Various groups are hying to reduce testing costs, among them: the airframers'Composite Materials Characterization, Inc.; the Suppliers of Advanced Composite Materials Association; DoD's Standardization Program (Composite Technology Program Area); and the American Society for the Testing of Materials.

Partly because of these expensive, time-consuming, and overly duplicative qualification procedures, the same material supplied for military use will cost a third more than for commercial use. *[4] This may just be paying for a certain amount of necessary overqualification up front, rather than buying liability protection as commercial companies must do.

Government Regulations

Aircraft manufacturers, parts fabricators that subcontract to the aircraft manufacturers, and materials companies that contract directly with the DoD often must set up separate divisions to comply with government regulations and procedures. Although personnel can be transferred from the commercial

[14] Contractor report by Technology Management Associates, summarizing a workshop entitled "The Relationship Between Military and Civilian PMC Technology," held at OTA, Sept. 23, 1988, Wash., DC.

divisions or hired from other defense contractors, industry analysts state that everybody in the defense division eventually thinks “government contracting.” Due to accounting costs, the overhead charged by that division is much higher than that charged by the rest of the company.

It will be necessary for the military to relax regulations to meet the goal of low-cost composite weapons; however, some materials vendors have encountered great resistance to a straight military adoption of a commercial material in a military procurement

Diverging Business Approaches

Most of the points of convergence and divergence described above centered on technical or economic factors. There is also a certain divergence of business approaches in the PMC industry between the military and civilian sectors.

Approach To R&D

Managers of civilian aircraft companies do not understand the extent to which company money must be spent to participate in government research programs. The general view among military airframers seems to be that R&D contracting is a “loss leader.” That is, although companies invest in product and technology development leveraged with government contract R&D money, these R&D projects do not turn a profit or break even. From the standpoint of companies that do business primarily in the commercial world (particularly small materials suppliers), R&D costs seem a substantial barrier to entering the military market.

Managements in the commercial sector are also unfamiliar with the government’s way of doing business. Note that while commercial airframers are used to “betting the company” during the development of a new aircraft, and materials suppliers are used to putting in a great deal of development money on a new material, they expect large payoffs from these investments within a given time.

Auditing Procedures

One civilian aircraft manufacturer indicated concern over contracts that require monthly tracking of costs and schedule status of every part. It is estimated that using military specification accounting would have added $13 million to a $200 million contract. The accounting costs for fixed price programs were considered by some industry representatives to be unnecessarily burdensome. For example, in a subcontract for a secondary structural part for a military aircraft, more money is involved in accounting and reporting than in engineering.

BARRIERS TO ACCESSING PMC TECHNOLOGY

The military sector was the first to apply advanced composite technology. Although the PMC industry envisions a very large commercial market for advanced composites in the future, it sees limited commercial opportunities today. PMC suppliers feel that commercial development is the key to profitability in advanced composites, and that sustaining a presence in the military marketplace is a way to pursue it. However, companies (even the large ones) that do not currently participate in the defense arena have reservations about entering the military market.

Military contracting and accounting procedures, and the potential loss of proprietary rights and patentability, are distinct drawbacks to participating in the military composites market. This last factor is considered by some commercial sector companies as a threat to their survival in a competitive marketplace. Forfeiting proprietary rights goes against the “corporate culture” in many non-defense companies, and fear of such loss inhibits the flow of technology between the defense and commercial sectors. Due to proprietary concerns, technology developed in the commercial half of the company will not be shared with the military half.

These barriers inhibit, but do not prohibit, the transfer of technology between the civilian and military sectors. Participation by commercially oriented companies in recent defense programs such as the Low Cost Composite Weapon Program and C-17 subcontracts indicates that such companies are willing to engage in military programs. One factor frequently cited as significant in its effect on technology transfer is classification, which is discussed below.

Government Business Practices

Government business rules and regulations have inhibited the transfer of PMC technologies from commercial to military applications. For example, in 1978 ACF Industries had successfully developed an inexpensive glass fiber composite railroad car based on aerospace technology (filament winding of large shapes). DoD repeatedly approached ACF to use this technology in an ongoing defense program. ACF management declined to work with the government because putting up with the government audit procedures was more trouble for the company than it was worth.

Similarly, the teaming arrangement for the Low Cost Composite Weapon program was designed to augment a military aircraft manufacturer's capabilities with the lower-cost commercial technology of nonmilitary subcontractors. The lack of simple purchase orders for commercial sector contractors and complying with government accounting requirements met with stiff resistance. Commercial sector subcontractors expressed reluctance to participate because of the forms, audits, and justification of overheads.

According to an industry spokesman, small commercial companies fear working with a military prime contractor in this environment. One subcontractor on the Low Cost Composite Weapon team is under criminal investigation because of purported irregularities; apparently technical errors were made and the subcontractor did not comply with every detail of the specifications.

Military Contract Specifications

According to one military aircraft manufacturer, the process that generates "red tape" starts when Congress tries to solve a problem by creating legislation that implies action but does not specify exactly what needs to be done, then interprets Congressional action and creates a number of regulations. In a mirroring of DoD action, the prime contractors then impose more requirements on the subcontractors.

Classification of Programs

Personnel working on highly classified programs sometimes cannot obtain clearance from their program monitors to share what PMC industry representatives believe to be nonsensitive information, such as generic materials and process technology data. This generic information is often embedded in classified reports. It is costly for the military or the contractor to employ personnel to extract generic types of information from classified reports, even though it would benefit them in the long run to avoid duplication of effort. There is no tangible reward for either the military or the contractor to undertake the effort Even in cases where a military contractor has a commercial side that could benefit, and proprietary concerns are few, unsensitive information is not available outside the classified regime.

DoD has similar internal problems. There maybe technology under development in the "black world" that the rest of DoD could build on but does not know about. PMC industry representatives have indicated that more attention should be placed on the transfer of "black" technology into a "white" technology base.

One militaryairframe manufacturer reports difficulty finding people to work on classified programs, citing the fact that they get "lost" in a professional sense. Considering the cost of secure areas, monitoring, and clearances, industry representatives estimate that a classified program may cost two to three times as much as a similar unclassified program.

Unwillingness To Share Data

Some sharing of materials databases is necessary to reduce current costs, which are expensive. U.S. companies also need to share advanced materials databases if they are to compete effectively in global markets.

As an indication of this concern, seven U.S. aircraft manufacturers have created a consortium, Composite Materials Corporation (CMC), for materials database development.[15] CMC does not specify particular designs (i.e., provide design allowable); instead, it screens new composite materials for subsequent testing by the individual companies. CMC is funded only by the participating companies, and the data developed by CMC are proprietary to them as a group.

According to one U.S. aircraft manufacturer, these companies really do not want to cooperate with each other, but cannot afford to pay to evaluate all the new materials being developed. Some companies feel that information disclosed to the government would become public and might be used by their competitor in a different market.

Teaming and Second Sourcing Requirements

Forced teaming is a response to DoD's industrial preparedness concerns: without a significant commercial business base in advanced composites,

[15] Several major airframers have not joined in this effort.

maintenance of the PMC industrial base has been taken to be the responsibility of DoD. For example, under the current teaming philosophy, DoD selected two teams from multiple competitor to develop the Advanced Tactical Fighter. Military aircraft manufacturers and DOD personnel contend that the team members, who normally are competitors, are willing to share technology to improve the chances that their team will eventually win procurement contracts large enough to benefit all the team members.

From the viewpoint of one military airframe manufacturer, military second source programs do not enhance the health of the industry; they drive down the price of a particular weapon system at the expense of industry. For example, in some instances contractors are awarded 70 percent of production one year and a competitor is awarded 30 percent. PMC industry representatives feel that a new DoD procurement is offered only when the smaller supplier will bid anything just to keep from shutting down production. The second sourcing approach exacerbates the competitive nature of the business and inhibits the willingness of competitors to share data and team naturally on other programs. Competition is heightened further in programs for which the lead prime contractor (with 70 percent of the procurement) is required to provide assistance, including materials technology, to the second source contractor.

Appendix F

Case Study: The Software Industry

CONTENTS

Appendix F

Case Study: The Software Industry

NOTE: This case study, along with those in Appendixes D and E, is presented in condensed form in chapter 9 of the main report, Holding the Edge.

INTRODUCTION

The word "software" means different things to different people. It encompasses everything from operating systems to home video games, missile guidance systems to database managers, file servers to compilers and translators. A more rigorous definition of software is: *the combination of data and computer instructions written in any of a variety of languages used to instruct or enable computer hardware to perform computational or control functions.* It includes computer programs, i.e., a series of instructions or statements in a form acceptable to a computer, designed to cause the computer to execute an operation or operations.

The software industry has advanced rapidly since it emerged in the early 1950s. At that time, computer programs were written in binary machine code specific to a particular mainframe computer. By 1955, assembly language, composed of abbreviated symbolic codes, replaced binary code as the computer instruction set. Soon after, the high-order languages FORTRAN (FORmula Translation) and COBOL (COmmon Business Oriented Language) were introduced, providing programmers with a more natural language interface to computers.[1] Since the late 1950s the computer industry has added a multiplicity of languages to the industry. By 1975, the Department of Defense alone used more than 450 computer languages and derivations of languages for its embedded systems.[2]

During this same period, advances in the hardware industry increased the performance of computers by six orders of magnitude and reduced the cost of computers by about the same amount.[3] Improvements in hardware have resulted in computer configurations ranging from personal computers (PCs) to mini-, micro-, and mainframe computers. Each type of computer is designed for a particular market and **a** different scale of applications. The variety of computers available at reasonable cost to the general public has stimulated a market for all types of software—the demand for some of which the software industry cannot currently meet.[4]

Increased demand, coupled with a global shortage of trained computer programmers and an exponential rise in the cost of developing and maintaining software, has created what some have called a "software crisis."[5] But the crisis presents ample opportunity to U.S. software fins, which have dominated the world software market since its inception, controlling 70 to 75 percent of the market share. The number of U.S.-based software firms has increased from 4,340 in 1982 to over 25,000 in 1987, with a corresponding increase in revenue from approximately $10 billion to $17.6 billion. The increase in the number of software firms can be explained in part by the introduction of the PC by IBM in 1981 and the resultant increase in demand for Software.[6]

Increases in both demand and revenues from software are expected to continue in the foreseeable future, but there are factors that may adversely affect

[1] U. S. Department of commerce, "A Competitive Assessment of 'I%c U.S. Software Industry," December 1984.

[2] Embedded computers are part of a larger (non-computer) system; automobiles, missiles, and microwave ovens all rely on embedded computers for their operation. Missile guidance systems are an example of embedded systems. Benjamin ElSon, "Software Update Aids Defense Program," *Aviation Week & Space Technology, Mar. 14, 1983,* p. 209. See also: Jeremy Tennenbaum, "The Military's Computing Crisis: The Search For a Solution" (New York, NY: Salomon Brothers, Inc., Sept. 22, 1987), p. 3.

[3] Frederick Brooks, Jr., "NO Silver Bullet: Essence and Accidents of Software Engineering," *Computer*, April 1987, pp. 10-19.

[4] John Morocco, "Coming Up Short in Software," *Air Force Magazine*, February 1987, p. 64; and U.S. Department of Commerce, op. cit., footnote 1, p. 7.

[5] Dieter Ernst, *The Global Race In Microelectronics: Innovation and Corporate Strategies* in *a Period of Crisis* (Frankfurt: Campus Verlag, 1983).

[6] U.S. Department of Commerce, op. cit., footnote 1; and "Programming the Future," *The Economist*, Jan. 30, 1988, pp. 3-18.

the prosperity and health of the U.S. software industry in the world market. These include increasing competition from foreign companies, R&D that often focuses on short-term, application-specific software projects, foreign barriers to U.S. exports, inadequate intellectual property protection for U.S. developed software, and the failure of software technology to keep pace with advances in the hardware industry.

The health of this industry is vital to the nation's defense technology base because it profoundly affects DoD's ability to acquire and operate computer systems. In a very practical sense, software runs DoD. It controls communications systems among the Services, monitors force logistics, models scenarios of nuclear and conventional warfare, controls missile guidance systems, maintains accounting and payroll data provides office automation systems, and coordinates Command, Control, Communications and Intelligence (C^3I) operations.[7] The Office of Technology Assessment (OTA) is examining software as a dual use technology from the perspective of its contribution to the United States military. This case study examines the transfer of software technologies between the civilian-based and defense-related software industries, and the ability of the DoD to acquire and use the best available software technology.

This case study addresses three central questions. First, what is the current status and relative health of the United States software industry, both the defense-based and civilian-based industry? Second, what are the similarities and differences between the two sectors? Third, what procedural, institutional, technical or other barriers preclude the exchange of software technology between the defense and civilian sectors? Several policy options and problems generated from these three questions conclude this appendix.

GLOBAL SOFTWARE MARKETS AND THE HEALTH OF THE U.S. SOFTWARE INDUSTRY

Software is categorized in several ways-by its end-use application, by the size or scale of application, and by the degree to which it is customized. Industry and economic analysts use a variety of software classification schemes, and in some cases fail to distinguish between software as a service and as a product. It is therefore difficult to make generalizations about the software industry's nature, health, and future. Despite the lack of consistent economic data, the U.S. software industry clearly appears to be strong and competitive, in both the defense-based and civilian sectors.[8]

In 1981, U.S. software firms held 70 percent of the $10.3 billion international market for all types of software. In 1983, U.S. industry again controlled 70 percent of the world market, but the market had increased to $18.5 billion, putting the U.S. share at **$13** billion.[9] These figures are based on the international market for packaged software, integrated systems software, and custom-built software.[10] In 1983, approximately 60 percent of U.S. revenues came from packaged software, 25 percent from custom software, and the remainder from integrated systems software. In contrast, the other major software producing nations, Japan, France and the United Kingdom, receive most of their revenue from custom-built software, followed by integrated systems-software designed primarily for their respective domestic markets.[11]

[7] Software's significance to the defense technology base should not be underestimated: recent estimates show that DoD spends approximately $12 billion a year on its embedded software needs alone. Total software rests (including systems development and maintenance) are expected to consume 10 percent of the total DoD budget by 1990. See Jeremy Tennenbaum, op. cit., footnote 2; Jonathan Jacky, 'The Star Wars Defense Won't Compute," *Atlantic Monthly*, June 1985, pp. 18-30; U.S. Congress, Office of Technology Assessment, *SDI: Technology, Survivability, and Software*, OTA-ISC-353 (Washington, DC: U.S. Government Printing Office, June 1988), p. 225; and National Research Council, *The National Challenge in Computer Science and Technology* (Washington, DC: National Academy Press, 1988), p. 31.

[8] See for example, "National Academy Looks at Computing's Future," *Science, vol.* 241, Sept. 16, 1988, p. 1436; and U.S. Department of Commerce, op. cit., foomote 1.

[9] U.S. Department of Commerce, op. cit., footnote 1, pp. 32-34. In contrast to the Department of Commerce's figures, INPUT/ADAPSO repotted that in 1982, U.S. firms had revenues of $26.5 billion for the aggregate of: software products, data processing services, professional (consulting) services, and turnkey systems; *Software: An Emerging Industry (part* 9 of the series, "Information Computer and Communication Policy") (Paris: Organization for Economic Co-operati'on and Development, 1985), pp. 63-64.

[10] Packaged software is commercially developed and broadly marketed. Integrated systems software is a complete system that is sold and integrated with a specific hardware architecture. Custom software is developed to meet a user's specific needs.

[11] U.S. Department of Commerce, op. cit., foonote 1, p. 32.

By 1986, the U.S. share of the worldwide market for packaged software alone, including applications tools, generic solutions, and systems software, was $17.6 billion.[12] The worldwide market for packaged software is forecast to grow at a compound annual growth rate of 22 percent; and under this scenario, U.S. firms would reach revenues of $47.35 billion by 1991.[13] Various software industry estimates highlight the fact that no "hard" dollar figures are available since 1986, but most experts believe that regardless of the dollar amount, the United States still dominates the entire software industry.[14] The discrepancies in these estimates, forecasts, and reported revenues are partly attributable to an economic slump in the sales of hardware after forecasts were made, to variations in exchange rates, and to the classifications and methods used to report these figures.[15] They indicate the need for accurate measurement of the various types of software sold so that better analysis of the industry can be made.[16]

Although the U.S. software industry presently dominates the world market-both technically and economically-its continued superiority will depend on a number of complex factors. First, the industry faces a growing demand for all types of software-packaged, integrated systems, and custom built. Second, international competition in the industry is increasing as other nations-particularly Japan, France, the United Kingdom, Korea, and India—increase their software production capacity and penetrate the global software market. Third, U.S. software firms are increasingly forced to deal in an unfavorable international market where trade tariffs and national policies directly and indirectly restrict U.S. software exports to many foreign countries. And trade that does occur often fails to provide adequate intellectual property protection. Fourth, the gap between advances made in the hardware industry and those of the software industry continues to widen, making it difficult for the technologies of both industries to complement one another. Fifth, current software R&D activities relating to state-of-the-art technologies are insufficient. Finally, as the world market continues to grow, its composition will undoubtedly change, and the demand for new types of software may outpace that for current types, creating an advantage for newly established foreign companies. Each of these factors is addressed in a separate section below.

Software Supply and Demand

The ability of the U.S. industry to meet the overall demand for software depends on the various types of software that exist and current market trends associated with those types. Software is often categorized as either custom-built or packaged software. Custom-built software is developed according to a user's specific or unique requirements. An example is software developed to meet the requirements specified by a missile guidance system. Packaged software[17] consists of standardized software designed to be marketed widely. Examples of packaged software include operating systems, compilers, word processing systems, and database management systems. Prior to the existence of standardized operating systems and high-order languages, custom-built software dominated the U.S. software market. Since these developments, and as the cost of software has continued to increase relative to that of hardware, packaged software has increasingly dominated sales in the software market. Custom software accounted for almost one third of U.S. revenues in 1981. By 1983, the custom segment had fallen to about one fourth of total software sales with an annual growth rate of 16 percent. During that same period, packaged software sales grew at an annual rate of 40

[12] "Computer Industry Review & Forecast, 1982.1991 ," Special Report, International Data Corporation (IDC), October 1987, p. 109. This figure excludes custom-built software.

[13] Ibid.

[14] Information provided at the July 1988 Workshop on the Relationship Between Military & Civilian Software (hereinaftecalled OTA Software Workshop) suggested that the U.S. controlled art estimated 80 to 90 percent of the worldwide software market, for revenues of $30 billion, in 1988.

[15] Depending on the type or source of software, revenue/sales are reported under several Standard Industrial Classification (SIC) codes and other industry "de facto" classifications. For example, custom-built software is often accounted for in professional services, and integrated systems may be included partially in hardware sales and services. For further information, see: International Data Corporation, op. cit., footnote 12, pp. 108-109: and U.S. Department of Commerce, op. cit., footnote 1, pp. 3, 10-11.

[16] Source: OTA Software Workshop. Metrics of the industry and accurate classification of what constitutes software are needed not only to study industry trends, but to clarify how software is treated with respect to intellectual property protections, tax laws, accounting procedures and product liability laws. *Software: An Emerging industry, op.* cit., footnote 9, p. 11.

[17] Packaged software is also referred to as commercial-off-the-shelf (COTS) or Non-Developmental Item (NDI) software.

percent. This trend is expected to continue,[18] and is significant for the military which predominately acquires custom-built software for its applications.[19]

Packaged software can be further classified as **systems software,** including operating systems and systems support software; **applications tools,** including database managers, compilers, program development tools and environments; and **applications software**, software designed for a specific end-user problem, including generic banking, accounting, and office automation programs. Each of these segments of the packaged market is expected to grow in the future. Systems software, which currently makes up the largest share of revenues for U.S. firms, is expected to increase at the slowest rate and to decrease its market share. This reflects this market's symbiotic relation with the hardware industry. Systems software is typically developed for a particular size computer or specific hardware architecture, and recent fluctuations in the hardware market-particularly for mainframe computers-have negatively affected sales of these types of software.[20]

The ability to meet the growing demand for software, and of the United States to maintain its dominance of the softvare market, largely depends on the supply of computer programmers and the technology available to them. The United States cannot meet the demand for ail types of software with the present number of computer programmers. This shortage is not limited to the United States.[21] In 1985, the shortage of U.S. software professionals, including programmers, software engineers, and managers, was estimated at 50,000 to 100,000. There are many indications that this gap will continue to grow in the immediate future.[22]

The lack of qualified software developers maybe part of a larger shortfall in trained science and engineering professionals in the United States. Beyond any doubt, there is a serious shortage of rigorous software engineering programs at U.S. colleges and universities. The poor performance of American students in the sciences shows no immediate signs of reversal,[23] and while the number of students entering the computer science field seems to be increasing, demand outpaces estimates of future supply.[24] Finally, while there are signs that universities are adding more computer science and engineering courses to their curricula, an increasing

[18] U.S. Department of Commerce, op. cit., footnote 1, pp. 17-22. "

[19] Acccording to GAO, as of 1983, between 95 and 98 percent of all software developed for U.S. Government agencies was custom built. Source: United States General Accounting Office, "Federal Agencies Could Save Time and Money With Better Computer Software Alternatives," GAO/AFMD-83-29, May 20, 1983, p. 4. It seems likely that the DoD has proportionately as least as much custom software as other Federal agencies, based on the DoD's numerous embedded systems, unique systems and languages, and security requirements. What has been acknowledged by many experta is that the DoD is incteasingly using COTS software in its applications.

[20] International Data Corporation, op. cit., footnote 12, pp. 112-113. In 1986 systems software made up approximately 43 percent of the revenues received by U.S. firms in the packaged software market, applications tools made up 25 percent and applications software, 32 percent of that same market. By 1991, these shares are estimated to be 39 percent, 28 percent, and 33 percent respectively.

[21] Currently all industrial nations report a critical shortage of "software specialists," and most member nations of the Organization for Economic Co-operation and Development (OECD) identify this situation as the most important policy issue the software industry faces. *Software: An Emerging Industry*, op. cit., footnote *9, pp. 131-137. See also:* U.S. Department of commerce, op. cit., footnote 1, p. 72.

[22] Estimates that this shortfall will reach 1 million by 1990 in the U.S. alone are often cited, as are projections that demand for software professionals will exceed supply by 40 percent. See for example: John Morrocco, op. cit., footnote 4, p. 6% Paul J. McIlvaine, "Software Logistics: A Sleeping Giant," Concepts, Autumn 1982, p. 157; Parker Hodges, "The New Maturity of Computer Science," *Datamation*, Sept. 15, 1988, p. 40; Jeremy Tennenbaum, op. cit., footnote 2, p. 3; and *Software: An Emerging Industry,* op. cit., footnote 9, p. 131.

[23] See for example, "Science Achievement in Schools Called Distressingly Low," Science, Sept. 30, 1988, p. 1751, which indicates that the poor scientific understanding demonstrated by 9, 13, and 17 year-olds poses a serious threat to our national security. Also: American Electronics Association, "Engineering & Technical Education Program," September 1987.

[24] The supply of computer programmers is estimated to grow at a rate of 4 percent annually (Jeremy Tennenbaum, op. cit., footnote 2, p. 3), while the demand for computer programmers will grow at 70 percent and demand for computer analysts will grow at 76 percent (*Editorial Research Reports, Sept. 9,1988,* p. 446). See also: Parker Hodges, "The New Maturity of Computer Science,''Datumtzón, Sept. 15, 1988, pp. 37, 40; Office of the Under Secretary of Defense for Acquisition, *Report of the Defense Science Board Task Force on Military Software*, Washington, DC, September 1987, p. 38; U.S. Congress, Office of Technology Assessment, *Demographic Trends and the Scientific and Engineering Work Force—A Technical Memorandum,* (Springfield, VA: National Technical Information Service, December 1985); and American Electronics Association, op. cit., footnote 23.

percentage of students enrolling in these courses are foreign nationals.[25]

Software Quality

While efforts are underway to increase the number of individuals entering the software industry through improved education programs, these are long-term investments with payoffs not expected in the immediate future. Of more pressing concern is the quality of individuals entering the software engineering profession, and of those already in it. The complexity of applications, and the variety of hardware architectures that software is designed for, require scientific and engineering skills beyond those defined as computer programming.

Programming can be defined as the translation or written representation of a system design to a form interpretable by a computer. The actual translation or coding of statements in a high-order language requires minimum training to master. The difficulty in developing software is in the formulation of that design—the specification of data, data relationships, mathematical formulas and functions-in a rigorous and precise manner.[26] This process requires the software developer to conceptualize system complexity, interfaces to other systems, and future changes to the system. It is complicated by the fact there are no methods readily available that accurately represent the abstraction of all possible states that software can assume. The written computer program is a sequential translation that reflects only one such state. Graphical representations, such as flow charts or data flow diagrams, are similarly unable to capture all possible states, so that in both cases the design concept is retained only in the developer's mind.[27]

The difficulty in developing software is aggravated by what many consider to be the focus of computer science courses on software as a soft science, synonymous with coding, rather than an engineering science.[28] As a result many new programmers are unskilled in large-scale systems development and in the maintenance of such systems.[29] They may have limited experience working as part of a project team, but do not understand the engineering and design principles necessary to build real-world systems. Because the capabilities of computer programmers and software engineers directly affect the productivity and health of the industry as a whole, rigorous educational and training programs are a critical factor in the health of the software industry.

The software development process can be improved through the use of formalized and automated engineering techniques that support the iterative building and testing of software prototype systems, allow for the reuse of software components, and accommodate the complexity of software systems. Many software development methods and practices used today are primitive when compared to sophisticated software engineering techniques. It is not uncommon to find programmers using practices 10 years behind today's most advanced technology, due to inertia and the incompatibility of existing systems with these techniques. The result is that many software tools and concepts commonly used lag far behind those of the hardware which that software controls. Software utilities and Computer Aided

[25] Approximately 39 percent of the computer science/engineering PhDs awarded in the United States in 1987 were granted to foreign nationals. David Gries and Dorothy Marsh, "The 1986-1987 Taulbee Survey," Special Report, *IEEE Computer*, March 1985, p. 53. See also: Parker Hodges, op. cit., footnote 2. It has been noted that some non-U.S. citizens who "partake of the educational opportunity in the U.S." do in fact stay in the United States, but that more often these students take U.S. technology back to their homeland. This is because of increased opportunity in their homeland or because of national policy that mandates the return of these students upon the completion of their education (as is the policy in Singapore) or as part of a contract with a corporation which has funded the training (OTA Software Workshop). See also: American Electronics Association, op. cit., footnote 23, p. 12; and Robert Park, "Restricting Information: A Dangerous Game," *Issues in Science and Technology*, Fall 1988, pp. 62-67.

[26] It is generally agreed that almost anyone can be trained to write computer programs in a high-order language (HOL), but the entire software development process is a rigorous one and requires systems analysis, design, and engineering skills that are not readily mastered.

[27] For further discussion of the difficulty in developing software, see: Frederick Brooks, Jr., op. cit., footnote 3.

[28] Structured programming refers to the decomposition of a computer program design into manageable, modular or functional pieces and the subsequent "coding" of these pieces. Software engineering, while encompassing this process, emphasizes the entire systems lifecycle development process. It includes the technologies and methodologies for conducting requirements analysis, risk analysis, quality assurance/software testing, configuration management, implementation, and future modifications of software. For further information, see *Software: An Emerging Industry*, op. cit., footnote 9, pp. 11-12, 30-39; and U.S. Congress, Office of Technology Assessment, *Information Technology R&D: Critical Trends and Issues* (Springfield, VA: National Technical Information Service, 1985), pp. 79-85.

[29] The problems associated with developing software programs of increasing size are detailed in Fred Brooks, *The Mythical Man-Month* (Reading, MA: Addison-Wesley, 1975).

Software Engineering (CASE) techniques that are available are employed erratically in the industry. These factors contribute to the impression that software state-of-the-art is still art, not science.[30]

Appropriate and leading-edge technology is critical to the development of correct and maintainable software. Current practices and conditions—the failure to recognize software engineering as a scientific discipline and the lack of trained software engineers—am largely responsible for the growing cost of maintaining operational software systems. Maintenance, which encompasses the modification of software both to correct errors and to incorporate changes or enhancements, has become the major cost in any software system. Maintenance costs consume between 50 and 80 percent of all software budgets. Present estimates indicate that in fiscal year 1990, DoD will spend 80 percent of its software budget ($16 billion) on maintenance. Industry-wide maintenance costs are estimated to exceed those for development by a factor of 50.[31] While no software can be expected to be error free, the use of engineering techniques, system prototypes, modular system development, standard languages, and CASE tools can minimize computer "bugs" and improve productivity. Additionally, these practices support the development of portable and upward compatible systems that accommodate future enhancements and modifications.[32]

DoD has responded to the software crisis in two ways. First, the Department mandated the use of a standard language, Ada, which supports the use of modem software engineering practices and which is designed to replace the multiplicity of computer languages used in the DoD for mission-critical systems. Second, DoD has stated a preference for the use of commercial-off-the-shelf software wherever possible.[33]

Foreign Competition

Today, approximately 40 percent of the packaged software revenues earned by U.S. firms come from outside the United States.[34] This share is threatened by the software industries of Japan, France, the United Kingdom, Korea, India, Taiwan, and Singapore.[35] Japan is the strongest competitor primarily because of its strong hardware industry and propensity to take advantage of standardized technologies and develop marketable products from them.[36] The strength of the Japanese, and to some degree Singapore, India, and Taiwan, is in their ability to close large portions of the world market to the United States and simultaneously penetrate the U.S. market with systems software created with U. S.-developed technology. The quality of these products is equal to those of the U.S. firms, and can partly be attributed to the facts that many foreign engineers are trained in the United States and that a number of U.S. firms have established development facilities overseas. However, the quality of other types of software developed in these nations, especially applications software, suffers in comparison to that developed in the United States[37]

A comparison of the U.S. and Japanese industries shows that, while the level of software technology in both countries is similar, Japanese firms establish more disciplined software engineering environments conducive to the development and use of software tools. Japanese firms make greater investments in the area of basic technology and distribute this capitalization within the entire firm, rather than localizing it to a particular software project as is typically done in the United States. Additionally, the Japanese incorporate experiences and lessons learned into their future projects.[38] The Japanese are, in fact, turning programming into an applied science as demonstrated by "software factories" that reuse approximately 30 percent of previously developed software, have an error rate one-tenth that of their U.S. counterparts, and have the potential to produce lower cost and higher quality software.[39] The result of these efforts is programmer productivity figures that greatly exceed those in the United States. However, many experts note that at least part of the discrepancy between Japanese and U.S. productivity and error rates can be attributed to the fact that much Japanese software production focuses on programming from extant design. Further, these figures tend to be balanced by more efficient project management practices in the United States.[40]

The third major competitor in the worldwide software market, France, receives a considerable portion of its revenues outside its own borders. This contrasts with Japan's larger, but almost exclusively domestic, market. As a result, France was second only to the United States in worldwide software sales in 1982. The strength of the French industry is partly a result of national policy and partly the result of its growing internal software needs.[41]

Competition from other foreign nations is partly the result of industry standards. The development of standards is seen as a mixed blessing in the software industry. Although a lack of standards spawns innovation and creativity, it can also create excessive numbers of incompatible systems that inhibit rapid development of the technology. It is generally agreed that standards are needed and appropriate for systems interfaces, computer languages and protocols, and they are useful in codifying existing practices. But this also makes it easier for foreign vendors to compete effectively in the software market by taking advantage of technology developed by others.

International Software Protection and Trade Policies

As U.S. software firms exploit the world market, they become increasingly subject to intellectual property violations and infringements by foreign vendors. U.S. intellectual property protections (copyrights, trademarks, trade secrets, and proprietary data) are currently insufficient to protect U.S. interests in foreign nations where penalties for intellectual property infringement are less than the potential profits to be made from such infringement. Foremost among the violators are lesser developed and newly industrialized countries-Taiwan, Korea, and Brazil-which have little to lose and much to gain by not honoring U.S. regulations. Japan is also cited frequently for violations. The International Trade Commission surveyed over 400 U.S. firms in 1986, and estimated that U.S. computer hardware and software firms lost $4.1 billion due to inadequacies in intellectual property protection. This figure includes loss of exports and domestic sales to foreign infringing goods and counterfeit products, unrecovered research costs, increased product liability costs, reduced profit margins, damage to corpora-

[37] Ibid., pp. 163, 168.

[38] Marvin Zelkowitz et al., op. cit., footnote 30.

[39] Ware Myers, op. cit., footnote 30, p. 89; see also: U.S. Congress, Office of Technology Assessment, op. cit., footnote 28, p. 85; U.S. Congress, Office of Technology Assessment, *International Competition in Services: Banking, Building, Software, Know-How* . . . , op. cit., footnote 35, p. 164; and U.S. Department of Commerce, op. cit., footnote 1, p. 11.

[40] U.S. Department of Commerce, op. cit., footnote 1, p. 11; and U.S. Congress, Office of Technology Assessment, *International Competition in Services: Banking, Building, Software, Know-How* . . . , op. cit., footnote 35, p. 164.

[41] U.S. Department of Commerce, op. cit., footnote 1, pp. 38-40; and U.S. Congress, Office of Technology Assessment, *International Competition in Services: Banking, Building, Software, Know-How* . . . , op. cit., footnote 35.

tion trademark or reputation, and lost employment opportunities.[42]

These losses translate into decreased incentive for affected firms to invest in new technologies and innovative research and development activities.[43] Three conditions appear to encourage this situation. First, the technology and resources required to produce counterfeits or imitations of legitimate software products are readily available and relatively inexpensive. Second, consumers remain indifferent to or unable to detect differences between legitimate and infringing products. And third, the cost of genuine innovation remains higher than that of imitation. As long as these conditions prevail, the problem of inadequate intellectual property protection for software will remain.[44]

Additional economic loss is attributed to restrictive trade policies that serve to foster native software industries at the expense of U.S. firms. Import quotas, discriminatory taxes, local ownership requirements, embargoes, trade tariffs, and preferential treatment for locally produced goods are among the common policies which discourage or preclude U.S. firms from seeking business in many foreign nations. These practices are most pronounced in Brazil, India, Mexico, and Korea.[45]

Hardware's Impact

A major portion of the software industry is intimately related to the hardware industry. This is particularly true for systems software and, more recently, packaged software geared to the PC market. Since the preponderance of computer manufacturers are U.S. based, this symbiotic relation has traditionally benefited the U.S. software industry. While efforts are underway to diminish this strong tie to the hardware industry-for example, 0S/2, UNIX, and MS-DOS-this relationship will remain as long as the demand for integrated systems software and software development environments designed for particular hardware architectures continues.[46]

The increasing complexity of software systems, and the inability of software technologies to keep pace with innovations in the hardware industry, is of great concern.[47] The gap between the hardware and software industries can be seen in the exponential rise in software costs relative to hardware costs, the low productivity growth rates of programmers,[48] the increasing incompatibility of software systems, and the high costs associated with integrating or retrofitting existing software for new distributed architectures.

The United States seems unable to take full advantage of many of the advanced hardware and software technologies it has developed, principally because of its large embedded and heterogeneous software base. The problem of technology insertion is exacerbated by inadequate provisions in the software for its maintenance or inevitable post-delivery modification. Many existing military and civilian software systems are old by software state-of-the-art standards, but young with respect to their life expectancy of 5 to 20 or more years. Their longevity implies that the potential to use many advanced or new technologies is limited to software "maintenance" or modifications. Too often, such changes are not considered in the design process—functionality and data structures are not isolated and there is no system modularity to accommodate

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[42]United States International Trade Commission, "Foreign Protection of Intellectual Property Rights and the Effect on U.S. Industry and Trade," USITC Publication 2065, Washington, DC, February 1988. Violations in Taiwan and Brazil accounted for over $1.05 billion of all lost revenues reported by U.S. computer firms to the ITC. In 1986, the Software Publishing Association reported that U.S. software manufacturers lost $1 billion in sales due to piracy. See Anne Branscomb, "Who Owns Creativity? Property Rights in the Information Age," *Technology Review*, May/June 1988, p. 42.

[43]United States International Trade Commission, op. cit., footnote 42, p. 4-1.

[44]Ibid., p. 4-7. Most respondents to the survey indicated their belief that the situation regarding intellectual property protections has deteriorated in the past 15 years, and expressed little hope of an improved environment in the near term. pp. 5-1 - 5-3.

[45]Ibid., pp. 3-12, 3-13, G-14.

[46]At this time the only major competitor to U.S mini-and mainframe computer manufacturers' 80-85 percent control of the computer equipment market, and therefore much of the related system software for these computers, is Japan. U.S. Congress, Office of Technology Assessment, *International Competition in Services: Banking, Building, Software, Know-How* . . . , op. cit., footnote 35, pp. 168-169. See also: Ware Myers, op. cit., footnote 30, p. 85.

[47]Edward Joyce, op. cit., footnote 30; John Morrocco, op. cit., footnote 4, pp.64-68; and "Summer Study 1985, A Report to the Director, SDIO," op. cit., footnote 31, p. 48.

[48]In 1983, U.S. software productivity grew at 4 percent while demand for software grew at 12 percent. Source: Jeremy Tennenbaum, op. cit., footnote 2, p. 4.

change. As a result, maintenance becomes a costly and time-consuming proposition. Finally, many new technologies and methodologies are incompatible with the computer language or dialect used in the original software." As a result of these factors and the United States' commitment to its software base, the United States is it at a relative disadvantage to those nations just entering the computer industry that have little or no historical computer base.[50]

R&D Investment

The present software crisis indicates the need for reinvestment and capitalization in the U.S. software industry that fosters R&D and technological growth and provides the capacity to exploit advances made in the industry. It is estimated that Japan spends approximately two-thirds of its R&D budget on process innovation, while the United States spends only one-third of its R&D monies on the same activities .51

Currently, the U.S. Government funds several software-related research efforts. The Software Engineering Institute (SEI) is a Federal Research Center located at Carnegie-Mellon University. It is responsible for numerous R&D projects relating to software productivity, reuse, and education. The objectives of DoD's Software Technology for Adaptable, Reliable Systems (STARS) include identifying possible technical solutions, methodologies, and tools that can be used to build reliable and cost-effective defense-based software. Without continued commitment to these programs, and further funding to support research and development in the areas of software engineering, development environments, distributed systems, and software metrics that record these efforts, it is likely that improvements in software productivity, cost, and reliability will be realized and put into common practice more slowly than necessary.[52]

CONVERGENCE/DIVERGENCE OF CIVILIAN AND MILITARY SOFTWARE TECHNOLOGY

The software industry is increasingly divided into two groups, one dedicated to military interests and another that supplies the commercial world.[53] These two sectors have always been present, and exchange between the two was assumed to be the norm, not the exception. But these groups seem increasingly to be diverging, a trend that is contributing to a weakening of the U.S. software technology base. As a major consumer of software and software services, the DoD has exerted, and will continue to exert, much influence over developments in the industry. Therefore, a strong software industry, one where the technology and research base is not divided between military and civilian environments, is in the interest of both communities.[54]

Convergence of Civilian and Military Software Technology

As in many other industries, the underlying software technologies are highly similar in both the military and civilian sectors, and divergence only becomes noticeable in the detailed requirements for specialized applications. Convergence between civilian and military software industries is most noticeable in the small-scale applications and systems software areas. Both sectors use packaged/ COTS software for the majority of their small-scale software applications. These include PC-based pro-

[49]See: Frederick Brooks, Jr., op. cit., footnote 3, p. 12; Office of the Under Secretary of Defense for Acquisition, op. cit., footnote 24, pp. 8-12; and "Suggestions for DoD Management of Computer Software," op. cit., footnote 30, pp. 64-67.

[50]Based on discussions at OTA's Software Workshop, held July 25, 1988. See also: *Software an Emerging Industry*, op. cit., footnote 9, pp. 21-63; and *Discriminate Deterrence*, op. cit., footnote 35.

[51]The importance of focusing R&D in innovative and leading-edge technologies as opposed to risk-free, conservative, market-based technologies is stressed in *Discriminate Deterrence*, op. cit., footnote 35; and "Picking Up the Pace—the Commercial Challenge to American Innovation," Council on Competitiveness, 1988. These reports and others, as well as comments made during OTA's Software Workshop, indicate the failings of the United States' short-term view of R&D activities and its emphasis on DoD weapons-based activities as opposed to project-independent, long-term, and innovative R&D.

[52]The importance of R&D is noted in, for example: U.S. Congress, Office of Technology Assessment, *International Competition in Services: Banking, Building, Software, Know-How* . . . , op. cit., footnote 35; and U.S. Congress, Office of Technology Assessment, op. cit., footnote 28.

[53]While the word "commercial" or "civilian" seems to encompass any for-profit company, in this analysis these terms exclude those firms that exclusively contract with the government (DoD) or those divisions of a firm that are explicitly established to do business with DoD; e.g., IBM Federal Systems must be considered part of the "military" industry since its management structure is distinct from that of other IBM activities. The management characteristics of government contractors will be addressed further in the later section on "Barriers."

[54]John Morrocco, op. cit., footnote 4, p. 64.

grams and office automation products. Packaged systems software, such as operating systems, compilers, and systems utilities, are used to the same degree in both environments as well. The basic requirements for these particular types of software are similar in both sectors, and there is little need for customization of these products. More importantly, the availability and cost of these types of packaged software products make them readily accessible and attractive to both military and civilian users.[55]

Convergence in the industry's two sectors is also evident in their acceptance of CASE tools and modem software engineering methodologies. Unfortunately, this convergence is not always at the state of the art. Experts from both sectors of the industry cite examples of the use of modern engineering technologies that increase productivity and performance; but they are quick to acknowledge that at least as many software projects use little or no advanced technology.[56] The unpredictable and varied use of modem software engineering techniques and tools throughout the software lifecycle[57] is not localized by organization. Discrepancies are found within the DoD Services and agencies, within civilian firms, and within software projects of both sectors. A probable explanation for the industry-wide discrepancy is in the relative age of the system being analyzed. New starts and recently developed systems are more likely to exploit new technologies; they will be implemented in high-order languages, and modem engineering techniques will be brought to bear in their design and development.[58]

Divergence of Civilian and Military Software Technology

In general, the military and civilian software industries have access to, and use, the same technology. But they diverge in the ways they acquire software and, in particular, at the point where they sponsor large-scale applications that require custom-built software.

Similar applications for software are not limited to the PC-based or systems software previously mentioned. Analogous applications of large-scale software systems can be found in both sectors as well and include software developed for avionics, telecommunications, and embedded systems. But while the applications are similar, military and civilian environments place different, sometimes opposing, requirements on the software that controls these systems.[59] This is particularly true for large-scale, *mission-critical* military applications.[60]

Different requirements, as well as differences in scale, create two distinct software industries in the large-scale applications area. The industry divergence is illustrated in avionics systems software, where military requirements for high performance avionics are exchanged for high survivability and safety in civilian avionics.[61] The significance each sector attaches to software requirements, and whether they become rigid specifications or economic trade-offs, partially explains why there is

[55] Source: OTA Software Workshop, July 25, 1988. Each sector is as likely to "tweak" COTS systems software (e.g., compilers) for its own performance, efficiency, or other requirements and thus end up with unique software; but ultimately the source is the same.

[56] The emphasis on modern software engineering is most apparent in both the military and civilian aerospace industries. Source: OTA Software Workshop. For further information on the disparate use of these practices, see Marvin Zelkowitz et al., op. cit., footnote 30, pp. 57-66, which indicates that software practices typically used in 1983 were 10 years behind the research of that time.

[57] Software lifecycle refers to all stages of the software development process, from its conceptualization to its destruction. It normally includes requirements analysis, design analysis, implementation or coding, testing, deployment, and post-deployment (maintenance).

[58] While neither sector seems to lead in the use or implementation of modern software engineering techniques and tools, software industry analysts agree that the DoD, through its mandate for Ada and software initiatives, seems more verbally supportive and encouraging of efforts to use state-of-the-art technologies.

[59] Source: OTA Software Workshop. Most analysts agree that there is an analogous distribution of software applications in both sectors, and that the basic direction of software technologies is similar but parallel. Basically, the military and civilian sectors have the same problems in two different domains.

[60] Mission critical software is that which controls weapons, command and control, intelligence and similar systems.

[61] Source: OTA Software Workshop. The *Report of the Defense Science Board Task Force on Military Software* (op. cit., footnote 24, pp. 6-7) characterizes military software as "fundamentally like advanced civilian software, only more so." This refers to the fact that the requirements of military mission critical applications stress the state of the software art more severely than do similar civilian applications.

little transfer of software between them at the embedded and large-scale application levels.[62]

In contrast to civilian industry, military requirements for custom-built and embedded software tend to be very rigid. Once documented and approved in the design stage, the specified requirements govern the subsequent development of the software, regardless of their criticality to the system. Any such change typically requires a System Development Notification and contract modification that delay development. In addition to user-specified requirements, military software systems must address the maintainability, survivability, security, availability, reliability and interoperability[63] aspects of software.[64] These requirements are usually specified in absolute terms, not all of which maybe necessary for a particular military system. But they are more easily copied from previous software contracts than tailored for the new system.[65] The need for specific performance and operational characteristics is evident in many DoD mission critical-systems. It is necessary to require near-loo" percent reliability for a missile guidance system and desirable to require multi-level security in a networked defense communications system. But when these requirements are unnecessarily transferred to other military systems, the cost of development increases and the ability to use analogous civilian applications or commercially developed software decreases.[66]

Many of the requirements identified as unique to military application—e. g., security, data encryption, interoperability, survivability, and reliability—are appropriate in banking, insurance, commercial flight control, and other civilian applications. Indeed many of the characteristics implemented for military purposes could be transferred to civilian applications.[67] But while these requirements are desirable and appropriate in civilian applications, their implementation would be based on economic and risk analysis. The bottom line in the civilian sector is economic. If the cost of implementing a requirement exceeds the expected return for that implementation, then the requirement is, in most cases, deleted or deferred. This analysis and design-to-cost approach rarely occurs in military software acquisitions, although similar accommodations will be more likely in the future if the cost of military software continues to escalate. In contrast to the civilian methods, military software is designed to a set of approved requirements that seeks to minimize cost and risk; often these requirements fail to distinguish between the user's needs and wants.

The requirement for custom-built software exists equally in both sectors, but custom-built software appears to be used more often in DoD applications. The General Accounting Office (GAO) reported in 1983 that 95 to 98 percent of applications software used by the government was custom-built.[68] There are indications that the military is increasingly using commercially developed software in its systems; nevertheless, the majority of mission-critical and embedded systems software is still custom-built. One report estimates that "custom development will exceed packaged software sales in the Federal segment, in contrast to the mass market, where COTS software products will exhibit more rapid growth."[69] The trend to use more COTS products acknowledges that the disadvantages of using commercially available software-not receiving the customized software to meet unique requirements—are clearly outweighed by the direct and indirect benefits of using such software. These include cost savings, improved documentation and operational support, and increased availability. As the relative

62There are instances of interaction and technology exchange between the two sectors in these applications areas, most notably in the areas of avionics and communications. But because this is not the norm, the majority of this software is custom-built exclusively for one sector or the other. The limited exchange is largely the result of government regulations and auditing procedures required of government-funded development efforts. This problem will be addressed in the "Barriers" section of this appendix.

63Interoperability is the degree to which systems can exchange data with each other without affecting the operation of either system.

64The development of defense system software, unless otherwise specified in the contract's Statement of Work (SOW), requires contractors to develop a Software Requirements Specification (SRS) which includes these and other standard requirements and enumerates to what extent they will be met by the software. See DoD-STD 2167A and Data Item Description (DID) DI-MCCR-80025 for required elements and their format.

65Source: OTA Software Workshop. See also "Suggestions for DoD Management of Computer Software," op. cit., footnote 30, p. 69. The practice of using existing contracts as the basis for a new procurement is understandable, given the number of Military Standards, Data Item Descriptions, and documents required by defense acquisition regulations.

66It is estimated that achieving the close-to-perfect levels of performance required by some systems raises the development cost 30 to 50 percent. Although this cost factor applies to performance at the margin for weapons systems, there is a direct correlation to software systems—ensuring near 100 percent reliability for a software system affects development costs similarly. Jacques Gansler, "Integrating Civilian and Military Industry," *Issues in Science and Technology*, Fall 1988, p. 70.

67Source: OTA Software Workshop.

68United States General Accounting Office, op. cit., footnote 19.

69Darryl Taft, "Fed's Software Buys to Hit $3 Billion in '92," *Government Computer News*, Aug. 29, 1988, p. 41.

cost of acquiring and developing custom software continues to increase, so does the trend to use COTS products.[70]

An approach intermediate between COTS and custom-built software is the customization of commercially developed software or reuse of existing software. As the technologies to support reuse mature, one would expect both sectors to adopt this practice and incorporate previously developed software as components of larger, integrated systems .71 The degree to which reuse is accomplished by either sector is not known, but it is an area of potential convergence. Whether economic reality in the civilian sector is likely to encourage this practice more than Directives and mandates issued by DoD may depend on the current DoD requirements and procedures that discourage contractors from adopting this practice. According to many experts, there are currently few economic incentives, particularly in "cost plus" contracts used by the DoD, for contractors to reuse existing software; building software is perceived to be more profitable than reusing software.[72]

Divergent Acquisition Procedures and Lifecycle Model

Much divergence between civilian and military software is related to the acquisition process. It is evident in the way in which software requirements are specified, in the design and development of software, and throughout the entire software lifecycle. This divergence is magnified in the areas of special applications and large-scale systems software.

The analysis and writing of system requirements based on a user's needs is the most critical and difficult aspect of developing software.[73] Once established and approved, requirements directly influence the entire design and development of software. It is therefore essential that software requirements accurately reflect the needs of the user; that they do not place impossible performance, interoperability, or similar demands on the software; and are not so rigid that they preclude inevitable modifications to the software. The optimal way to accomplish this crucial task is to develop software requirements iteratively .74 Success ultimately depends on having a flexible vehicle that allows for iterative development, not only of requirements, but of the entire software lifecycle.

The mechanism used by the military is DoD Standard 2167A, which establishes the "requirements to be applied during the acquisition, development, or support of software systems." DoD-STD 2167A is designed to provide flexibility in the software development process, and at the same time provide the DoD with a mechanism to monitor that process.[75] Its objectives have not been fully realized because many government procurement officers still follow the older "waterfall" lifecycle model of software development exemplified in DoD-STD 2167.[76]

The waterfall lifecycle identifies distinct stages during the life of software that are associated with requirements analysis and definition, system design, system implementation or coding, systems testing, and deployment (including maintenance). Based largely on weapons acquisition, the military interprets this model to describe a sequential software development process, where each stage of development naturally leads to the next. Each phase is documented and is normally accompanied by a government review. Once the system requirements

The analysis and writing of system requirements based on a user's needs is the most critical and documented and is normally accompanied by a government review. Once the system requirements

[70]Frederick Brooks, Jr., op. cit., footnote 3, pp. 16-17.

[71]Software reuse includes the reuse of software designs, data, algorithms, software modules or entire programs. Technologies are needed to identify and develop appropriate reuse components, catalog these items, and retrieve them. Additionally, issues such as Quality Assurance testing, product liability, and intellectual property protection for reuse components must be resolved. See: Edward Joyce, op. cit., footnote 30; Tom Durek and Fred Van Horne, "Systems Software Development: Building Canonical Libraries," *Signal*, April 1988, pp. 89-93; and Frederick Brooks, Jr., op. cit., footnote 3.

[72]Source: OTA Software Workshop.

[73]Frederick Brooks, Jr., op. cit., footnote 3, p. 17.

[74]Ibid., pp. 17-18; and "Suggestions for DoD Management of Computer Software," op. cit., footnote 30, p. 66.

[75]*Defense System Software Development*, Military Standard, DoD-STD 2167A, Feb. 29, 1988. 2167A encourages the use of an appropriate

are specified and system design is complete, it is assumed that the implementation can and will automatically fall out from that design. In reality, the software development process is evolutionary and requires an iterative approach.[77]

While DoD-STD 2167A was designed in part to correct the waterfall lifecycle bias currently used, it continues to emphasize a document-driven, specify-then-build approach to software development.[78] The procedures set forth by DoD-STD 2167A and corresponding documents are designed to ensure that DoD gets the highest-quality software at the best price. But the system has not improved the quality or timeliness, or decreased the cost, of military software. Instead it remains a major part of the problem. The military's approach is based largely on competitive procurements that necessitate establishing requirements as early as possible in the lifecycle. The process backfires, however, once bids are awarded; many requirements turn out to be impractical, beyond the scope of current technology, or simply unneeded. The inevitable result is software that is delivered late, at higher cost, and with less functionality than planned.

DoD-STD 2167A attempts to avoid the cascade effect of this approach by allowing for all lifecycle stages to occur iteratively. But the standard directly or indirectly requires that developers comply with numerous other DoD and Military Standards, Directives, and Data Item Descriptions at each major development stage, milestone, or prior to a major revision in order to provide government oversight of the entire process.[79] These procedures perpetuate the inflexibility and bureaucracy that DoD-STD 2167 originated. The acquisition process used by DoD illustrates the government's propensity to use process specifications and standards that dictate how-to-design and how-to-manage, rather than performance specifications and standards that focus on desired results.[80] This approach contrasts with the civilian sector's tendency to negotiate for a final product and design-to-cost, and precludes the use of innovative or unproven techniques and methodologies by DoD contractors .[81]

Ada

A more recent divergence in the two industries relates to the military's mandated use of a single high-order language, Ada, in its mission-critical software systems. DoD's sponsorship for Ada began in 1974 when the "software crisis" was acknowledged to have potentially serious consequences for the military's ability to maintain and operate its many computer systems.[82] In 1983, Ada was approved as an American National Standards Institute (ANSI) and Military (MIL-STD 1815A) standard. By 1987, Ada was approved as an International Standards Organization (1SO) standard.

The DoD Directive that Ada shall be the single high-order language used in command and control, intelligence, and weapons systems has no counterpart in the commercial environment. With the exception of civilian avionics systems, Ada is not widely used in U.S. commercial applications. Instead, civilian-based software continues to be implemented in the language thought best for that application—whether it be COBOL, Assembly, a

77 The benefits of an iterative approach and prototyping of systems development, are described in: Frederick Brooks, Jr.. op. cit.. footnote 3; Office of the under Secretary of Defense for Acquisition, op. cit., footnote 24, pp. 11, *33-35;* U.S. Department of Commerce, National Bureau of Standards, '*Application Software Prototyping and Fourth Generation Languages," NBS Special Publication 500-148, May 1987; John Morrocco, op. cit., footnote 4; Mark Gerhardt, "The Language of Abstraction," *Aerospace America,* July 1988, pp. 32-34; and U.S. Congress, Office of Technology Assessment, op. cit., footnote 28, The ill-effects of the waterfall lifecycle and DoD-STD 2167 are addressed further in the following section on barriers between the military and civilian sectors.

78 Office of the Under Secretary of Defense for Acquisition, op. cit., footnote 24, P. 33.

79 DoD-STD 2167A, op. cit., footnote 75, see pp. 1-4, 35-36.

80 Donald Firesmith, "Should the DoD Mandate a Standard Software Development Process," Proceedings of Joint Ada Conference on Ada Technology and Washington Ada Symposium, March 1987, pp. 159-167.

81 Source: OTA Software Workshop.

82 A 1983 memorandum from the Under Secretary of Defense for Researc h and Engineering recommmended that Adabe the single high-order language used in all DoD mission-critical computer systems; but this rec ommendation was not implemented until 1987 in DoD Directive 3405.1, which states that Ada shall be the *'single, common, computer programming language" used in command and control, intelligence, and weapons systems. Policy regarding Ada is also provided in DoD Directive 3405.2, which mandates the use of Ada in all weapons-related computer systems.

Fourth Generation Language,[83] or any other computer language.[84] As new DoD computer systems are developed, the convergence of new software technologies and the ability to transfer software between the two sectors will depend a great deal on several factors: first the civilian sector's acceptance of, and demonstrated use of, Ada; second, DoD's willingness to grant waivers to its Ada mandate; and finally, the military's acceptance or ability to incorporate commercially developed, non-Ada software in its computer systems. The barriers potentially introduced by Ada will be examined further in the following section.

BARRIERS TO MILITARY ACCESS TO CIVILIAN SOFTWARE SECTOR AND VICE VERSA

Despite similarities in technologies available to the civilian and military software sectors, it is apparent that there is a growing divergence between them. Such differences, primarily in their respective acquisition strategies, obstruct the exchange of software technologies and applications. This continuing divergence not only damages the U.S. software industry, but also erodes the defense technology base. Previous studies, reports, and directives have identified the importance of technological exchange between the commercial-based and military-based software industries, and the need for DoD to adopt a more commercial-like acquisition process. But these reports, prepared by the Defense Science Board and others, have had little impact on the systemic problems identified to date. The persistent barriers to the transfer of technology, methodologies, and products between military and civilian interests are identified below.

Acquisition Regulations

In 1987, a Defense Science Board Task Force reported that the "major problems with military software development are not technical problems, but management problems."[85] This finding was revised during a follow-up workshop to state that while both technical and management problems are evident in military software development, the latter are more significant. These management problems relate to the manner in which the DoD procures software, and they represent the major barriers to the exchange of software technology between civilian and military sectors.

According to industry representatives, the principal barrier to exchange of software technology between the civilian and military sectors is the bureaucracy and administration overhead associated with DoD acquisition procedures. Requirements regarding the procurement, design, and development of DoD software are enumerated in DoD-STD 2167A, which provides "the basis for government insight to a contractor's software development, testing, and evaluation efforts."[86] DoD-STD 2167A does not profess to follow a particular software lifecycle model and does not require a particular software development methodology. Yet, as a review mechanism, it unnecessarily burdens contractors with the many Standards, Directives, Data Item Descriptions, and Federal Acquisition Regulations that it directly or indirectly requires.[87]

DoD has defined eight major activities for software development, each of which requires a formal review or audit to be conducted or supported by the contractor. Additionally, the contractor must document his plan for completing all activities and DoD must approve this plan before any development

[83] Fourth-generation languages arc application-specific languages or program generator% not geaeral-purpose or high-order languages. They include database languages, spreadsheets, natural query languages, and any language designed to be used in a limited problem domain. Office of the Under Secretary of Defense for Acquisition, op. cit., footnote 24, p. 18; see also: U.S. Depart.mentof Commerce, National Bureau of Standards, op. cit., footnote 77.

[84] Source: OTA Software Workshop. There are examples of civilian applications being designed and/or developed in Ada, but most commercial firms have adopted a "wait and see" attitude regarding the language. By comparison, European firms have elected to usc Ada in a variety of applications more frequently than their Us. counterparts have.

[85] Office of the Under Secretary of Defense for Acquisition, op. cit., footnote 24, p. 24.

[86] DoD-STD 2167A, Feb. 29, 1988, pp. iii/k.

[87] Ibid., pp. iii, iv, 3,4, 35, and 36.

efforts can begin.[88] The entire process is designed to guarantee that the government acquires the software that best meets its needs, ensuring that government funds are not misused or used for commercial benefit. The results of DoD's procurement strategy are contractual obligations that force commercial vendors to employ specialists fluent in the military regulations, government reviews, documentation, and accounting procedures required by the DoD. These regulations, audit requirements, and associated legal issues have forced many DoD contractors to establish autonomous divisions for conducting business with the government. Finally, vendors need a sufficient economic base to survive fluctuations in the DoD contracting and budget cycle.[89]

As a consequence, few civilian firms regularly contract with the DoD.[90] It has been argued that the limited base of contractors established to do business with the government inhibits DoD's ability to acquire quality software. While seeking the same quality software and the same assurance of a fair deal, the civilian software sector has no such regulatory mechanism. Performance, quality, and operational requirements of civilian software applications are weighed against cost. The commercial procurement process is designed to acquire the best software at the best price. Commercial-based contracts make no attempt to regulate or control the management practices of the developer, focusing instead on specification of the software functionality required. The numerous reviews and procedures required during the development of military software conflict with such a commercial-based practice.

The acquisition procedures and contracting practices used by the DoD not only limit the number of potential vendors, but discourage those contractors already qualified by the military. Civilian firms who contract with the DoD receive no guarantee of a continued relation with the DoD, accept poor profit margins, and often lose the rights in data to their software.[91] Government contractors therefore have little incentive to provide software that is innovative or of superior quality. The mechanisms used by the defense sector to select a software contractor in a sellers' market not only increase the chance that the DoD will get mediocre software, but frustrate many contractors from doing business with the military .92

Data Rights

The actual acquisition of software illustrates a further barrier to the transfer of software between the two sectors. Often, regardless of the software type, government contractors lose most, if not all, of their intellectual property rights to the software they develop.[93] The government's claim to unlimited data rights is based on the notion that these rights protect the government and will ensure public dissemination of publicly sponsored research efforts. In negotiating for unlimited rights in data for its software, the government gains the ability to maintain and modify its software systems in the future. Perhaps more importantly, this practice is intended to ensure the competitiveness of future

[88] Ibid., p. *9. The* eight major activities are: System Requirements Analysis, Software Requirements Analysis, Preliminary Design, Detailed Design. Coding and Computer Software Unit Testing, Computer Software Component Integration and Testing, Computer Software Configuration Item Testing, and System Integration and Testing. These activities may overlap and may be applied iteratively. It should be noted that 2167A was developed to supercede DoD-STD 2167 and the waterfall lifecycle model it represented for software development. Yet the categorization of the development process in 2167A does not differ significantly from that in DoD-STD 2167; what it does allow is for the iterative application of the design and *review* processes in an attempt to accommodate a prototyping approach to systems development.

[89] Office of the Under Secretary of Defense for Acquisition, op. cit.., footnote 24, p. 30. As an example, the time that elapses from requirements specification to letting a contracting to full deployment typically runs from 8- 14 years. By the time large defense systems software is deployed and operational, the computer hardware is 5 to 12 years behind that available on the market.

[90] The Defense Science Board Task Force on Military Software reported in 1987 that there were approximately 24 contractors regularly involved with mission-criticaJ software development for the DoD. More recently, International Resource Development, Inc., identified over 50 firms able to contract for large DoD software projects. In either case, these firms represent a minority of software firms in the United States. See: Office of the Under secretary of Defense for Acquisition, op. cit., footnote 24, pp. 29-32; and *Ada Data, International* Resource Development, Inc., Fall 1988.

9! Office of the Under Secretary of Defense for Acquisition, op. cit., footnote 24, PP. 29.

[92] OTA Software Workshop; also Office of the Under Secretary of Defense for Acquisition, op. cit., footnote 24, pp. 29-32.

[93] The government's *claim to* software *rights* in data are usually unlimited or restricted. The former allows the government to "use, duplicate, disclose . . . software in whole or part, in any manner and for any purpose whatsoever, and to have or permit others to do so." For software developed wholly with private funds, the contractor can negotiate restricted data rights that give the government the right to modify software and make backup copies, but allow the developer to incorporate a typical licensing agreement with the government to protect lefforts. See: Michael Greenberger, "Rights-In-DataPolicies Affecting Department of Defense Acquisition *of* Computer Software and Related Products," presentation for the Computer Law Association, Washington, DC, April 1988, pp. 4-6.

software maintenance and follow-on contracts. But according to many experts, in its efforts to foster fair competition, the government appears unable to compete effectively for its software. Further, many government employees and government contractors view the practice as onerous, burdensome, unnecessary, expensive and unfair.

Despite these acknowledgments and the flexibility allowed government contracting officers to negotiate less than exclusive rights to data in software acquisitions, the government usually insists on full transfer of data rights. In the commercial world, no company would demand exclusive rights to proprietary information, and many are dismayed by the government's expectation of these rights.[94] This practice clearly inhibits DoD's access to software developed by many civilian firms. The Institute for Defense Analyses Rights In Data Technical Working Group reported that because of the government's unlimited data rights demands,

> . . . the government is failing to obtain the most innovative and creative computer software technology from its software suppliers. Thus the government has been unable to take full advantage of the significant American lead in software technology for the upgrading of its mission critical computer resources.[95]

The commercial sector typically protects proprietary information through laws relating to trade secrets. Contractual or licensing agreements govern the disclosure or dissemination of the intellectual content, or trade secrets, of software. Such licenses provide developers with continued revenue as they control the marketing of their product. In contrast, DoD's exercise of exclusive data rights does not guarantee the developer continued income or a further relationship with the government.. While the most recent DoD directives and regulations cite the ability and desire of the government to "negotiate" the rights to intellectual property, several factors have limited the practice or success of such negotiations. First, many DoD contracting officers and program managers intimate with the software contract do not have the guidance, knowledge, or experience necessary to request anything short of exclusive data rights. Second, the government generally receives exclusive rights to software that has been developed, either in part or wholly, with funds from the government. Third, developers who negotiate for restricted rights must meet government regulations and contractual obligations in order to Fully realize their rights.[96]

Ada

Some civilian software firms cite Ada as a barrier to working for DoD. The directive stating that Ada shall be the "single, common, computer programming language"[97] used in command and control, intelligence, and weapons systems may dramatically alleviate the military's software crisis. But because of Ada's relative immaturity, the number of commercial-oriented fires proficient in its use is limited. The mandate to use Ada appears to further decrease the already limited number of firms willing **and** able to contract with DoD.

Some experts cite Ada as an example of the government's tendency to standardize too many things too early. While the mandate to use Ada for mission-critical applications was arguably premature in 1983, developments associated with Ada weaken that argument.[98] But many commercial vendors, with the exception of those in the avionics industry, still have a wait-and-see attitude about Ada. While this is the prevalent strategy regarding Ada, there are successful examples of commercial Ada ventures, for example, in the development of

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[94] Ibid.; also M. Greenberger, T. Shuba, J. Edmond, and R. Strassfeld, "Seeking the Balance Between Government and Industry Interests in Software Acquisitions" (SEI-87-MR-9), Software Engineering Institute, May 1987.

[95] Institute for Defense Analyses Rights In Data Technical Working Group, Draft Final Report, Nov. 22.1983. sec. 1-1.

[96] OTA Software Workshop; also Michael Greenberger, op. cit., footnote 93; and M. Greenberger et al., op. cit., footnote 94.

[97] DoD Directive 3405.1.

[98] The original Ada mandate was issued as a memorandum from then Under Secretary of Defense, Richard DeLauer. But at the time of DeLauer's memorandum, there was a scarcity of validated, and more recently, performance-quality Ada compilers and development environments available in the industry, This situation has recently changed—the *Ada Information Clearinghouse reports that the* number of Ada development projects increased from 35 in August 1986 to 315 in September 1988. During the same period, the number of validated Ada compilers rose from 74 to 153, with an additional 65 compilers derived from these base compilers for similar hardware architectures. The market for Ada compilers, tools, environments, and training is growing at a compound annual growth rate of 35 to 40 percent and should exceed $750 million by 1990; see Jeremy Tennenbaum, op. cit., footnote 2.

compilers, tools, and in banking and communications applications.[99]

The merits of a single, standardized language will always be debated. In the case of Ada, the benefits include its embodiment of engineering techniques essential to the development of maintainable software; its support for modular (and reusable) components necessary in the development of large-scale, integrated systems; and increased portability among computer architectures. Additionally, because Ada was standardized early and trademarked, there are none of the incompatible dialects that have long been a problem in the software industry.[100] These characteristics may bridge some of the technological differences between the civilian and military sectors.

Whether Ada becomes an area of convergence, rather than a barrier, remains to be seen. Because the DoD remains the single largest consumer of software, and remains committed to the use of Ada, the language is potentially a major factor in future software technologies. Its potential, though, contrasts with the current situation where many military mission-critical applications are required to be implemented in Ada, while similar civilian applications will continue to be developed in the language thought best for that application.

Military Hardware Requirements

Requirements for hardened computers often result in the DoD buying specialized computers for some embedded and mission-critical systems. Given the close relation between hardware and software in these systems, this situation limits the potential number of vendors who can develop software for these applications. It is particularly evident in the Navy, which typically contracts for special-purpose, non-commercial, hardware.[101] These specialized hardware requirements exacerbate the incompatibility that exists among many software systems with similar applications. Barriers of incompatible interfaces, languages, operating systems, and protocols created between militarized hardware and commercial hardware architectures make it less likely that any transfer can or will occur between the defense and civilian software sectors.

[99] Source: OTA Software workshop: also: John Burgess, "'Universal' Computer Language Finally Takes Hold at Pentagon," *Washington Post*, July *17, 1988, pp.* H1, H5.

[100] Ada was originally trademarked to prevent the creation of "supersets" (extensions) and "subsets" of the language—all implementations of the language must meet MIL-STD 1815A fully to be considered Ada. This, combined witb the requirement that all Ada compilers pass a validation (conformance) process, helps ensure that Ada is portable across computer architectures.

[101] Based on the Navy's Next Generation Computer Resources Program briefing to OTA.

Appendix G

European Organizations and Policies for Research and Technology

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Appendix G

European Organizations and Policies for Research and Technology

INTRODUCTION

This appendix focuses on the approaches European government and multilateral groups employ in sponsoring research and technology. Among the countries reviewed are the United Kingdom, France, West Germany, Italy, Sweden, the Independent European Program Group (IEPG) and the European Community (EC) have been studied. The following country summaries and concluding review of collaboration contain some "themes" that may apply to the U.S. Department of Defense's Science and Technology operating concepts.

Overall Findings

1. There appears to be a trend for governments to reduce funding for defense research and technology (R&T) and to place more emphasis on broadly based (civil) research. Industry, in turn, is expected to introduce new technology into defense products and systems at the "applications" stages.
2. Civil research programs are increasingly established as "national (or strategic) goals." Although specific projects retain some latitude, the trend is toward more central direction and control. Financial control from the top is becoming the norm.
3. Although there is a widespread demand that governments receive "value-for-money" in research, "peer review" remains the standard method of assessing results. Several nations are examining more elaborate schemes,
4. Research costs are prompting nations toward both rationalization and collaboration. In the case of rationalization, separate research activities are being merged, with "centers of excellence" becoming a common means to assemble sufficient scarce resources to make headway in selected (strategic) technology areas. Collaboration has also become a way of life for governments, companies, and academia. The Single European Act, creating a single economic entity in 1992, is giving this trend an added push.
5. Universities appear to play a major role in both formulating and executing national research policies. A significant percentage of national R&T budgets goes into academia, with strong links encouraged between universities and industry to effect "technology transfer."
6. There has been some backlash, especially among those European industrialists who question the wisdom of emphasizing technology-based industrial growth. Their dominant concern is that Europe take care to invest in technologies that are new and unique, rather that continue to "chase" the United States and Japan for a share of today's markets.
7. Most countries view space research as a major area for R&T funding. It appears that this area has replaced defense as a "locomotive" for research, providing potentially lucrative spin-offs for commercial market exploitation. In the view of industry, however, these expectations have not materialized.

1992 and the Single European Act

Overview

Europe's potential can be summed up by the date 1992, when Europe is to become a true common market. A campaign that began with the original commitment establishing the European Economic Community aims to propel its 12 nations[1] toward a common market in which goods, people, services, and capital could move unrestricted among member nations.

1 Ireland, Britain, Portugal, Spain, France, West Germany, Belgium, Luxembourg, Holland, Denmark, Italy, and Greece.

Background-In the early 1980s Europe, with decreasing revenues and high employment, found itself lagging in comparison with America's and Japan's strong economic positions. In 1985 the new EC President, Jacques Delors, a former French finance minister, toured the member states and found growing support for a renewed campaign for a true European market. Lord Cockfield, a British Conservative ex-businessman, was the EC Commissioner charged with drafting a White Paper on the subject. He drafted a list of 300 initiatives that would be needed to produce a wholly unified European market.[2] Cockfield laid out an accompanying timetable to accomplish these initiatives over the next two EC Commissions' 4-year terms (1985-88; 1989-92). The target completion date was the end of the second term—December 31, 1992.

Although 20 or more of the original 300 initiatives have since been dropped or replaced, the magic round number represented all that European governments wanted. They accepted the challenge and passed the Single European Act, which became effective on July 1, 1987. This Act states:

> The Community shall adopt measures with the aim of progressively establishing the internal market over a period expiring on 31 December 1992 . . . The internal market shall comprise an area without internal frontiers in which the free movement of goods, persons and capital is ensured in accordance with the provision of the Treaty.

Member Nations Support-Of the 12 member nations, France embraces 1992 with the most passion, with polls showing that more than 70 percent of French companies regard "quatre-vingt-douze" as a golden opportunity. This attitude was promoted by a new French Government that despises old French habits of "dirigisme." West Germany's industrial giants are also eagerly awaiting 1992. The large chemical companies-Bayer, Hoechst, and BASF—are confident that no one can beat them in a free market. Italy's industries, such as Olivetti, are leading their government in supporting 1992 concepts. Some say this is a timely accompaniment to an Italian industrial trend to create Europe-wide business empires. Some of the medium-sized companies are less optimistic, and smaller nations are resigned to accept what they cannot control.

The biggest surprise is the United Kingdom, which could benefit the most from a free market (especially in the areas of finance and insurance). A 1988 survey by the accounting firm of Ernst & Whinney found that fewer than 40 percent of British company directors were aware of 1992 plans in the EC. In financial services, an area where Britain should dominate, fewer than 30 percent of companies had planned for the 1992 goals. However, British businessmen have launched a Club 1992 to discuss the implications of a single market, and the government is promoting a publicity campaign in support of 1992. Prime Minister Thatcher now insists, "It is not a dream. . . it is for real, and it is only five years away."[3]

Other European Nations-Outside the EC, the six countries of the European-Free Trade Association (ElTA),[4] fear that they are going to lose their "good deal.'* Each has a free-trade agreement with the EC, permitting duty-flee access to EC markets and vice versa, without having to share in the cost of supporting the EC's farm policy. They fear that once 1992 arrives, they will become outsiders; to prepare themselves, they are now modifying their relations with the Community. Although the neutrality issue keeps Sweden and Switzerland from joining the EC, Austria may apply for Community membership sometime in the 1990s. Unencumbered by neutrality, Norway may ask to join after its 1990 elections. But the EFTA ministers have already called for a proper system of consultation between the two groups, and are ready to cooperate with the community in new fields of industrial research, the environment, and education. They hope to create a "single European economic space" (without agriculture, of course) that would encompass a Western Europe of 18, not 12, members.

Japanese Actions-Scores of Japanese corporate planners are visiting Europe to analyze the 1992 phenomenon. It appears that Japan, viewing the EC as "safer" than the protection-prone American market, is turning its export focus towards Europe. Japanese firms such as Nissan, NEC, Fujitsu, and

[2] Commission of the European Communities, "Completing the Internal Market," A White Paper prepared for the European Council, COM (85) 310 Final, Brussels, June 14, 1985.

[3] M. Thatcher to British businessmen, reported in *Christian* Science *Monitor,* June 27, 1988, p. 111.

[4] Switzerland, Austria, Sweden, Norway, Finland, and Iceland.

Toshiba are targeting direct investments to two or three EC countries, building factories from which they aim to serve the whole Community. They are watching the European market closely, ready to grab any opportunities as frontiers come down.

Fearing the economic strength of a Washington-Tokyo connection, many EC members believe direct Japanese investment in the EC could enliven the European economy-as American multinationals did when they set up European plants in the 1950s and 1960s. To do this, however, Japanese firms in the Community would have to become part of the local economy; they would have to transfer technology from Japan to Europe and buy more components from European suppliers. They would have to abandon their current practice of setting up "screw-driver plants," in which the final product is largely made up of parts imported from Japan.

EC and the COMECON-The EC and the Soviet-led economic bloc COMECON (Council for Mutual Economic Assistance) signed a joint declaration of mutual recognition on June 25, 1988. This will boost trade and economic ties with COMECON and enable the EC to open diplomatic relations with individual COMECON members.

With a potential market of more than 400 million consumers, COMECON traded a total of just under $50 billion with the EC in 1987. EC officials view the East Bloc as a highly underdeveloped market for exports. They are watching closely to see if *glasnost* will succeed, and whether that will open the way for increased trade opportunities with the East Bloc.

Analysis

Economic 1rnplications-Dissolving the frontiers of the European Community means that all 12 countries will be using just one passport, stamped EC, with the EC symbol (a circle of 12 gold stars on a blue background) on the front. Individual country citizens will now be EC citizens-able to live anywhere in the EC they want, able to practice their profession in any of the 12 countries, able to retire to any EC area they desire.

However, the true impact of the Single European Act will be economic. A recent study, "The Cost of Non-Europe,"[5] estimated that the customs costs attributed to border delays and trade barriers might run as high as 8 billion ECUs[6] to firms and 1 billion ECUs to governments. This study supports the long-held belief of many European industrialists that the governments' nationalistic policies have retarded the growth of strong, world-class companies in Europe.

Given such savings, calculation indicate that 1992 lifting of frontiers could result in an increase of up to 7 percent in gross domestic product (GDP) and 5 million new jobs.[7]

The Market

Selling to a Single Market—For business, the single market is welcome. The EC estimates there are more than 100,000 technical regulations and standards (most often in high-tech sectors) where market fragmentation places Europe at a major competitive disadvantage vis-a-vis American and Japanese competitors. In electronics and engineering, the different requirements will be reduced or eliminated. For the Netherlands-based electronics giant Philips, it means making one kind of television set instead of 12. For the transportation companies, who face appalling obstacles of frontier documentation and corruption, it means cutting delivery time and costs in half.

What it does not mean is marketing a product in the same way. If the companies are to be competitive, they will have to shift their emphasis to an expanded market outside their national boundaries. In this respect, the larger EC companies already have an edge. Accustomed to different marketing strategies for different areas, the larger conglomerates show no fear in the face of 1992; they have subsidiaries in many countries. It is the smaller and middle-sized companies of the EC member nations that are going to have to play "catch-up" in marketing strategies in general (with a "pan-European" flavor specifically)-an area where they may lack experience.

[5]Commission of the European Communities, "The Cost of Non-Europe: Basic Studies" (vol. I), 1988.

[6]The European Currency Unit (ECU) is the unit of accounting used by the EC. Its value is set by a basket of European currencies. 1 ECU= US $1.23. (November 1987 ratio).

[7]Commission of the European Community, "'he Economics of1992," No. 35, March 1988.

European Industrial Mergers—The problems that small and medium-sized European firms anticipate have generated several hundred industrial mergers since 1985. These mergers are especially significant in the software industries. The CAP group, a British software and services company, has announced a merger with France's Sema-Metra to form Semacap. There was a similar deal between two British companies, Systems Designers and Scicon, the latter of which also has interests in France, West Germany, and America. *These mergers create companies that can sell in the American market and compete with American companies in the emerging pan-European software business. The two* new companies, Semacap and SD-Scicon, are now rated second and third, behind Europe's premier software firm, Cap Gemini Sogeti of France. The thinking is that pan-European software companies stand the best chance of winning contracts from European giants in retailing, communications, and financial services.

With estimates that the European software and services market will grow from under $50 billion today to about $250 billion by 1996, competition between American and European companies is now likely. In the past, Europe's software market has been fragmented by language and culture; now, more companies are becoming international. And as information technology becomes more complex, customers are turning to "one-stop shopping," rather than assembling a different package themselves. Although vendors are now adopting international standards that make it easier for computers to talk to each other, the large American computer firms should continue to hold the edge in Europe for a while-unless they fail to adapt.

A hostile takeover bid for the Belgian conglomerate Société Générale de Belgique in early 1988 represented, for some, the downside of 1992 economics. The Italian financier Carlo de Benedetti, who finally settled for a minority interest in Générale (plus a stake in the French financial group Suez and a $1 billion profit), works as if 1992 already exists. One of his aides explained it: "He says if he is really a European there is no reason, for instance, [not] to meddle in French politics. We are all part of the same country."[8] The recent GEC/Siemens bid to take over Plessey and Plessey's countermove with Thomson-CSF and possibly AT&T are other examples of how the "takeover game" is heating up. The effect on Europe's defense technology base will be profound, but is yet uncertain.

Public Procurement-The buying of goods and services by national and local governments and public and private utilities amounts to about one-sixth of the EC's GDP. Strong nationalist interests have resulted in an abundance of duplicative production: 11 EC telephone exchange manufacture, 10 turbogenerator manufacturers, etc. Although the EC has been compelled to put large construction contracts (anything over 1 million ECUs) out to Europe-wide tender since 1971, and to do the same with other large purchasing orders (above 200,000 ECUs) since 1977, just 2 percent of orders in each category go to other European countries.

There are four main aims of the procurement part of 1992:

1. to broaden the scope of, and block loopholes in, existing obligations;
2. to give the EC greater police powers over regulations;
3. to improve redress procedures for disappointed offerors; and
4. to extend open procurement to businesses that have remained exempt until now (energy, transport, water, and telecommunications).

Impact on NATO and European Defense—Members of the EC include all European NATO members except Iceland, Norway, and Turkey. Only one EC country, Ireland, is not a member of NATO. Although the EC charter maintains that the Community is an economic body uninvolved in defense matters, anticipated changes are so broad that almost all aspects of European defense operations will feel their impact.

Like most EC officials, European defense ministers resist the 1992 changes out of a reluctance to surrender the political power they now hold. However, European economic unity may require the establishment of central procurement agencies, such as those the Independent European Program Group is now studying for defense purposes. More centralized research and development will be necessary to avoid duplication and cut costs. A European R&D agency like the U.S. Department of Defense's

[8]"Businessmen: They Grow Than Bigger Now in Europe," *The Christian Science Monitor,* June 28, 1988, p. 118.

Defense Advanced Research Projects Agency (already recommended by the 1986 IEPG report, “Towards a Stronger Europe"[9]) could assist in expanding a European technology base. Multilateral European projects like the European Fighter Aircraft, will have to change their form to accommodate the economic realities of a single European market. International consortia will compete for European defense contracts without the added burdens of different national policies (e.g., financial, industrial, etc.)—and the implications for U.S. defense/aerospace firms will be significant.

Impact of Advanced Technology-Accompanying Europe’s concern about its economic position in world trade is a heightened sense of concern about its technological future. Many papers have focused on this issue, with some suggesting that Europe’s problems lie in the failure to organize properly for exploiting innovations with commercial potential.[10] Many European companies still rely on home markets or operations dedicated to each national market. Breaking down the barriers that have isolated European companies from each other, as well as from other European national markets, is an explicit objective of the collaborative high-technology initiatives now being pursued. Breaking down these same barriers is also a goal of the Single European Act.

In pursuit of technological achievements, the EC has agreed to spend 5.2 billion ECU on R&D collaborative programs over the next 5 years. Within that framework are several individual spending lines, including information technology, advanced telecommunications, biotechnology, alternate energy sources, environmental research, and nuclear safety. These subjects have their own specific research programs such as ESPRIT, RACE, and BRITE. In principle, the EC supports, but does not fund, EUREKA, a separate program approaching $5 billion in value. All of these advanced research programs support Europe’s 1992 goals.[11] European advanced-technology collaborative efforts are bound to help Europe succeed in meeting the challenge of the single market-and to compete in world markets.

Problem Issues

Trade Barriers and National Subsidies-Article 115 of the White Paper[12] allows governments to bar imports of non-EC goods “entering” in indirectly through another member country. If Article 115 were abolished, France and Italy, for example, would want higher trade barriers against imports from outside. Otherwise, they argue, non-Europeans will be the main beneficiaries of a single market. The West Germans and the British point out that, for maximum benefits, external trade policy should produce a lower rather than higher level of overall protection.

The EC has to come to terms, not only with trade barriers, but with the issue of national subsidies, which are quite high in some countries. Stiff rules against subsidies must accompany the removal of trade barriers, if the full benefits of a single market are to be realized.

A Central Bank—The financial community will gain from the completion of the internal market in 1992. Peter Sutherland, the Commissioner responsible for competition policy in the European Community, believes that the financial sector will benefit more than others, with gains exceeding $30 billion annually .13 Presently, there is a wide variety of service charges levied by banks and insurance companies. These charges will probably be reduced and brought into line with one another, so that consumers can make payments anywhere, thanks to truly European credit cards.

Changes in the European Monetary System are being made, and there are already discussions on establishing a new central bank for Europe. Yet plans for this “Bank of Europe” must go hand in hand with a common currency; more and more businessmen are now using the “ECU” as a unit of accounting in their European operations. A central bank with a common currency would bring about monetary stability in Europe, as it merges EC

9Independent European Program Group, "Towards a Stronger Europe,” vols. I and II (Brussels, Belgium: NATO Headquarters, 1987).

10See for example, Commission of the European Communities, op. cit., footnote 5.

11See Commission of the European Communities, op. cit., footnote 7.

12Commission of the European Communities, op. cit., footnote 2.

13"Window on the European Community," in "A Letter From Europe: A Monthly Update on the European Community From Its Delegation in Washington," No. 51, June 14, 1988, p. 4.

members into one economic unit. The microeconomic benefits that would result from a single market-no border delays, greater efficiency thanks to larger markets, and more effective competition-would be multiplied by a single currency. A macroeconomic gain could also be achieved. With monetary policy no longer under national political influence, reckless spending would give way to financial stability and lower inflation.

The EC summit meeting in Madrid in June 1989 will review the report and recommendations of EC committees studying monetary policy. Since the committee is headed by France's former Finance Minister Jacques Delors, who has just been reappointed to the EC Presidency for another 2 years and is the prime driver in the movement toward 1992 goals, it is anticipated that the meeting will recommend a central bank and a common currency.

Value-Added Tax-One of the biggest problems the EC will have to overcome is the wide variance in member nations' value-added tax (VAT) (similar to a sales tax). Current variations range from O to 33 percent. In a frontier-free economy, this variation would allow citizens to go shopping across the border where prices were cheaper. The EC has proposed two bands of VAT: a standard rate of 14 to 19 percent and a rate of 4 to 9 percent for "necessities."

Conclusion

"Fortress Europe''—Many Americans fear that 1992 will mean a "Fortress Europe''-impenetrable to outside competitors. Europeans officials loudly proclaim "No!" "If Europe is strengthened internally," says Lord Cockfield, "there will be less fear, less need for trade protection, not more."[14] "We are each other's biggest and best customers," says EC Commissioner de Clercq. However, accompanying those reassuring words is an underlying message that Americans should heed—because the Commissioner goes on to say: "The Community . . . will actively share (benefits) with *those who are willing to cooperate with us."*[15] *The* downside of 1992 is that Europe intends to be stronger, more competitive— a potent rival in world trade and a hard negotiator in trade talks. Reciprocity will be a key to dealing with the Europe of 1992.

The United States is currently the EC's largest trading partner-about $133 billion in 1986, $53 billion of which consisted of American exports to the EC (double the value of American goods sold to Japan). However, Americans are still wary of potential European protectionism. Alfred Kingon, U.S. Ambassador to the Community cautions: "When I speak to EC leaders, I receive reassurances that the Community will not become 'Fortress Europe'. But when I hear talk of 'nurturing' industries, I become concerned."[16]

U.S. Industry-Segments of U.S. industry are gearing up for 1992. Giants like IBM, Ford, and AT&T have set up planning groups to develop strategy. As things stand, both their subsidiaries in EC countries and teaming efforts with European companies place them in a strong position-IBM has subsidiaries in every EC country; Ford operates assembly plants in six European nations; and AT&T is in partnership with Olivetti of Italy, Philips in the Netherlands, and Telefonica in Spain. *Inside-Europe sales by U.S. subsidiaries dwarf U.S. exports to* ***Europe: $500 billion*** *in 1987 compared to $75 billion in U.S. exports to Europe. They are* ready to seize the opportunity to sell to this unified market of 320 million people. On the other hand, the "smaller" American companies will feel the competition, as the European companies grow larger and stronger through mergers and acquisitions and expand their "target" areas, venturing into countries previously closed to their sales.

U.S. companies' ability to compete with a unified Europe-and Japan-in global markets will require new attitudes and strategies. In an intense international economic competition, technological isolationism is not an option. Markets are becoming increasingly international and information flows worldwide despite restrictions imposed by government or industrial organizations. A recent study by the National Academy of Engineering (NAE)[17] suggested that better focused efforts are needed for

[14] "Setting Sights Boldly on *Unity," Christian Science Monitor,* June 27, 1988, p. 10.

[15] "U.S. Begins Assessing Impact of 1992 Deadline," *Europe, May* 1988, p. 15.

[16] "Toward Real Community," *Time*, Apr. 18, 1988, p. 55.

[17] National Academy of Engineering and Office of International Affairs, "Strengthening U.S. Engineering ~ @ International Cooperation: Some Recommendations for Action. " (Washington, DC: National Research Council, 1987).

the United States to remain a leader in world markets. There needs to be a new level of international collaboration on technological issues and an increasingly international outlook of major corporations. Once again, it is the small and medium-sized companies that are at a disadvantage. Most of them lack the resources of large companies for accessing international markets and technical developments. "Banding together" must become commonplace-and government policies must be set to encourage this process.

U.S. Government-Industry alone cannot be responsible for U.S. international competitiveness. In a 1988 report, an NAE committee on technology issues that affect international competitiveness[18] outlined several areas in which U.S. Government policies must respond to the global challenge. There must be, the committee said, a reassessment of the Federal Government's role to support and enhance U.S. competitiveness. There must be government policies that stimulate industry to create new products and improve productivity. A climate must be created for the early development of innovative technologies, as well as for promoting industry consortia and joint government/industry/academia cooperation. In a 1992 environment, U.S. protectionist policies will only hamper U.S. efforts in an increasingly competitive global market.

U.K. POLICY FOR RESEARCH AND TECHNOLOGY

Background

Civil v. Defense R&D Trends

Throughout 1986 and 1987, the U.K. *S policies for R&D were subjected to intense scrutiny by the British Govemment, Parliament, industry, and the scientific community. In mid-1987 the government published its plans for sweeping changes in the management and funding of R&D in the United Kingdom, including a restructuring of university science programs.[19] The proposal, which p1aced a strong emphasis on exploiting the economic potential of research, were drawn up after sharp criticism earlier that year from a House of Lords Select Committee of the Government's $9 billion annual R&D effort.[20] (Note: Funding levels are given in US$ with an exchange rate of US$l.89/l pound sterling.) The Lords said that the R&D strategy lacked coordination, particularly in the way research was applied to industry. If the advance of science and technology were to restore and sustain economic growth and prosperity, they said, its promotion should be a central objective of government policy, with the impetus coming from the Prime Minister.

As reported in the 1987 Annual Review of Government Funded R&D issued by the Cabinet Office,[21] the Ministry of Defence spent 52 percent of total government R&D in the year 1985/86. This high proportion of total R&D dedicated to defense has generated widespread concern among economists and industrialists of all parties that *defense may be crowding out valuable investment in the civil sector.* In its 1987 Defence White Paper** the government noted this concern and announced that it would, over the next few years, take a closer look at defense programs with a large R&D element to ensure that government funding was essential. Significant reductions in funding could, therefore, be expected in 2 to 3 years as defense R&D became more efficient and competitive-and as Britain reduced its duplication of Allies' research efforts through greater collaboration. The aim would be to release more government money to support the civil sector, in both industry and academia.

Beside the need to transfer R&D funds from defense to the civil sector, there was also a clear desire both in government and industry for greater civil spin-off from R&D carried out by the government's Defence Establishments. Several initiatives have been introduced, both to exploit technologies within the Establishments for the benefit of the civil sector, and to offer selected facilities for use by industry.

In implementing its new R&D policy, the British Government sees two challenges: 1) to target

[18]National Academy of Engineering, "The Technological Dimensions of International Competitiveness" (Washington, DC: 1987).

[19]"Civil Research and Development," Cmnd 185 (London: Her Majesty's Stationery Office, July 1987).

[20]"Civil Research and Development: Report of the Select Committee on Science and Technology," vol. I (HL 20-1), British parliament, House Of Lords, November 1986.

[21]"1987 Annual Review of Government Funded R&D," Government Statistical Service, United Kingdom, 1987.

[22]"Statement of the Defence Estimates 1987," CM 101-1 and 11 (London: Her Majesty's Stationery Office, 1987).

scientific and technological resources without constraining individual creativity; and 2) to coordinate parallel R&D programs without divorcing them from the individual objectives they are meant to serve. The new policy has been given an impetus by the government's acceptance of two principles: 1) the collective ministerial consideration, under the Prime Minister's leadership, of science and technology priorities; and 2) the creation of an independent advisory body to comment, not only on British scientific and technological endeavor, but on international efforts as well. The government's aim is to harness Britain's total R&D resources, both civil and military, in a science and technology program that will enhance both the U.K. economic growth and its defense capability. To assure value for money, a government committee will coordinate and oversee the more-or-less independent civil and military programs.

The 1987 Annual Review of Government Funded R&D reflects the status of departmental plans as of July 1987. It does not take into account the changes agreed during the Public Expenditure Survey held in fall 1987; these changes will be reflected in the forthcoming Public Expenditure White Paper.

Total spending in 1985/86 was $8.5 billion, of which 52 percent was spent by the Ministry of Defence (MoD). Civil spending was $4.1 billion, over half of which was in the Research Councils and universities. Civil Departments, such as the Ministry of Agriculture, Fisheries and Food, the Department of Energy (including the U.K. Atomic Energy Authority), and the Department of Trade and Industry (DTI) accounted for less than 22 percent of spending on R&D. Government R&D expenditure was 2.9 percent of total Government expenditures in 1985/86. Compared with 1984/85, the final figure for 1985/86 was 6 percent higher in current prices; spending on defense R&D was 7.5 percent greater, compared with a rise of 4.4 percent in civil R&D.

The $8.5 billion government expenditure on R&D in 1985/86 is expected to increase to $9.2 billion in cash terms by 1989/90. Total civil spending is expected to increase by 12.8 percent to $4.65 billion, and defense by 2.9 percent to $4.55 billion. However, these are net reductions in real terms, with defense R&D spending programmed to fail by 10 percent and civil by 5 percent in constant value. In the 1988 Defence White Paper[23] the total defense R&D expenditure for 1987/88 was given as $4.43 billion, with the following breakdown:

	Research	*Development*
In-house	$0.48B	SO.89B
Contracted out.	$0.28B	$2.79B
Total	SO.76B	$3.68B

The "push" in government for a more even distribution of government R&D funds between military and civil sectors has come from Mr. John Fairclough, Chief Scientific Adviser to the Cabinet, with support from DTI. But in recent years a widespread view among economists, industrialists, and politicians has been that, compared with many other countries, Britain directs too large a share of the R&D funds to a relatively small sector, defense. Their main arguments are that those countries spending least on defense R&D have prospered most—Japan, West Germany and, to some extent, Italy. Although France and the United States direct a high share of government R&D into defense, they are seen as richer countries anyway, also spending more on civil R&D. The second concern, as the 1987 Defence White Paper puts it, is that Britain's pool of scientists and engineers is " . . . not inexhaustible. . . ," and". . . it would be regrettable if defence work became such a magnet for the manpower available that industry's ability to compete in the international market for civil high-technology products became seriously impaired. " Some believe that has already happened.

The Levitt Report in 1985[24] found a perverse correlation between defense procurement and productivity: in the electronics components sector, which in the United Kingdom depends very little on military sales, productivity was rising quickly, while in the radio, radar, and electronics capital goods sector, which does depend on military sales, productivity growth was negative. It also found that the inflation rate for defense procurement was significantly higher than the national rate of inflation—even for dual-purpose products like oil and non-military vehicles. Other analyses of the benefits (or lack thereof) to the British economy from expenditures on defense R&D reached broadly similar

23"Statement of the Defence Estimates 1988" (London: Her Majesty's Stationery Office, 1988).

24M. S. Levitt, "The Economics of Defence Spending," National Institute for Economic and Social Research, London, 1985.

conclusions. The essential point is that, of the $4.55 billion spent on defense R&D, only $0.75 billion was spent on research as opposed to development—and much of defense R&D was thought inherently unsuitable for civilian use. Most defense R&D led to product innovation, while much of the innovation on which civilian industry depended was in improvements to manufacturing processes; it was mainly through process improvements that companies competed to achieve price and/or quality advantages.

House of Lords Select Committee Report

The comprehensive report by the Select Committee on Science and Technology of the House of Lords focused on civil R&D. Specifically, a subcommittee was set up to consider "the policy and practice of public support for civil science and technology in the United Kingdom," with four main areas of inquiry:

1. the organization of civil R&D;
2. sources of funds for basic, strategic and applied R&D;
3. the working of the customer/contractor principle; and
4. the civil implications of defense research.

Although it had no charge to analyze the management of defense R&D except for spin-off, the Select Committee Report embraced the "annual" or "whole" national R&D effort, which must include the defense element.

The report described *the central weakness of Britain's annual R&D effort as its fragmentation and lack of coordination,* with flagging morale among scientists and a low level of public interest in R&D-particularly in the City (London's "Wail Street"). The committee called for companies to disclose their R&D investments to encourage "financial interests to take R&D strength more into account when weighing a company's future prospects." The report recommended that a Cabinet Minister should take responsibility for the national R&D, with a central body to coordinate the whole effort and that a new source for public funding of R&D should be introduced to supplement present mechanisms. The new source would finance "strategic" research, which was defined as that undertaken with eventual applications in mind-even when these could not be clearly specified. Only in the 1980s had such research been identified as a distinct category, funded as if it were basic research, with no specific application in mind, through a dual-support system involving the science budget of the Department of Education and Science and the University Grants Committee. -

The Lords urged a third route "for funding that strategic research which is of most significance to the United Kingdom's economic future." But they also saw the Research Councils and Government Departments, as proxy customers in non-commercial fields, retaining responsibility for some strategic research. They also criticized the research community's own efforts to evaluate the performance of research, finding its approach "less scientific than the science and technology it is designed to assess." The Committee suggested that about 1 percent of all government R&D funds should be spent on evaluation, which must be approached as a discipline, and not as a threat.

Among the 39 conclusions and recommendations of the Lords' report were the following:

- The advance of science and technology, which is essential to the economic recovery of the country, must be a central objective of government policy.
- Anew impetus is needed to raise the morale and focus the effort of the scientific community and industry. This requires action at the highest levels of government.
- Neither government nor industry is spending enough on R&D to restore Britain's industrial position in world markets.
- Departmental policies and spending on R&D must be looked at horizontally across the whole of government, in addition to the traditional vertical look by individual Departments.
- A Cabinet Minister should be designated to be responsible, under the Prime Minister, for the science and technology dimension of governmental policy and the promotion of national effort in R&D.
- A Council on Science and Technology (chaired by the Prime Minister) should be established, with the designated Minister as deputy. Its Secretariat should be located in the Cabinet Office under the Chief Scientific Adviser. It would oversee the whole of scientific and technological endeavor.
- The five Research Councils should as far as practicable harmonize their administrative procedures, criteria, and approaches and work

more closely on corporate planning, marketing of results, and external relations.

- Strong management and clear decisions about priorities between Research Councils are essential in present circumstances.
- The customer/contractor principle for R&D funded by government departments is endorsed.
- Beside the dual-support system and the customer/contractor principle, a third method of public funding of R&D is required. To this end, a process should set in motion to fund that strategic research of most significance to the United Kingdom's economic future.
- The government should assist in funding the process for generating strategic research in exploitable areas of science, and should make new pump-priming funds available for research generated by the process.
- Any other initiative to ensure that the government's R&D funding makes a greater contribution to the economic well-being of the country is to be welcomed, but it must be adequately funded and its relationship with exploitable areas of science must be clarified.
- The Science and Technology Assessment Office (STAO) is welcome to carry out its assessment function, as well as to evaluate the operation of the exploitable areas of science. Approximately 1 percent of all government R&D expenditure should be devoted to evaluation.
- Closer links between government Research Establishments and Research Council Institutes, adjacent universities, and polytechnics are desirable.
- Civil and defense R&D budgets should normally be recorded separately. The size of each should be determined by the civil and defense programs which it supports. A thorough examination of defense R&D expenditure should be an early task of STAO and the proposed Council for Science and Technology.
- The Committee welcomed recent initiatives to improve the effectiveness of defense procurement, reduce R&D costs, and increase spinoff, and recommended that further efforts be made to pursue the industrial opportunities for obtaining more civil benefit from defense R&D.
- The security classification of the results of defense R&D should again be examined with a view to introducing a more liberal policy. Further, a more detailed annual report on the results of defense R&D should be published.
- The committee recommended a high profile for science and technology, dynamic leadership at the center, and a new approach to funding R&D.

The Lords' report has been covered at length because the British Government has incorporated much of it in its new science and technology policy. Some actions were taken before the committee had finished its inquiry, causing the committee to report that it had "sometimes felt they have been operating on a moving staircase."

U.K. R&D Program Overview

The Politics of Research and Development

The Government's Response—The government published its interim response to the report of the House of Lords Select Committee in July 1987.[25] The 1987 Conservative election manifesto had given an early indication of the government's intended policy with the following:

> Government support for R&D amounts to more than 4500 million pounds sterling [$8.5 billion] per year. It is larger as a share of our national income than that of the United States, Japan, or West Germany. A country of our size cannot afford to do everything. These resources need to be better targeted. The task of Government is to support basic research and to contribute where business cannot realistically be expected to can-y all the risks. We will ensure that Government spending is firmly directed towards areas of high national priority by extending the role of the Advisory Council on Applied Research and Development, drawing on the full range of advice from the academic community and business.

All that was missing in the manifesto statement, from what was eventually to become the new policy, was the commitment to fund it and the establishment of new centers of excellence independent of the universities.

[25] "Civil Research and Development, Government Response to the First Report of the House of Lords Select Committee on Science and Technology, 1986-87 Session" (London: Her Majesty's Stationery Office).

These components were still missing when the government published its initial response to the Lords' report. However, it did accept the two principles mentioned earlier: collective ministerial consideration, under the Prime Minister, of science and technology Priorities; and advice by an independent body, which will comment not only on the whole of British scientific and technological endeavor, but on international efforts as well. The first of these two principles was decoded by the press and others[26] to signify the establishment of a Cabinet-level Committee on science and technology, chaired by the Prime Minister. Although the existence of this committee and its work are probably shrouded in the Official Secrets Act, it appears from leaks and government briefings that the committee will have four main tasks:

- considering important ad *hoc* issues, e.g., U.K. involvement in space and nuclear research;
- considering major policy developments in science, e.g., the government's response to the Lords' report;
- overseeing reviews of particular parts of government-funded R&D in relation to general policy considerations; and
- undertaking an annual review of science funding priorities as a major input to the Public Expenditure Survey process, beginning in 1988.

This last task is thought to be particularly important as, for the first time, it appears that government will scrutinize the level and distribution of its R&D expenditure across all departments. The new advisory body will be known as the Advisory Council on Science and Technology (ACOST), with an independent chairman reporting directly to the Prime Minister.

Soon after his appointment as Chief Scientific Adviser in 1986, John Fairclough established the Science and Technology Assessment Office within the secretariat of the Cabinet Office. Its terms of reference were, broadly:

- to establish a central body that will analyze the contribution made by each component of government-funded R&D to the efficiency and competitiveness of the economy,
- to advise ministers and officials on the shape, content and conduct of the national program, and
- to advise on priorities in spending.

The STAO will complement the activities of ACOST by analyzing data gathered by it. The Lords' Report welcomed the STAO in its own right-and hoped that it would "help evaluate the operation of the exploitable areas of science process." As noted earlier, the Lords had recommended that approximately 1 percent of all government R&D expenditure should be devoted to evaluation, having found that the research community's own efforts to evaluate the performance of research are inadequate. Throughout all documents consulted in this study, no measure of research quality has been mentioned other than a count of patents or published scientific papers; in all cases, evaluation of research has been by subjective peer review.

The ABRC's Strategy for the Science Base—Published together with the Government's response to the Lords' report was a discussion document prepared for the Secretary of State for Education and Science by the Advisory Board for the Research Councils (ABRC), and called "A Strategy for the Science Base."[27] The ABRC includes the Government's main scientific advisers, as well as representatives from industry and the universities. Although the document did not have unanimous ABRC support, there was consensus that British science was underfunded and underdirected, and that research was too widely spread. It was also agreed that universities and other institutions in all fields of experimental science lacked staff and resources with which to compete in the international arena, and that some rationalization was needed. Earth sciences research, for example, was distributed over 54 departments in 41 university institutions.

The ABRC suggested that the provision for science in the universities would have to be fundamentally reordered, and proposed the following re-categorization:

[26] Sir David Phillips, "A Strategy for Science in the U.K.," The International Science Policy Foundation's 1987 (23rd) A.Mild Lecture, Science and Public Policy, February 1988.

[27] Advisory Board for the Research Councils, "A Strategy for the science Base" (London: Her Majesty's Stationery Office, May 1987).

- Type R: Institutions offering undergraduate and postgraduate teaching and substantial research activity across a range of fields.
- Type T: Institutions highly competent in undergraduate and MSc teaching, with staff engaged in the scholarship and research necessary to support and develop that teaching, but without provision of advanced research facilities.
- Type X: Institutions providing teaching across abroad range of fields and engaged in substantial, world-class research in particular fields where they are already preeminent or could achieve eminence in collaboration with other institutions.

The ABRC did not recommend that such differentiation be imposed from above but that, as Sir David Phillips, the ABRC Chairman, emphasized:

> **Significant** responsibility will rest on the institutions themselves in identifyng their main strengths and future roles, in developing collaborative arrangements, and in pursuit of the necessary restructuring. We recommend that the Research Councils should collaborate with and, where appropriate, prompt institutions to bring about appropriate concentration of research activity."[28]

The ABRC also called for interdisciplinary research centers associated with Type R institutions, and with the Type X institutions which can make a good case collaboratively. It wanted much of the research councils' support for universities channeled through such multidisciplinary centers, which "would each have a positively managed coherent programme of work undertaken by a small number of core staff and visiting teams of researchers." It wanted to see Type R and X institutions bidding to host such centers, and for all additional equipment, materials, technical and support costs to be transferred from the universities to the research council concerned.[29]

These proposals challenge the universities as now run; since the Robbins Report of the 1960s they have been seen as equals. Acceptance of the proposals would mean that Britain could not remain at the forefront of all the sciences. There might be some areas from which the country would have to withdraw altogether at the advanced level—and someone would have to decide which these were. Until now, priorities for research have been made on a somewhat ad hoc basis; while budgets have been reasonably constant under the Conservative government, salaries and the cost of equipment have risen. At the same time, because industry expected a growing science base to help it compete internationally, it had to set some priorities. The ABRC proposed that they and the research councils should *adopt new common criteria for gauging priorities in science, taking account of timeliness, pervasiveness, excellence, exploitability, applicability, and significance for education and training.* It also urged the research councils to give higher priority to programs of research and research training undertaken collaboratively with users, to increase the chance of exploitation and reduce the information gap between business and science.

The ABRC document went further. Not only did it call for a wholesale reorganization of British science, it wanted it immediately. "Additional funds will be necessary to facilitate the necessary transition from a widely distributed university research base to a system in which fewer centers are equipped to world class standards, including funds for the establishment of university research centers and for further re-structuring of Research Council institutes. The Government should adopt a business-like approach to this essential investment in restructuring . . . .If our centers of excellence are to be equipped to compete internationally and to provide U.K. with the support it needs, the centers must be adequately resourced now. They cannot wait for the gradual release of funds from elsewhere in the system, as and when commitments can be run down within the constrained recurrent budgets."

In its turn, the government consulted universities, industry, and the various parties involved before taking any decisions on the somewhat controversial changes advocated. The government had always side-stepped policies based on "picking winners" as being too risky politically; in this case, the international scientific community at least appeared to agree on the three broadly-based "winners" of enabling technology: microelectronics, materials, and information technology.

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[28] Ibid.

[29] The United Kingdom has five Research councils: science and Engineering (SERC), Materials (MRC), Agriculture and Fisheries (AFRC), Natural Environment (NERC), and Economic and Social (ESRC).

Organizational Aspects of Government R&D Policy

Beside the Cabinet Committee on Science and Technology described earlier, the government has made other changes in the course of implementing its plan for national R&D.

Advisory Council on Science and Technology-As mentioned earlier, in mid-1987 the British Government established, as the closest advisers to the Cabinet Committee on Science and Technology, the Advisory Council on Science and Technology to help it shape the national research and development program. ACOST, which absorbed and replaced the Advisory Council for Applied Research and Development (ACARD), has an expanded charter to cover the whole of national science and technology, particularly those areas previously regarded as academic science, including the life sciences. Its principal roles are to identify areas of science and technology that British industry can exploit, and to identify areas where the government might realize substantial savings. It will also advise the government on the nature and extent of U.K. participation in international science and technology collaborations. ACOST inherited ACARD projects already begun, including a 2-year study of the efficiency of defense research under the chairmanship of Dr. Charles Reece, and a study, headed by Prof. Stan Metcalf, of factors that hinder the growth of small British companies. ACOST's terms of reference are broad and should allow advice to be offered to the government in a much more comprehensive and coherent reamer than has been possible before.

Following the various debates and studies mentioned earlier, the government made two further announcements in late 1987 as part of its plans for reshaping British science: the creation of a Centre for the Exploitation of Science and Technology (CEST) and the choice of Cambridge University to host the first of the government's University Research Centres (URC). Although just a beginning, each illustrated British Government thinking about R&D-and each was undergirded by a novel collaboration among academics.

CEST-First came the establishment of CEST, based at Manchester University. Envisaged as a think-tank, along the lines of the Brookings or Hudson Institutes in the United States, and with a Steering Committee headed by Sir Robin Nicholson,[30] CEST's role is to help improve Britain's ability to exploit R&D, imported as well as home-grown. Above all, it will back-up the ACOST, which in turn reports to the CSA, John Fairclough. CEST was conceived two years ago to bridge the gap between industry and the scientific community; over 80 percent of its finding will come from major science-based companies (18 contributed from 40 invited) and the rest from the government. Its task will be to encourage research in promising aspects of technology where there are commercial opportunities to be exploited for the national benefit. CEST will not be an agency of either the government or its university hosts, but will interact directly with industry and the research community.

The idea has always been that CEST would be hosted by a university, but would operate as an independent center under a strong executive-preferably someone with both academic and industrial experience. The successful bidders were a consortium of seven universities and polytechnics based in northwest England, which pooled talents to make their case; their proposal showed the clearest understanding of the purpose of CEST and its objectives, and it had strong industrial backing in the northwest, CEST's first Chief Executive is Dr. Robert Whelan, former Marketing Director of PA Technology (and ex-Lucas and Monsanto).

University Research Centres—As "agents of change," the new URCs have a vital role in the government's plan. Similar in concept to the Engineering Research Centers set up in some U.S. universities, they will be laboratories devoted to a specific scientific opportunity believed to be exploitable within a decade. The idea is to establish and manage a directed research program in a center of excellence, concentrating resources and expertise in order to create a "world research force. " It is thought that the Chief Scientific Adviser considers that Britain must speedily establish 30 to 40 URCs to bring about the changes he seeks in British science. Those changes can be summed up simply as a science base more responsive to society's needs and wishes.

The disciplines from which the first URCs will be chosen include:

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[30] As John Fairclough 'S predecessor as government CSA, Nicholson laid the foundations for the government's new plans for R&D.

- high temperature superconductivity (including power engineering);
- surface science;
- synthesis and characteristics of semiconductors and novel materials;
- molecular sciences;
- lasers in manufacturing;
- engineering design; and
- process simulation, integration, and control.

The National Committee for Superconductivity (a joint DTI/SERC committee headed by Sir Sam Edwards) chose Cambridge University to host the first URC because it could demonstrate that no fewer than five different departments (physics, chemistry, materials science and metallurgy, engineering, and earth sciences) were already collaborating informally on the newly discovered possibilities of high-temperature ceramic superconductors. Although CEST played no part in the Cambridge decision, it is expected to have a vital role in the grand plan and to help identify the most suitable topics for other URCs. Fairclough himself was reported to have believed that the first URC should focus on high-temperature superconductors, seeing it as a good test of academic readiness to break down traditional barriers and embark on truly multidisciplinary research programs. According to SERC, Cambridge also won because of its program of industrial liaison in the technology, including finding, equipment sharing, and staff exchanges with GEC, Oxford Instruments, PA Technology, and the Central Electricity Generating Board's research facility.

Based in the University's Cavendish Laboratory, the Cambridge URC will receive $10 million in SERC funding over 6 years and be the lead laboratory in a three-tier program of government support, The second tier will include such schemes as the Harwell-based club of companies and Oxford University departments, together with the runner-up for the first URC. (In early 1988 the government followed up by announcing a $30 million national program of research into high-temperature superconductivity, and sought proposals involving the collaboration of British industry in "clubs" (or consortia) to pursue a common objective, with which it would match investments.) The third tier will be smaller university and polytechnic efforts also funded by SERC.

Coordination of Research Into Information Technology-In May 1988 another part of the government's plan was launched, aimed at improving coordination of government-funded research projects into information technology (IT). All research onto IT, whether sponsored by the DTI or SERC, will now be done under an "umbrella" advisory organization with an overview of the entire sector, thereby strengthening links between industrial and academic researchers. This restructuring is seen as placing further emphasis on industry's responsibility for investing in product development, while the government itself is adopting a stronger role in disseminating the results of basic research, and encouraging companies to adopt a more adventurous approach to high technology.

In addition, the DTI has redirected its support for high-technology research towards collaborative European projects, particularly the ESPRIT program for information technology run by the European Community. As a result, it decided late in 1987 not to repeat the ambitious Alvey research project (see later Section, "The Alvey Program"), which pioneered joint research by industry and the universities and which still has some on-going projects. Partly as a result of the experience with Alvey, the DTI believed there was an even greater need for coordinating the government's approach to high-technology research. Several committees in DTI and SERC, under which electronics research had hitherto been organized, will now be made redundant under the new structure. Resource allocation will be directed by a top-level advisory committee drawn equally from industry and the universities.

Ministry of Defence—A section on the organizational aspects of government-funded R&D would be incomplete without reference to the largest consumer, the Ministry of Defence. As the 1987 Annual Review of Government Funded R&D puts it:

> The R&D work of the MoD has the overall objective of meeting the needs of the Armed Services for equipment and weapons in a timely and cost-effective reamer. There is a major distinction between the objectives of research and development however. The research programme is aimed at sustaining an underlying basis of scientific and technological expertise on the basis of which support can be given to the selection, development, production and operation of weapon systems and equip ment, and assessments can be made of the likely future evolution of the threat and options for

countering it. It contains no element of basic, curiosity-driven research. In contrast, development is directly related, item by item, to the procurement of specific military equipment and is the essential forerunner to the production of such equipment.[31]

With regard to defense research, the Review continues:

The research program is undertaken both in MoD establishments and as funded research in industry, research institutes, the universities and other institutions of higher education. The contributions of these separate sources are brought together into a coherent programme through an integrated management within which responsibility for specific major fields is delegated to the relevant Research Establishments. Overall the research programme may be characterized as follows:

1. Strategic Research. [A]imed at strengthening and extending the scientific and technological base for future exploitation, which is broadly aimed at known military needs. This is maintained at a level equal to at least 5 percent of the Defence scientific effort available to them.
2. Applied Research. This is work which is directed primarily towards equipment projects in 5 to 10 years' time and absorbs the largest part of the Research Establishment effort . . . .

The Review goes on:

The research programme covers a wide range of scientific disciplines and technologies. Priorities within it are reviewed annually having regard for the largest assessment of Service needs, the timescales of application opportunities, and the varying prospects of making significant technological progress in different fields. . . It is the Ministry's longer term objective, however, to reduce its involvement in well-established technologies where there is a substantial capability in the private sector.

The major fields of research referred to above are listed in the Review as follows:

- Air Vehicles, Aerodynamics, Structures and Materials;
- Gas Turbines;
- Navigation and Avionics;
- Space;
- Ships and Submarines, Signature Reduction, Human Factors;
- Ships Systems;
- Undersea Warfare and Countermeasure Systems;
- Rocket Propulsion, Explosives and Weapons Materials;
- Conventional Weapons, Armaments and Command and Control;
- Military Vehicles and Army Engineering Equipment;
- Chemical and Biological Defence;
- Guided and Air-launched Weapons;
- Tri-Service Electronic Systems;
- Electronic Components; and
- Electronic Technology.

The reduction in defense R&D for which the government and others are pressing is likely to arise from:

- increased collaboration, in R&D as well as production, with European allies and the united states;
- increased competition in British procurement—new MoD contracts are now being awarded on the basis of either competitive fixed-price bids or a maximum-price arrangement; and
- more R&D being contracted out to the private sector, and possibly carried out at private industry's expense, i.e., getting industry to increase its contribution to the cost of R&D.

The MoD Research Establishments have been reduced in number from 22 to 7, with a workforce of about 22,000 compared with more than 30,000 ten years ago. One third of their total research in now extramural (contracted out to industry), and that trend will accelerate. In return, British industry is looking for tax incentives.

Military/Civil Trade-Off

Several of the documents referred to in this section have stressed the need to redress the balance of government funding between civil and military R&D, and secure greater benefits for the civil sector from technology developed under defense R&D programs. Several initiatives have been taken by the British Government in pursuit of that objective, including a study into the role and status of the Research Establishments.

[31] British Parliament, House of hinds, op. Cit., footnote 20.

Technological advances initiated for defense purposes have been exploited successfully by civil industry in fields ranging from new materials and electronic devices to advanced aerodynamics with application to civil aircraft and jet engines. The MoD Research Establishments interact with industry and the civil sector in four main ways, as described by the 1987 Annual Review of Government Funded R&D:[32]

- Some $285 million of research work is carried out under contract to industry and the academic sector, with the MoD joining with the Research Councils to make grants to institutions of higher education for work of high scientific merit that is relevant to defense.
- The Defence Research Establishments carry out some $83 million of work a year funded by other government departments for civil purposes. Much of this is complementary to defense work and uses the same staff and facilities. A further $43 million of work is done for other paying customers, including the use of facilities by industrial firms for both defense and civil work.
- Much of the work carried out in the Defence Research Establishments is relevant to civil as well as defense technology. The Alvey programme and the British National Space Centre, in both of which the MoD is a major participant, spearhead work across the civil/military divide in their respective areas. The MoD consults with industry and with other government departments on the scope for collaborative research programmed (e.g., the research initiatives in electronics at RSRE Malvern). The MoD will be a major participant in the LINK program announced by the Prime Minister in December 1986 to "pull through" innovative work into industry.
- Defense-related work may have commercial applications. To further such work, the MoD has assisted in establishing Defence Technology Enterprises (DTE) Ltd; a privately owned, profit-motivated company, established specifically to assist industry in identifying, developing and exploiting work carried out at the major Research Establishments, to which the company has access under suitable safeguards. Where ideas are not immediately transferable to civil applications, DTE may arrange further development. It operates at four Establishments-RAE, RSRE, ARE, and RARDE.[33] There are now some 500 items on the DTE database judged to have potential for exploitation, and DTE has recruited some 180 companies as associate members. Fifteen licenses for exploitating innovative technology have been negotiated, or are in the final stages of negotiation. As a further initiative directed to enhancing spinoff, work has been done on the idea of establishing a "science park" adjacent to one of the Research Establishments. This idea is currently at the feasibility stage.

A different kind of collaboration is the joint venture between an Establishment and a private company, as epitomized by the July 1986 agreement between Cummins International and RARDE. Cummins manufactures diesel engines, and wanted to enter the international tank market; RARDE has first-class facilities for testing tanks. Under the agreement, Cummins will provide engines valued at about $470,000 in return for a RARDE test program of similar worth.

Another initiative recently publicized is the Civil Industry Access Scheme, whereby MoD will allow companies to use its research equipment and for a fee consult experts at four of its major centers. The centers are RAE, RSRE, ARE, and RARDE. The new scheme, to be operated jointly by both MoD and DTI, is aimed at British companies, but applications from foreign firms will also be considered.

Perhaps the most controversial option in the government's review of the future of the Defence Research Establishments is to privatize them. Six non-nuclear Establishments are being studied for possible change to commercial status: ARE, RARDE, RAE, RSRE, A&AEE,[34] the Chemical Defence Establishment, and (possibly) the Meteorological Office. The options appear to range from simply putting an "agency" label on the Establishments to full privatization. The MoD team conduct-

32Ibid.

[33]RAE—Royal Aircraft Establishment; RSRE—Royal Signals and Radar Establishment; ARE-Admiralty Research Establishment: RARDE—Royal Armament Research and Development Establishment.

[34]A&AEE—Aeroplane and Armament Experimental Establishment.

ing the study on behalf of the Controller Establishments, Research and Nuclear (CERN) is due to report to the government in June 1989. Privatizing any of the Establishments should immediately reduce the cost of defense R&D, at least until the proper "commercial" rate is applied. Full privatization that entailed outright purchase would immediately raise questions about the Establishment's ability to act as a neutral technical adviser in assessing competitive proposals, as well as its willingness to sponsor fundamental and intermediate research where the returns are too distant to be commercially attractive.

Collaborative R&Din the United Kingdom

DTI's Role

A White Paper (Cm 278) described the role of DTI in encouraging enterprise, one of the major economic goals of the government.[35] It set out the main policies of the DTI and announced changes both in those policies and in the organization of DTI. On collaborative research the DTI "will encourage the participation of U.K. companies in technological collaboration with other European firms and research communities, including programs such as ESPRIT and RACE." (The DTI uses "collaboration" in a national context to include intercompany and industry-university ventures.)

The White Paper continued: "There are four main ways in which DTI, with other government departments in some cases, will encourage and finance collaborative research:

- LINK encourages companies to undertake joint research with Higher Education Institutions (HEI) and Research Councils. The research will be precompetitive but industrially relevant. Programs currently under preparation include new technologies such as nanotechnology and industrial measurement systems.
- National collaborative research programs promote longer-term, industrially led collaborative projects between U.K. companies in advanced technologies. DTI's role is to help establish the collaborative links both between firms and between firms and the research community at the precompetitive research stage. Once those links are established, decisions on further collaboration and commercial exploitation should be taken by industry itself. DTI, with advice from its Technology Requirements Board, is currently running collaborative programs in such advanced technologies as robotics and gallium arsenide. A new program on superconductivity is now being launched, linked with initiatives by the Science and Engineering Research Council,
- General industrial collaborative projects encourage collaboration through a variety of projects. Some foster R&D serving the interests of fragmented industries where small firms typically do not have the resources for advanced technological projects; Research Associations that pool resources can meet those needs. Some encourage the adoption of technology originating in the science base, particularly in the government's research establishments. Some are collaborative projects involving only industrial participants in joint research for companies with similar interests, especially small and medium-sized companies.

According to the White Paper: "In the future DTI will only contribute funds to research which would not and could not go ahead without some support from the taxpayer. It will normally be DTI's policy to fund any particular project or area of work only over a specific time period and where appropriate to reduce the rate of funding over time. Companies themselves are expected to become aware of the benefits which collaborative arrangements can bring and to undertake collaborative research without Government tiding."

On Information Technology, the White Paper stated that: "Within the context of the policies outlined above, the Government have considered whether the proposals in the report of the IT86 Committee should be included amongst the national collaborative programs. The Government have already agreed to support ESPRIT H, for which there will be a U.K. contribution through the Community budget of the order of [$380M]. The Government also recognize that the Alvey Programme has provided a good focus for the IT research community, which has helped to bring together different parts of industry as well as industry and the HEIs.

[35] Department of Trade and Industry, "DTI—The Department for Enterprises," White Paper Cm 278 (London: Her Majesty's Stationery office, January 1988).

The involvement of secondees from industry, academia and the Government departments involved has also proved successful and has assisted U.K. organizations to participate fully in ESPRIT. The Government nevertheless accept that some resources should be devoted to a national initiative complementary to ESPRIT, within the framework of the national collaborative research programme. . . "

From 1988 the Directorate will be known as the Information Technology Directorate, not Alvey, and its program reoriented towards precompetitive research. The DTI has earmarked $55 million over the next 3 years (1988-90) for IT programs, and SERC has plans to devote $104 million over 5 years to related academic research, mainly in partnership with companies. As mentioned earlier, all IT research will now be done under a joint DTI/SERC umbrella advisory organization with an overview of the entire sector.

The Alvey Program

The Alvey program was Britain's response to the national program that Japan launched in 1981, aimed at developing a so-called fifth generation of computing systems. The Alvey Report of 1982, which persuaded the U.K. Government to launch the program, assumed it would take at least a decade to meet the program's objectives. Launched in 1983, the Alvey Program focused on four "enabling technologies" thought to be crucial: very large scale integration (VLSI); software; man-machine interface; and intelligent knowledge-based systems. Three government departments-MoD, DTI, and SERC (for the Department of Education and Science)-jointly sponsored a common $375 million, 5-year program under its own directorate, with industry contributing another $285 million.

The 5-year program in Information Technology is now coming to a close. All the funds have been committed to over 200 industry-led projects, typically with two or three firms and one or two academic teams working together on each project. Over 110 firms have been involved in the actual research projects, and another 200 on the "awareness" side. The academic world was broadly represented with 56 universities and 12 polytechnics, together with 24 U.K. Research Associations or Government Research Laboratories.

Alvey-generated VLSI technology is being applied to fabricating integrated circuits, as well as memory chips offering switching speeds comparable to U.S. and Japanese products. A major achievement of the Alvey Software Engineering Program is the success with which "Formal Methods" from the academic world are being applied to industrial products. Widespread use of these Formal Methods may revolutionize software writing, with considerable economic benefit. Projects for artificial inteilligence/knowledge-based systems, systems architectures, and man/machine interfaces have led to significant advances, owing to collaboration between industry and academia. Plans for commercial exploitation exist for about half the projects; for the others, it is still too early to judge. Beside the four enabling technological areas already mentioned, the Alvey Program supported four large scale demonstrators, with the aims of stimulating enabling technologies for practical applications, and visibly demonstrating the exploitable results of the program.

Having generated a research strategy based on multi-departmental funding, the government will continue to fund IT research based on the same principles for which Alvey was the model. As was mentioned above, the Directorate has been renamed and the name Alvey has been dropped.

Lessons from the Alvey Program and its relationship with ESPRIT have been documented in detail in an Interim Report of the Evaluation of the Alvey Programme *by a joint team from Sussex and* Manchester Universities.[36]

U.K. Collaboration on Advanced Research

The U.K. 'S policy to support fully European collaboration, both in civil R&D and major military projects is well documented. The U.K. Government, and industry in general, are firm supporters of collaboration among European high-technology companies, academia and research institutes. The heightened sense of concern in Europe about its technological future is attributable to three factors: the sheer breadth and scale of the impact of information technology; the growing perception of

[36] K. Guy, M. Hoboday, R. Duncombe, H. Cameron, T. Ray, and L. Geoghiou, "Interim Report Of the Evaulation of the Alvey Programme" (London: Defense Technical Institute, October 19S7).

advanced technology in strategic terms and the need for self-sufficiency; and the severe "structural" handicaps to Europe's international competitiveness. Collaboration has become an accepted way of life among the high-technology community within the United Kingdom and the other European industrial countries. Put simply, no country can now afford to go it alone on all scientific fronts; it must collaborate or retreat from some or all of the world technological state. That point is well accepted in the United Kingdom.

FRENCH POLICY FOR RESEARCH AND TECHNOLOGY

Background

The administration of government funding for French R&D is highly centralized, though civil and defense R&D are budgeted and administered separately. Innovation and exploitation are encouraged by an elaborate system of aids and incentives; economic growth is sought through market-driven technology; and officials affirm that defense R&D should enrich the overall economy with scientific and technical progress for non-defense. Policies for nationalized firms and the government-supported research system are incorporated in long-term plans for R&D and innovation, with relatively specific priorities and goals. *Science and technology policies (especially technology) are also integrated wherever possible with the government's industrial and broader economic policies.*

The Law of 15 July 1982 established guidelines and a system of planning for French research and technological development; it also legislated the introduction of the High-Level Research and Technology Council (CSRT) to advise the Minister of Research and Higher Education (responsible to the Minister for Education) about the government's major scientific and technological policy options.[37] The Law on R&D[38] stipulated that the Minister should present to Parliament each year "a report on research activities and technological development which outlines the strategic choices for national policy and illustrates the progress made towards achieving the objectives fixed by the Law . . . " (Article 16). The Law also stipulated that "[t]he High-Level Research and Technology Council shall deliver an opinion each on the evaluation of research and technological development policy. The opinion shall be published. It shall be attached to the report on research and technological development specified by Article 16 of this Law" (Article 18).

The basic aim for French Government R&D policy is to stimulate rapid science-based economic growth, with key, technologies assigned priority in either national or collaborative programs. In the Preface to the first Annual Report (pursuant to the above Article 18), the Minister saw the draft 1987 R&D Budget Plan as an essential element in relaunching and reviving the French economy. "The field of research and technological development is a fundamental component of that policy, because research and technological development are seen by everyone as being a powerful factor for the long-term development of our economics and providing a decisive advantage in present-day economic competition worldwide. The policy I am pursuing in the research sector is based on one absolute principle and requirement-evaluation. In my view, it is impossible to define and implement a research policy with relying on means of evaluation. It would bean illusory and irrational misuse of public money if a number of ambitious, not to say over-ambitious quantitative objectives were fixed in advance without providing for a critical analysis of the substance and repercussions of the measures envisaged."[39]

The Minister also promised to review the central administrative structure of the Ministry for Research and Higher Education, and to review the activities of the government research organizations. He reported that, despite budget stringency in 1987, major scientific investment projects had been maintained and their funding assured, allowing basic research to develop within "a modernized technical framework." At the same time, the Minister noted "the need to develop industrial research in France" and "to make a very serious evaluation and re-evaluation of the relevance and cost of projects conducted by

[37] No. 85-1376, Dec. 23, 1985.

[38] No. 85-1376, Dec. 23, 1985.

[39] "Annual Report on the Evaluation of the National Policy Concerning Research and Technological Development," Ministry of Research and Higher Education, October 1986.

the many different intermediaries, whether research agencies or particular research organizations."[40]

R&D Budget Structure

Funding Levels and Priorities

The French Government issues 5-year national plans. Its policies become laws when the particular plans are approved by Parliament. The annual budget law is programmed for Parliamentary approval in January when "credits" or outlays are voted for the spending departments.

When the 1985 5-year plan was being prepared, the CSRT stressed the importance of regular evaluation of research activities; it also specified the principles and criteria of evacuation, particularly the independence and transparency of evaluation results. The law gives the CSRT the power, to consider how well the evaluation process has been conducted and to draw appropriate conclusions. Because there is no precise, operational evaluation system, CSRT confined the scope of its first annual report to selected areas outlined by the Research Committee for the 9th Plan, namely: industry research; scientific posts; research and the universities; the role of the regions; evaluation and forecasting.

Although a budget analysis[41] shows civil R&D to be decreasing as a percentage of government-funded R&D [Effort Budgetaire de Recherche et Developpement (EBRD)], actual expenditures have been fairly constant since 1985. There is, however, an apparent budgetary shift from civil to defense R&D expenditures in the 1988 R&D Budget. Compared with other sectors of government expenditure, R&D funding has actually fared well in the 1988 budget, with an increase of 8.3 percent (+10 percent for defense and +7.2 percent for civil), compared to an average of +3 percent for all ministries. Government-funded defense and civil R&D was split 39/61 percent in 1988, compared with 33/67 percent in 1985. Defense R&D, at about 26 percent of the defense equipment budget, has risen to support the programmed increase in defense equipment expenditure for 1987 to 1991. About 50 percent of defense R&D funding is spent with industry, accounting for about 70 percent of total state R&D funding for industry.

The civil component of the EBRD, the Budget Civil de Recherche et Developement (BCRD), (i.e., the civil element of the EBRD less telecommunications and university staff costs generally attributable to research) shows an increase of 7.2 percent for 1988, owing to the inclusion of expenditure on European collaboration and the loss of income due to the research tax credit system. As part of total government spending on R&D, European collaboration naturally belongs in the EBRD, but the program costs are not attributable to specific ministries' budgets. The civil R&D budget, for 1988 was FF39.3 billion, an increase of 2.3 percent over 1987. Of this, approximately 70 percent was to be spent on the following organizations and programs:

- Centre National de la Recherche Scientifique —FF8.96 billion on general research. Many laboratories are located on university campuses.
- Centre de la Energy Atomique (CEA)-FF6.65 billion on atomic energy research.
- Centre Nationale pour l'Exploration de la Space (CNES)-FF5.43 billion on space-related research, including finding the European Space Agency.
- Aeronautics Program-FF2.49 billion.
- Filière Electronique (electronic components) —FF1.99 billion
- INSERM (medical, health, biology)--FFl.92 billion.

This heavy commitment to Government Research Establishments makes it difficult for the French Government to effect changes of policy or to redirect research rapidly. The influence of the civil servants appears to militate against a cohesive strategy for the Research Establishments, but the Research Ministry is moving them towards a concept of strategic planning. However, the 1988 R&D budget has been heralded as one to "encourage industrial R&D," to get industry to do more R&D, and to make up for the decline in such finding prior to the 1986 changes.

In June 1988 the French Government approved an FF830 million increase for research that will augment, by 2 percent, the FF39.3 billion currently spent. The first priority will be to spend approximately FF90 million recruiting more young researchers to redress existing shortages. There are

[40] Ibid.

[41] Unpublished French Government budget analysis.

currently mom than 300 frozen vacancies for technicians in public research agencies. The remainder of the money will fund 150 new research posts in public research agencies. Of these, 100 jobs will be in biotechnology research at INSERM, the national agency for medical research, and at the national institutes for agronomy, cancer, epidemiology, and immunology. Fifty more jobs will appear at the French national space agency, CNES. Not all the new researchers will be French; some of the money will pay for 200 foreign scientists to work in French laboratories.

In addition to this new money for personnel increases, FF700 million will go to French industry to encourage greater involvement in basic research. Priority will be given to joint projects between industry and research agencies and to the "national priorities," notably research on new materials, set by the government last year. To remedy deficiencies in research in French universities, FF50 million has been earmarked to help universities develop their own research policies, particularly in conjunction with industry. ANVAR,[42] the agency that supports the development of promising *new* technologies, will receive another FF1OO million, and is slated for further funding later from the new industry minister.

This increase in funding results from a long battle by the new French research minister Curien, who held that post until 1986 and resumed it in early 1988 after Mitterrand's triumph in the presidential election. During his 1981-86 tenure, Curien planned to increase the science budget by 4.4 percent per year. But the Chirac Government cut the science budget by 6.6 percent during its 2 years in power (1986-88).

Despite the FF830 million additional allocation, Curien says that he will be unable to realize his original plans, set in 1985, to spend 3 percent of France's total revenues on research by 1990. However, the infusion of new money will allow some research institutions to survive the year.

Beside allocating more money, *the new proresearch government will reaffirm its original goals of streamlining the national research councils and agencies, to promote liaison among these agencies, industry, and the universities.* In support of this goal, the principal data networks used by researchers in France are being unified to permit intercommunications and file transfers. The new national research data communications network is seen as a "federation" of data networks already used by the major French research establishments. The new network will encompass those of the CEA, the electric power agency, the institute of computer science and automation research, and the research center for telecommunications. The network will interface to the "Reunir" network developed by the association of universities that links centers of higher education. INSERM, the center for agricultural research, the research center for cooperation with Third World countries, and the research center for agronomic in developing counties.

Government-Funded Civil R&D

Civil R&D funding is managed by the two Departments of Industry and Education (through the Ministry of Research and Higher Education). The several government Research Establishments (or Organizations) receive the majority of the funding, with about 70 percent of the EBRD going to the six organizations and programs listed earlier. The research budget for Higher Education was FF1.65 billion in 1988, (staff costs of FF7.44 billion are included in the EBRD but excluded from the BCRD).

The Industry Department disburses funds to industry for innovation, or the exploitation of research, through ANVAR. The Ministry of Research and Technology disburses funds for downstream R&D through the Fends de la Recherche et de la Technologie[43](FRT). As noted, the CSRT is a High-Level Research and Technology Council, whose role is to advise the Minister of Research and Higher Education on scientific and technological policy options. Scientific committees act as steering and advisory bodies on programs and objectives for each spending department and are answerable to the Minister for Research an Higher Education.

The FRT is the Research Ministry's principal mechanism to support R&D of downstream projects, usually involving at least one industrial partner. The 1988 R&D budget (BCRD) of FF39.3 billion included programs for electronics and information technology (formerly in the Postes and Télécommu-

[42] Agence Nationale pour la Valorization de la Recherche (Agency for Research Evaluation).

[43] Foundation for Research and Technology.

nications budget), of which the FRT budget was FF930 million (+8.8 percent) for 1988, plus about FF63 million unspent from 1987. Over 40 percent of planned FPT expenditure was allocated to the "National Programs" with 11 priority sectors: biotechnology, foodstuffs, medical research, life and social sciences; technology and production; electronics and information technology; transport; natural resources; new materials; new chemistry; and research for developing countries. On average, the FRT funds about 33 percent of these programs, with priority areas (besides AIDS) in superconductors and mechanical engineering (including optics).

In recent years, the FRT has acted as a transfer mechanism between the government Research Establishments and industry; however, little real technology transfer has occurred. In addition, the spending departments concerned received little "impartial" guidance on which programs to support. The Research Minister has now changed the system and (reintroduced scientific committees to act as steering and advisory bodies to each of the departments.

The FRT also funds about 50 percent of the French Government's involvement in EUREKA (21.5 percent of the FRT budget), and training (17.2 percent of the budget). The rest of EUREKA finding comes from the Industry Ministry's Information Technology and Electronics budget. Increasing the number of researchers in industry remains a high priority, and training initiatives include:

- technology transfer schemes (Centres de Recherche, d'Innovation, et de Transfert de Technologies and technology counselors, aimed at giving low-technology companies an entry into the Research Establishments;
- Poles Firtech[44] - centers of expertise that group industries, research facilities and educational establishments by geography and discipline;
- Conventions Cifre - placing doctoral students with companies to encourage industry research.

Manned by career civil servants, the Research Establishments are involved in these initiatives; together with short-term secondments to industry, trial loans, and incentives to public sector workers to transfer to industry, do contract work, or set up their own companies, they improve the transfer of technology into industry.

As noted, the Industry Ministry funding for the exploitation of research is effected through ANVAR. This funding has been increased to FF784 million ***(+8*** percent) for 1988. (With repayment of loans the budget rises to about FF1 billion). ANVAR offers grants for pre-project studies and interest-h loans to convert the results of such studies into a marketable products. For 1988, about FF200 million will be spent on information services to help small companies to collaborate with public sector researchers and professional technology centers. It is also proposed that ANVAR fund the costs of insuring risk capital. (It appears that the Industry Minister has also proposed risk insurance as a funding mechanism for EUREKA projects.)

Most of the Industry Ministry funding for industrial R&D (about FF2 billion) is for the favored areas of IT, electronics, manufacturing technologies, and the space sector, and is administered through SERICS. SERICS also funds about 50 percent of the Government's contribution to the EUREKA program, worth FF200 million for 1988 (the other 50 percent comes from the FRT). Funding for electronic components of FF1.99 billion is thought to come jointly from both the ANVAR and FRT budgets.

As already noted, most of the BCRD funding is spent with the Research Establishments. CNRS, the largest, accounts for about 10 percent of total government-funded R&D expenditures and 42 percent of the Research Establishments' budget. The Establishments employ over 25,000 persons, of whom nearly 11,000 are researchers; staff costs absorb 63 percent of their total budget of FF9.1 billion.

Government-Funded Defense R&D

The 1988 defense budget for both research and development was FF3.2 billion, an increase of 10 percent over 1987. Fundamental to French procurement strategy is the need to maintain an industrial base that ensures independence in armaments and preserves France's freedom of action. The "strategy of means" involves comprehensive planning, programming, and budgeting, with the results embodied in legislation. There must also be a parallel industrial policy to guarantee the development and procurement of the equipment the Armed Forces require; and this industrial policy must be integrated into the

[44]Formation des Ingeniurs pour le Recherche sur les Technologies.

government's other industrial, economic, and social policies.

The organization for defense R&D should be seen against this clearly stated policy background.

Délégation Générale pour l'Armement-The central institution in the French procurement organization is the Délégation Générale pour l'Armement (DGA). It has a dual responsibility:

- to organize the implementation of all of the Ministry's armament programs; and
- to ensure that the country has an up-to-date and effective armaments manufacturing capability.

In short, the DGA is the agency to which implementation of the "strategy of means" has been entrusted. It has both government and industrial tasks.

Its government tasks include:

- determining the Services' armaments requirements in consultation with them;
- supervising the State establishments and the (wholly or partly) publicly owned companies engaged in armaments research, development, and production; and
- developing a long-term program to ensure that France can be assured of the "means" to fulfill its armaments requirements.

The DGA's industrial tasks include:

- acquiring weaponss systems and materiel for the Services; i.e., acting as the government's buyer in the market;
- actually producing these equipments in the arsenals and other establishments it runs; and
- responsibility for bringing the State's interests to the attention of industry, and vice-versa.

The DGA is the institutional expression of the "strategy of means" in that *it is the link between the high command and the defense industrial base.*

The Delegué General pour l'Armement.-At the head of the DGA is the De1egue General Armement, who is directly responsible to the Defense Minister and normally acts as the vice-chairman of research, development, and equipment programs, He is assisted by a "cabinet" of scientific, technical, and military advisers, including a head of research. His entire area of responsibility includes over 75,000 personnel thoughtout France, many of whom are staff military engineers who are graduates of l'Ecole Polytechnique. *These* civil *servants have a full career structure with ranks analogous to military ones,* and often use their ranks as a *mode of address.*

DGA Functional Directorates—The task of the DGA's functional Directorates and one technical service is to provide coordination among the four Technical Directorates and Departments. The Direction des Pro grammes et Affaires Industrielles is the functional directorate that translates the requirements of the Services into research, development, and production programs (in line with program laws and the annual budget), while the Direction des Recherche, Etudes, et Technique D'Armement coordinates the basic defense research effort, disseminates results, and sets priorities for exploratory development; several study centers and services come under its aegis.

Each of the four Technical Directorates is responsible for both government and industrial tasks. Each is both a "puissance publique''—(public authority) undertaking research for, and exercising direction over, the armaments programs within its area of interest-and a "fournisseur" (provider), itself conceiving, developing, producing, and repairing weapon systems. In other words *the four technical directorates within the DGA are responsible for research, development, production, test, and evaluation of the equipment for which they are also responsible as customers.* Although procurement procedures are similar to those of other major Western nations, the French process is probably more flexible and pragmatic. It has also been observed-specifically in relation to procurement of aircraft for l'Armee de l'Air-that a stress on initial prototype production, and an aversion to the use of projects to "prove" several new technologies at the same time, are distinctive and successful characteristics of the French way of doing things. The four Technical Directorates are:

- Direction Technique des Armements Terrestres for ground defense equipment, technical assistance, and after-sales service of equipments;
- Direction Technique des Constructions Navales for naval ships, equipment, and weapons;
- Direction Technique des Constructions Aeronautiques (DTCA) for the whole range of military aviation engineering, including aircraft design, development, and production; its responsibility also extends to all aspects of civil aviation. The DTCA is organized to deal

separately with the supervision and control of development and manufacturing programs, and test and trials; and

- Direction Techniques des Engins for all aspects of ballistic and tactical missiles.

Policies for Collaborative R&D

Collaboration in Civil R&D

The French Government which initiated EUREKA, is firmly committed to the collaborative programs established under the aegis of the European Commission. The concluding section of this appendix describes some of these programs. Together with West Germany, France is a major partner and contributor to the European Space Agency (ESA) program, with each providing a quarter of its annual budget of about $1.7 billion. The French SNES has a budget of about FF5.43 billion ($1.1 billion), of which 40 percent is spent through ESA. Two of its major projects are the French designed and led Ariane-5 launch vehicle and Hermes, a manned orbiter now in development.

Collaboration in Defense R&D

What the French Government sees as the benefits of collaborative arrangements in defense R&D and procurement is rarely stated explicitly and authoritatively. Formally, France supports the Independent European Programme Group initiatives for coordinating and integrating armament procurements, and is an active partner with Alliance members in several projects such as sonars, army weapons, missiles, aircraft, and ships. It is also involved in the early stages or development of other collaborative projects across the whole range of defense equipment. But it is significant that the country's Loi de Programmation for 1984-88 mandates that French defense industries give France almost complete independence in armament production. The inference is that, for France, collaboration is seriously considered only when there is no alternative. A March 1987 agreement to cooperate with the United Kingdom on arms purchases (and nuclear issues), discussions in 1988 with the United States and United Kingdom on mutual requirements for a stand-off missile, and an accord with West Germany on operational issues, appear to have consolidated that position for the French. With an indigenous capability in most areas of defense technology, the main motivation for collaboration can only be economic. It is difficult to see France collaborating with other nations if the costs of such ventures would exceed those of a nationally produced product. Pragmatism prevails.

Research and Technology Evaluation

There is a Center for Evaluation and Prospective Development (CPE) which has created an intelligence nework that collects scientific, technological, industrial, economic, and social data worldwide—especially from the United States, Japan, the Scandinavian countries, and Germany—and makes them available through publications. CPE also acts for the EC as the French coordinator of data collections in the EUROT'ECH program, which aims at providing information on technological innovation in the EC. CPE was instrumental in providing French data to the Organization for Economic Cooperation and Development (OECD) for its 1986 report and is now working on models dealing with the influence of technical advances on production, on new ways of international technological cooperation, and on problems in creating a potential for intellectual investment. By virtue of its quasi-independent status, CPE hopes to establish itself as a center for evaluation of the major scientific organizations and to apply its studies of evaluation procedures to the technologies of artificial intelligence. It will act also as consultant in evaluations required by the EC and OECD.

The concept of "valorization," that is, assessing research in terms of transfer to definite applications, was one that the previous government hoped to address by creating the CPE and new advisory councils such as the CSRT. Recommendations had already been implemented concerning this area. especially by giving the Ministry for Research and Higher Education a central role in overseeing science and technology. However, the new advisory council CSRT, has recently called for another general review and recommendations for increased effectiveness in this area. It has been suggested that establishing technology transfer techniques alone does not automatically generate acceptable policies, and that advisory councils adequate for administrative purposes are insufficient to devise policy. Parallel experience in the United Kingdom shows that advisory bodies do not arrive at acceptable recommendations unless they have available the findings of policy research groups on which to base decisions. The data assembled by the CPE in science and technology will be at the disposal of a new assessment unit *(observatoire)* intended to lay the ground for wide-ranging research on which policy decisions in science and technology can be based.

France now seems to possess adequate machinery for the design of science policy. While value for money is a criterion for evaluation, the decision process in France is easier because there is a more general consensus on encouraging promising new projects-particularly international ones. On the national scene, while France is hoping to persuade industry to make a larger contribution to R&D, it is nevertheless encouraging industrial R&D with grants and tax concessions. The Government is not coercing industry with threats to withdraw support, for fear of undermining the very position in high technology that the French Government is supporting.

WEST GERMAN POLICY FOR RESEARCH AND TECHNOLOGY

Background

Although no country in Europe matches the total spending on research and technology of the West German Government and industry, the proportion devoted to defense R&D is small. The country is also one of the world's leading exporters, but its industry has been less dynamic than that of the United States or Japan in shifting emphasis to growth sectors such as electronics. This is true for R&D as well as production. Overall, the country's competitive position in advanced technologies has not suffered noticeably in the 1980's, but neither has it improved despite a period of weakness for the deutsche mark. West German officials realize they cannot alone match the spending of the United States and Japan, and that the scale of today's research and technology requires cooperation between countries and companies in areas such as aviation, space, and nuclear power. Even then the investment pays off only if a sufficiently large market is available. West Germany is therefore committed to collaboration.

Despite its support for international cooperation, West Germany joined with the United Kingdom in 1987 to oppose an increase in funding for European Community-wide research programs for 1987-91. German officials first wanted to see other governments, particularly those in southern Europe, strive to boost national R&D spending. Germany and the United Kingdom shared the view that the EC is not a replacement for a minimal national R&D policy; EC money should be seen as a stimulus for cooperation, to bring partners together-but not to finance projects, None the less, Germany strongly supports programs such as ESPRIT which have led to the formation of several hundred European research groupings, and believes that, during the next 5-year period, there should be more of them.

Because the EC's existence helps account for the success of Germany's export-oriented economy, very few Germans would want to cast doubt on their support for the EC. Membership has involved a price in that West Germany is, and will continue to be, the EC's biggest contributor; but the political and economic benefits of belonging to a united Europe have always been thought adequate compensation. Now, however, there is less certainty. The view appears to be growing that the country stands to lose more than it gains from the southward shift in the Community's center of gravity, the Commission's bid to reform its agricultural policy, and its plan to harmonize competition rules throughout the EC. Relations are also improving with East Germany—visibly so since the East German President visited the country in September 1987 and pledged scientific cooperation on projects ranging from physics to production technology.

With 1992 and the single European market approaching, a powerful coalition of West German industrial and trade-union interests is opposed to opening borders to genuine EC competition in such areas as insurance and telecommunications services, electricity supplies, and road haulage. The West German Government, like the Italian, sees the need for a closer coordination of European monetary policies and increased cross-border cooperation, to underpin the planned single market.

West German R&D Program Overview

Budgetary Aspects and Statistics

Total spending on R&D in 1987 was expected to be about DM48 billion (2.9 percent of GDP), of which approximately 75 percent was to be privately funded by industry and other sources, and the rest provided by the government (federal and state). The government's share was divided between the Ministry for R&T (60 percent) and the Defense, Education, and Environment Ministries (40 percent). The Government's share of total R&D has steadily decreased from 41 percent in 1983; to some extent, this reflects the administration's efforts to improve the investment climate by using indirect mechanisms rather than direct funding of R&D.

A 1988 report,[45] indicates a 5-percent increase over the initial estimate of DM 48 billion spent on research and development. When adjusted for inflation, this represents a real 2.5 percent growth over 1986. Privately funded research in 1987 was also slightly higher than expected, with 83.6 percent of all research being privately funded, as compared with the approximately 75 percent anticipated. This means that government funding of private research was actually only about 15 percent of the total.

Of government funds appropriated for research and development, most of the federal funds come from four ministries: the Ministry for Research and Technology (more than 50 percent), the Ministry of Defense (approximately 20 percent), the Ministry of Economics (about 10 percent), and the Ministry of Education and Science (which together with the other federal ministries, makes another 8 percent).

A high proportion of West German spending on R&D is for basic research, approximately 70 percent of which is performed in the higher education sector, with about 25 percent in the public sector, and industry spending nearly 20 percent of total basic research funds. Applied research is embedded in "development" figures and is difficult to identify separately; but together these categories constitute almost four-fifths of total R&D expenditure.

The Ministry of Defense accounts for about 15 percent of federal R&D finding, compared to about 50 percent for the United Kingdom. Put another way, in 1986, government-funded *R&D for defense as a percentage of GDP was only 0.11 percent in West Germany, compared with 0.68 percent in the United Kingdom and 0.81 percent in the United States.*

West German Government R&D expenditures consist of both federal and state funds. In 1983 the federal government was responsible for 60 percent of the total government funds. By law, the states fund almost all of the research and half of the capital expenditures of the universities. For the most part funds awarded to universities for general research are not allocated to specific categories-various independent specialist organizations set priorities. Nevertheless, the volume of funds is large enough to distort any breakdown of government R&D objectives by fund category. Funding for the Max-Planck Society, the German Research Society, and the Fraunhofer Society, as well as funding for basic research in the natural sciences, constituted more than 14 percent of the federal R&D budget in 1983 (compared to 20 percent for energy and 15 percent for defense).

Policy Aspects

Basic Pillars of Research Policy-"Art and science, research and teaching shall be free. Freedom of teaching shall not absolve from loyalty to the constitution." These words from the Basic Law of the Federal Republic of Germany echo similar words found in the constitutional legislation of the 11 federal states. While the federal and state governments are authorized to create a climate conducive to research, the researchers themselves are free in the choice of their subjects. Furthermore, the scientists are free to accept third-source funding if money from their own institution is insufficient.

An R&T Ministry director once described the constitutionally guaranteed freedom of scientific research policy in the Federal Republic. The second of these four pillars can be seen as West Germany's federal structure, where the 11 federal states assume independent responsibility in education and science. (The states are thus solely responsible for their colleges and universities, and it is only the area of expansion of the university system that federal and state governments share tasks.) The third pillar is the declared intention of the federal and state governments to interfere as little as possible with the research systems. The fourth pillar is symbolized by the intention that German research be integrated closely and effectively in international—specifically, in European-research cooperation, with a corresponding effort to design generally accepted regulations and standards for innovation and market expansion within Europe.

The significance of this freedom of research is two-fold. One point is that this freedom is never questioned. One institution, the German Research Society (Association), DFG, is an autonomous organization that wields great influence within the scientific community. The DFG's influence manifests itself in key research programs, whether in

[45] "Research Policy for the Federal Republic of Germany," The German Research service, Special science Reports, Special Issue, January 1988.

helping set the direction of research or in generating ideas for research policy itself. Although the federal and state governments currently allocate DM1 billion to the DFG, it is not subject to direct government influence.

It *merely shares the government's goal to build upon a high standard of achievement in basic research in West Germany. The* DFG's independent experts evaluate research grant proposals submitted by researchers of all disciplines. If their decision is affirmative, approval of payment of the grant money is almost a matter of course. The Max Planck Society and the Fraunhofer Society, both currently funded largely by federal and state governments, are also independent establishments that exert great influence in formulating research policies. The Max Planck Society is able to determine what research projects are needed at any given time, while the Fraunhofer Society series as a catalyst for technology transfer between the scientific and business communities.

The second point that bears upon freedom of research is that it is accomplished in an atmosphere of trust and cooperation. These research establishments discussed above build a network that is both multifaceted and an integral part of the federal structure of the Federal Republic of Germany. Their cooperative attitude is almost always harmonious with respect to the federal and state administrations, and conversely, the federated structure appears always to support the scientific community's work. This cooperation between the government and the scientific community extends to the private sector as well. Decisions by the Ministry of R&T consider the likely impact of a project on the national economy, and whether the nation as a whole will profit. Government funds are available, should the company responsible for a project incur technical or economic risks. This freedom of research is fundamental to Germany's success in research and development

Trends-h June 1983, the Ministry of R&T published a long-term financial plan that detailed Federal R&D spending plans through 1987. The plan showed government promotion of R&D to be slowing, with growth rates dropping to 2.4 percent by 1987. While the government remains concerned about the competitiveness of its industries, it has moved away from concentrated direct funding of product development, as illustrated by developments in the Information Technology sector. Instead, the government announced a more comprehensive plan to promote the development of microelectronics and information and communications technology, one that required overlapping ministerial responsibilities in a variety of areas. This initiative began at about the same time as the U.K. Alvey program, with which it has much in common. As with Alvey, this program was a point of departure for German participation in ESPRIT and other European collaborative programs.

The 1983 reorientation of government policy on research and technology called for increased reliance on private initiative and entrepreneurial responsibility, and restraint by the government in supporting R&D in industry, particularly in advanced development projects. Public funds were to be targeted at those areas where the government had its own responsibilities, or where overriding social or macro-economic concerns warranted government support of R&D. This was not unlike similar philosophies underlying the U.K. science and technology policies.

In 1987 the Ministry of R&T presented a "Comprehensive Program" explaining in detail the basic concept underlying its research promotion policies. This program suggests that there a reorientation in several is underway areas. The program emphasized five central tasks involved in research promotion:

1. to promote basic research (Max Planck Society), support large-scale projects, and further research in the arts and humanities and social sciences;
2. to promote government-run long-term programs (space, polar, nuclear fusion research);
3. to promote research in the area of prophylactic care (health, humanization of job life, environmental protection, climate);
4. to support market-oriented technologies (gene technology, molecular biology, materials research, information research and processing, and energy technologies); and
5. to improve the existing framework conditions and prerequisites for economic innovation.

There are specific programs for each of the first four tasks. The final task is more general, but its importance should not be discounted.

It is the Ministry of R&T's policy to emphasize new technology innovation by small and medium-size businesses. The allocation of funds to benefit large businesses is being reduced, with smaller companies being strongly encouraged to involve themselves in new developments. Tax reforms will also provide a better environment for innovative developments.

The continued goal for research policies in Germany is to intensify cooperation between research, academia and business. Collaborative projects will be emphasized and personnel exchanges between government and privately run research institutions will be encouraged. Accompanying this goal is the expansion of the Fraunhofer Society in its role as "mediator for technology transfer between the science and business communities."

The pattern of industrial R&D which results from a policy of encouraging industry to shoulder more of the national R&D effort will inevitably be dedicated by the strategic needs of companies as they strive to be competitive in world markets. The balance between civil and military R&D must, however, be influenced by the budgetary policies of governments. *The most prosperous countries appear to be the ones which spend least on defense R&D*, attracting scarce scientific manpower into industries capable of competing in the international civil market for high-technology products, and depleting resources available for defense R&D. As one such prosperous country, with only a small allocation of government funds for defense R&D, it is not surprising that in West Germany both the government and the defense industry strongly favor collaboration.

Referring to civil R&D, the Director of International Cooperation in the Ministry for R&T said that "... the scale of today's research and technology requires cooperation between companies and countries for areas such as aviation, space and nuclear power." Even then, the resulting end-product "... only pays off if you have a large market. So the push for cooperation is stronger for Europeans than for America or Japan." This "push for cooperation" is evident in several major European projects, civil and military, in which West Germany is involved, such as the Eurofighter, Airbus, the France-German helicopter and, of course, the European Space Agency—to which it and France are the major contributors.

European Space Program-In 1987 the federal government made a strategic decision to bolster its aerospace industry. This included a plan to increase government spending on space by 10 percent in 1988, to DM1.2 billion, one-sixth of the total budget for the Ministry of R&T. In addition to the extra money, the space program would also require extra scientists and researchers, perhaps limiting research in other fields. The Research Minister has also suggested that 20 to 25 percent of his ministry's budget could eventually go for space research programs. That idea does not appeal to West Germany's industrialists, who question the wisdom of committing so much money to one sector. The Confederation of Industrial Research Associations (AIF) has warned against this emphasis on space if it means limiting research funds for small- and medium-sized companies, arguing that such a policy is too roundabout away to benefit German industry. The government's reasoning that space-based research findings have other applications does not convince everyone. However, the Columbus, Hermes, and Ariane 5 projects are ambitious and will in time inevitably produce spin-offs for all partners. Also under study, in collaboration with the U.K. (through British Aerospace and HOTOL) is the Saenger rocket-plane concept as the next, and possibly more economical, step into space.

EEC *Budget for* R&D-Realizing the limits to national funding for R&D, West Germany adamantly opposed a major increase in EC funding for 1987-91 Community-wide research programs. Officials first wanted to see more effort from such countries as Greece, Portugal Spain, and Ireland—each of which spend much less than 1 percent of GDP on private and public research-before the EC provides more of its own funds. None the less, West German is firmly committed to collaboration in both civil and military fields, with an estimated 70 to 80 percent of its researchers involved in international cooperation of one form or another, according to the Ministry for R&T

The Role of Science and Technology-The West German Government also uses science and technology *to shape international politics, as* in greater cooperation with East Germany, the Soviet Union, and other Eastern Bloc counties.

The goal of West German industry-staying competitive through high-quality products produced by high-productivity factories-has led the country to create R&D teams in several areas. Government policy now is to use these groups to strengthen

European R&D efforts to produce a stronger European Community while, at the same time, looking eastwards to new markets-and using science and technology agreements to exploit them.

Not all senior researchers agree with the government's research and aid-to-industry programs. The head of Bochum University's Institute for Applied Innovation Research, Professor Erich Staudt, was reported as saying that" . . . state subsidies for high technology lead to peaks, but then there is no connection. The Ministry talks only of *more* high technology, but that doesn't pay off. There's no economic context any more if you're far ahead."[46] He felt it was better to ignore high-technology trends and concentrate instead *on* new untapped areas. Staudt criticized the Ministry for R&T for "pushing" research into technologies where the United States and Japan already had an advantage. The result, he chimed, was the march of national research institutes into saturated market areas, producing new over-capacity already evident for such products as steel and personal computers. West Germany needed to innovate, not copy the world's latest high technology.

Whether by government or not, there is now a virtual hiring freeze at the 13 National Research Centers, 52 Max-Planck Society Institutes, and 34 Fraunhofer Society Institutes, together accounting for 25,000 staff jobs. Having filled these government and big-industry sponsored research centers, there is now thought to be a latent technological potential developing, with job pressure forcing young researchers into small to medium-sized firms where innovation and market-oriented effort should pay off in increased sales.

Evaluation of R&D-In a recent survey of the world's influential S&T journals, German scientists and engineers were found to have authored 6.5 percent of the articles, twice Germany's share of the world's researchers. In some subfields, German articles represented up to 15 percent of the articles. Patent applications, another research quality indicator, increased 9 percent in Germany in the period 1981-83, compared with a 1 percent decline in the United States. The number of U.S. patents granted to West German investors rose more than 40 percent between 1970 and 1984, with over 60 percent in machinery, and chemical and allied product technologies. The main evaluation method for R&D is the expert peer review.

Organizational Aspects

Overall Structure-The West German Government *achieves a degree of coordination of basic research without direct government control, largely due to the efforts of autonomous associations in its science system, e.g., the* DFG, which provides academic project support and scientific advice, and the Max-Planck Society (MPG), which conducts in-house research and operates over 50 research institutes. The Federal science and mission agencies take a more aggressive stance for applied research and work in the national laboratories, but the Association of National Research Centers (for the 13 "large-scale" centers) participates in setting research directions. A Science Council advises the government, DFG, and MPG.

Although no formal government-to-industry coordinating body exists, the Ministry for Research and Technology is the major source of federal funds and plays a coordinating role. Federal, state and industrial funds support the Fraunhofer Society, whose work reflects both government and industry needs. There is industry-government collaboration in the work of the national laboratories.

The system for funding and coordinating science and technology activities in West Germany thus relies on *certain special* organizations in executing the government's research and technology policy. Although many of these are considered to be nonprofit institutions, OECD guidelines state that the sector which largely controls a nonprofit organization, or is served by a non-profit organization, is the one to which the organizations performance and funding should be assigned. If the organization mainly serves or is financed by government, the guidelines consider the work as having been performed in the public sector. If the organization renders services primarily to industry, it is considered private sector work. As a matter of budgeting, however, government funds allocated to the organization are credited to public sector accounts.

The Science Council-The main coordinating body among the federal government, state governments, and the scientific community is the Science Council (WR), founded in 1957 by an administrative

[46] *Financial Times*, London, May 18, 1988, p. 20.

agreement between federal and state governments. It provides advice and recommendations on science policy matters, especially those concerning the higher education sector. Without executive powers, its recommendations carry weight because they constitute the consensus of the Council, whose members represent a variety of sectors and disciplines. An example of its recommendations was the establishment of the special collaborative programs that the German Research Society now sponsors (see below).

The WR is not a funding or granting organization. Nonetheless, it is mandated to review annually planned expenditures of the federal and state governments for higher education, including university proposals for new laboratories, scientific equipment, etc. The Council is thereby able to reduce duplication of major scientific equipment and facilities.

The Council recently reviewed the health of West German universities, especially as they pertained to the age structure of university staff. Most of the university positions were filled by tenured professors hired during the expansion period of the 1960s and 1970s. Since most would not be eligible to retire for another 20 years, there was little room for bright young researchers to enter academia. Moreover, many of the faculty positions had to be filled rapidly during the earlier expansion, and some of the staff were now less qualified than the younger researchers. To create and justify new positions, universities introduced new specializations. This led to the problem of overloading of the university curricula. The academic requirements in individual disciplines became so cumbersome that it was virtually impossible for students to complete their studies in 4 years.

The Science Council considered restructuring the higher educational training system to shorten the length of the first degree programs, and to strengthen graduate education, including the role of R&D.

Other issues with which the Science Council is concerned include the importance of outside funding for universities and research institutions, mobility of researchers, increased competition among states for R&D facilities, employment problems, and evaluating the quality of education and R&D.

Mux-Planck Society— The Max-Planck Society is an important performer of basic research. It is financed largely (94 percent) by public funds from both federal and state governments. Although its budget represents only about 2 percent of total national R&D expenditure, its influence on the national R&D effort is considerable. The MPG consists of 52 institutes, three clerical units, and two independent research groups. Independent research groups are a means through which new research efforts are promoted for a limited time and working relations between MPG and universities are increased. The institutes are not expected to perform basic research in all fields. The Society supplements research in universities and is charged by the Science Council to carry out research that requires large or specialized facilities; to supply adequate human and financial resources to areas of particular scientific importance and promise; and to conduct research in emerging and interdisciplinary fields. Over 60 percent of the MPG's research funds are in natural sciences, and most of the rest are in biomedical fields.

The importance of increased cooperation between the Institutes and universities is being emphasized, with most Institute Directors and senior scientists teaching at universities. The Institutes also offer research facilities to doctoral students. Despite an increase in research projects conducted jointly by the Institutes and universities, competition remains, with scientists preferring the research environment at the Institutes.

Fraunhofer Society - The Fraunhofer Society is to applied research what the MPG is to basic. It is a nonprofit society that sponsors and performs applied R&D through contract research, defense research, and services. The Society's main clients are industry and the federal and state governments. More than half of its 3,700 staff (in 1985) were in natural sciences (40 percent of funding) and one-third in engineering (50 percent of funding).

The Society performs a mix of its own research projects and contract research. Twenty-two Institutes are engaged in contractor project research with government and industry. Six institutes are dedicated to defense research and are supported by the Ministry of Defense. The Society also provides technical information; technical evaluations; economic studies; and assistance in obtaining, maintaining, and exploiting patents. There are four Institutes responsible for such services. The Institutes conduct applied R&D in specific areas:

. microelectronics and sensor technology,

- information technology and production automation,
- material and building component behavior,
- production technologies,
- process engineering,
- energy and construction technology,
- environmental research, and
- technical economic studies and technical information.

The federal and state governments provide subsidies through the Society to assist small and medium-sized companies for R&D projects leading to new or substantially improved products or processes, as well as for technical assistance. The Society has excellent links with industry; in addition to contract work and technical assistance, many of the heads of Institutes are on the boards of directors, or are R&D directors at some of the larger companies. The Society also has close links with the universities, with Institutes usually located near research universities, and more than half of the heads of Institutes university professors.

In 1985, less than half of the Society's funding came from federal and state government's in the form of institutional funding, and about 60 percent from contract research. The importance of contract research is expected to increase still further, thereby reducing reliance on government funding.

The Society performs research for the Ministry for Research and Technology in such areas as electronics, automation, and production technology (CAD/CAM and robotics); materials development (ceramics); and biotechnology and gene technology.

"Large-Scale" National Laboratories-In addition to the MPG and Fraunhofer Society, there are 13 "large-scale" national laboratories. funded by both federal and state governments but primarily supported by the Ministry for Research and Technology. They were established to supplement the efforts of the universities by conducting research requiring large-scale instrumentation and large-scale investment. The first centers began in the 1960s in nuclear research, while others now include space research, mathematics and data-processing, cancer research, biomedics, environmental protection, marine, and polar research. The full list is as follows:

- Alfred Wegener Institute for Polar Research,
- German Electron-Synchroton,
- German Aerospace Research & Testing Institute,
- German Cancer Research Center,
- Society for Biotechnological Research,
- Research Center Geestact Ltd.,
- Society for Mathematics & Data Processing,
- Society for Radiation & Environmental Research,
- Society for Heavy Ion Research Ltd.,
- Hahn-Meitner Institute for Nuclear Research,
- Max-Planck Institute for Plasma Physics Ltd.,
- Nuclear Research Plant Juelich Ltd., and
- Nuclear Research Center Karlsruhe Ltd.

Although supported almost completely by public funds through the Ministry of R&T, these laboratories are legally independent. Each has a supervisory board that establishes research priorities, and all are linked by an Association of National Research Centers that coordinates their activities and represents their interests with the federal government. The Ministry for R&T provides about 90 percent of the financial support for the centers, by "influencing" their research priorities. The laboratories conduct research in areas of technology of interest to the government; when investment in a particular area is reduced, there is a "domino" effect in the laboratories which leads to diversification into other priority areas.

Federal and State Research Establishments-h addition to the research laboratories already mentioned, the federal government maintains 40 research establishments that perform mission-related research for their respective ministries. The various states also own and support 50 of their own laboratories, which conduct applied R&D important to their particular region and economy. There are also 48 research institutions that are funded about equally by federal and state governments, and which are usually referred to as the "Blue List" institutes. They perform research that is usually more basic than that performed by the other federal and state research enterprises; a general requirement is that they conduct research of multiregional or national importance.

The *German Research Society-The* German Research Society (DFG), an autonomous organization somewhat similar to the U.S. National Science Foundation, finances R&D on a proposal review basis, relying on expert peer review. Besides funding research proposals, the DFG supports the training of young scientists, fosters cooperation between researchers, including international cooperation, and provides advice on scientific matters to policymakers. The Society does not have its own research institutes or perform research; it distributes R&D funds, mainly to the higher-education sector.

The DFG receives most of its funding from government sources; in 1984, 58 percent of its budget was provided by the federal government and 41 percent from the state governments. About one-third of its funds were allocated to life sciences, an area for which funding appears to be increasing. Other fields include physical sciences and mathematics (25 percent), engineering (23 percent) and social sciences and humanities (15 percent). The largest proportion (45 percent in 1984) of the Society budget goes to support its normal or core program, in which individual researchers initiate their own proposals and select their own topics. The Society also spends about 13 percent of its funds on proposals under a priority program; for a limited time the priority program supports research in those fields determined by the Senate of the Society to be priority areas, and for which it seeks to improve West German capabilities in order to match international standards.

A special collaborative program, that not only fosters cooperation but also promotes interdisciplinary research, was established in 1968 on the Science Council's recommendation. Under this program the Society provides long-term, but not permanent, funding that was about 30 percent of its budget in 1984. An institution or university, rather than a group of individuals, develops a proposal to demonstrate its commitment to long-term support of the research. Such a proposal must be examined and agreed by peer review. Unlike the other programs, this one is financed primarily (75 percent) by the federal government. A university must identify an area in which it excels, with the university or state government committing itself to continue funding the area after the Society support ends. The sites at which special collaborative programs are developed could be looked on as "centers of excellence," although they may not be the only centers of excellence in that particular field. One of the first special programs was so successful that it has now become a Max-Planck Institute for Mathematics. These programs are able to attract international scientists and engineers and even pay their expenses. In fact, one of the criteria by which a program is reinstated every 3 years is its international standing, calculated in part by the identities of the scientists, engineers, and publishers who have agreed to associate themselves with the program.

The Society is also responsible for administering special fellowship programs to enable young scientists with insecure positions to remain active in research.

Confederation of Industrial Research Associations-The Confederation of Industrial Research Associations is an autonomous organization that finances and coordinates cooperative industrial research-generally applied research and development. This organization is particularly important to the small and medium-sized industrial firms who find it difficult to support their own R&D. It was founded in 1954 and is now an umbrella organization encompassing 92 member associations, many of which have their own research institutes; the AIF even has 63 of its own. Industry supports most of the AIF's activities, but funds are also received from the federal government, particularly the Ministry for R&T and the Ministry of Economics.

If a problem common to member associations exists, a research proposal can be made to the AIF, which relies on a group of 120 experts from various fields to evaluate them. About half of the experts are from industry and half from the research institutes and universities. Reviewers must decide if the proposed project is technically sound and of scientific interest; whether the project is of economic interest to small or medium-sized fires; and whether sufficient resources are devoted to the projects. If the project application is approved, it will be supported with funds from the Ministry of Economics on condition that individual associations demonstrate that they are spending their own R&D funds in cooperative work.

The AIF also administers a federal government R&D support project for small and medium-sized firms that began several years ago. The exact terms have changed over the years; but essentially, they permit the Ministry of Economics to subsidize 40 percent of the labor costs for scientists, engineers and technicians engaged in R&D for those firms with annual sales of DM50 million and not more than 500 employees (1984 figures). It will also pay 55 percent of the labor costs for new R&D personnel if the firm can show that it has increased its R&D effort. In 1985, the program was expanded to include payment for 45 percent of labor costs associated with new R&D personnel in those firms with annual sales of DM200 million and 1,000 employees. Also in 1985, the EC decided that the plan was allowable under Community rules, and it is now scheduled to continue until 1989.

The AIF also administers the Ministry of R&T program that encourages small and medium-sized companies to contract for R&D work. The program subsidizes the costs of an R&D project contracted out with external research bodies (including universities and even foreign institutes). The Ministry subsidizes up to 40 percent of the costs of extramural R&D projects for those companies that have up to DM50 million in annual sales, and up to 30 percent of the costs for those that have annual sales of up to DM500 million.

Defense R&D—The Bundeswehr Plan, harmonized between all three Services, forms the basis for the Defence Ministry's annual contribution to the Federal Government's budget estimate. The military staff implement the equipment aspects of the plan through annual programs of research, development and procurement.

Within the Ministry of Defense there are two agencies concerned with procurement but not part of the military departments. The Armaments Department is specifically concerned with procurement plans, focusing on technological problem areas "project-free." Within the Armaments Department, and reporting to its head, is the Commissioner for Defense Research, who collates the research requirements from all three Services, including international aspects. The Federal Office for Military Technology and Procurement (BWB) is the principal body responsible for carrying our procurement plans. These two agencies administer research, development and procurement for virtually all West German military equipment acquisitions.

As mentioned earlier, West Germany commits only 0.11 percent of its GDP to defense-related R&D, or about 15 percent of government-funded R&D. This is spent within the defense-related industries, with the national laboratories, and with the Fraunhofer Society, which has six of its Institutes devoted to defense research funded by the Ministry of Defense. The defense R&D program is coordinated by the Commissioner for Defense Research in the Armaments Department, but procured through the BWB.

ITALIAN POLICY FOR RESEARCH AND TECHNOLOGY

Background

In recent years, Italy has enjoyed one of the fastest GDP growth rates in Western Europe. The huge state industrial concerns brought their losses under control and last year even turned in small profits, while private-sector industrial concerns have been reaping the profits of major restructurings and cost reductions. During the 42 months of the Craxi government, Italy experienced political stability; however, in the last 7 months, proposals for major changes in Italian Government policies indicate a period of significant turbulence ahead for industry as the government tries to control the country's economy.

In October 1987, the Senate budget committee suspended work on the 1988 budget and told the Italian Government to rewrite it. In the Senate's view, the assumptions on which it was based were just not credible. Since then the fragile, five-party coalition government has proposed the following:

1. *A plan to reconsider the use of large sums of public money to bail out struggling private-sector companies.*

- While not proposing to withdraw all state aid for companies in crisis, the Senate thought it was time to put an end to a policy of rescue tied to exceptional events, and to create instead a system of intervention in crisis situations with well-defined aims, instruments, and a period of implementation. The politics of modernization now have to prevail because European Community rules on industrial aid are becoming more restrictive as the 1992 deadline for a free internal market approaches. A consensus has grown on the need to reduce government intervention in industry in all forms. Previous "rescues" too often saddled the government with an expensive "flock of lame ducks," a welfare activity that protected jobs without specifying a time limit to government aid. Since EEC law will prohibit this, a new approach is essential to ensure competitiveness.

2. *A rnultiyear procurement plan to boost spending on defense equipment by 60 percent over 10 years.*

. This would be the first attempt in 13 years to take a comprehensive view of defense procurement related to Italy's changing strategic requirements. The Defense Minister's political aim is to secure parliamentary endorsement for his planning approach, serving both to establish a consensus and to strengthen the ministry's bargaining position with the Treasury over budgetary entitlements. The plan represents an agreed approach among the three Services, and should reduce the crude lobbying that traditionally has prevailed at the expense of coherently balanced demands.

3. In May, the government sought to end a decade of rising budget deficits and public debt by *adopting a 5-year strategy for boosting taxes and cutting spending.*

. *This* is the first time an Italian Government has committed itself to medium-term budgetary reform; but there are still a great many details to be worked out if the policy is to succeed. The motivation has come from EC's push to free all capital movements beginning about 1990; without a credible budget control program, a debt financing crisis would risk a return to capital controls. An essential complement to the government's approach is closer coordination of monetary policies at a European level_.

With the approach of 1992 and the single European market, the Italian Government will be expected to conduct its policies—whether on science and technology, industrial assistance, or whatever—according to the rules of the European Commission. In that respect, therefore, Italian policies will be similar to the policies of other EEC members.

Compared to the complexity of the country's domestic politics, Italy's approach to the European Community and collaboration has been straightforward. It is: an active participant in the various European collaborative framework programs for research, a strong supporter of the European Space Agency, a member of a European five-nation R&D and design program in nuclear reactors, and a partner in the quadri-national Eurofighter program. In aerospace, as in other sectors of advanced technology (e.g., telecommunications or semiconductor manufacturing), Italy has had to look abroad for (mainly European) collaboration to deliver the "spearhead" technological know-how, markets, and "niche" activities. Nonetheless, its *research activities and development efforts still lag behind the European average, which is in turn, behind that of the United States. This relative under-commitment to R&D is causing concern within Italian industry,* which believes that current levels of technology, though significant, provide no guarantee of being able to maintain present achievements in the future without an increase in government funding of R&D.

Italian R&D Program Overview

Structural Problems With Industry

Any review of the Italian defense industry (and other sectors) must note the excessive number of relatively small companies. This causes many resource problems-including those related to R&D, where the long "gestation" periods of projects absorbs resources. The disadvantages of this structural arrangement were identified in a Parliamentary committee report (unpublished), finally adopted in mid-1987; the report observed that there is a limit to the amount of public money available to finance projects (referring to aerospace, but applicable generally), and deplored dividing it among competitive enterprises. Keeping public companies which offered similar products under separate banners also militates against the economies of scale in manufacturing that can only be achieved by creating companies closed in size to the European average. Industrial "rationalization" seemed necessary; the criterion governing which state holding company an operating enterprise should belong to should be the degree of support and synergy that other companies within the state group can provide.

Proposed alternatives to rationalization included the formation of consortia, and cross-border mergers such as that between SGS-Ates (Italy's main microchip manufacturer), owned by Stet and the nonmilitary semiconductor interests of Thomson in France, spawned by the ESPRIT program. In the telecommunications sector, however, the collapse in late 1987 of Italy's attempt to bring together its two main indigenous equipment manufacturers-Italtel (owned by IRI Stet) and Telettra (owned by Fiat)-epitomized the pitfalls of pursuing a national rationalization policy in Italy. The more aggressive companies have taken the initiative without waiting for the government to act. Olivetti, for example, has embarked on a particularly ambitious program of marketing and licensing deals to increase its access to world markets, while also embarking on an equally ambitious program of acquisitions.

Whatever the pitfalls, there is consensus in support of further rationalization within the defense industries, provided a coherent plan for developing industrial capacity exists. However, there is no sign yet that this is about to happen or, with the vested interests of politicians, is even possible. The situation is further complicated by the complex network of shareholdings, linking companies in which shareholders from other parent groups are still represented.

Financing of Research

With over 1500 amendments to be discussed, the finance bill for the 1988 budget was hotly debated. The comments in this appendix refer, therefore, only to proposed policies and priorities; these are subject to change until passed by Parliament.

Total research funding in 1987 was estimated at 1.45 percent of GDP, an increase of 22.3 percent over the previous year. Although funding is lower than for other industrialized countries, the gap has closed significantly in the last decade in spite of devaluations of the lire. The figure is also lower than the 3 percent recommended by the Dadda Report on the future of science and technology in Italy; but at least the government has recognized that increasing the research effort is the key to improving economic conditions.

Overall public sector spending on R&D accounts for 46.4 percent of total R&D. University research expenditure continued to increase in real terms (+24.3 percent), and in 1987 represented 16.4 percent of public sector spending on R&D—higher than for the research organizations.

In 1987, industrial R&D accounted for the other 53.6 percent of total R&D spending, with private sector companies registering a 25.3 percent increase. Public sector companies registered an increase of 22.2 percent further underlining the growth of R&D outlays since the early 1980s. Figures vary with companies, but one public company, Italtel, spent 12.4 percent of group revenues on research in 1987. This increase in R&D expenditure since 1980 compared with growth in GDP in the same period underlines the effort Italy has made to develop a broadly based R&D system.

In 1985, public agencies performed 43.1 percent of the country's R&D, but financed 51.8 percent; whereas companies performed 56.9 percent and financed 44.7 percent. The government shows its commitment to research by supporting the universities and large research organizations, but spends only modest amounts in its own laboratories. Company effort in research and innovation is sustained by public funding (17 percent of total public sector funding in 1985) and from foreign sources (3.6 percent of the total in 1985). The external funding that companies receive represents about 25 percent of their total R&D expenditure.

Trends-In October 1987, amid political and financial uncertainty, the National Research Council (Consiglio Nazionale delle Richerche, or (CNR) submitted its report on the state of Italian science and technology to the Plenary Assembly of the National Consultative Committees prior to submission to the Inter-ministerial Committee for Economic Planning (CIPE). Although presented publicly, the report had still not been passed for publication by the Camera dei Deputati several months later. This review refers to statistics presented in the CNR report.

Italy has a Minister of Scientific and Technological Research (MRST) who coordinates *national* policy on civil R&D. Defense R&D is the responsibility of the Minister of Defense. The major scientific institutions that advise the MRST on his S&T options for basic or long-term research are the CNR, the National Committee for Research & Development of Nuclear Energy and Alternative Energy (ENEA), the National Institute of Nuclear Physics (INFN), and the Higher Institute of Health (ISS). The National Space Plan (PSN) is managed by CNR.

The CNR reported that technological developments were making it difficult to demarcate between basic and applied research. The change in government priorities, combined with increases in the costs of basic research (growing complexity of instrumentation, use of databases and need for more efficient security systems, etc.) created problems for institutes in general and universities in particular. While university research expenditure had decreased significantly in most other Western countries between 1971-83, in Italy it had been maintained at around 15 percent of total public R&D expenditure.

The public research sector favors disciplines with potential economic or social impact; thus, one finds significant support for engineering and technology

(18 percent of 1988 public sector R&D budget), space research (11.4 percent), physical sciences (11.9 percent), and biological and medical sciences (14.4 percent). Net funding has decreased for nuclear research and, strangely, for interdisciplinary research.

A major principle of the Italian Government's S&T policy for supporting companies is that publicly funded R&D tends to contribute to increased industrial competitiveness; as a result, CNR aggressively funds high-technology areas such as aerospace vehicles and materials (28.4 percent of public finding), other vehicle and transport materials (11.2 percent), telecommunications (15.7 percent), and information technology (8.7 percent). The IMI Fund favored telecommunications (21.6 percent of the year's disbursements) and Information Technology (19.6 percent). The CNR presumably sees these industries as Italy's most competitive-but there could also be a circular argument.

Major S&T program funding is identified by laws when the annual Finance Bill has been passed. For example, the following earlier laws were listed in the bill for the 1988 annual and multi-year national budget:

- Law 651/1983: Triennial funding for special intervention in Southern Italy.
- Law 456/1984: R&D programs, AM-X, EH-101, CATRIN for aeronautical construction and telecommunications (Defense).
- Law 284/1985: National Antarctic Research Program.
- Law 331/1985: Urgent provision of university buildings.
- Law 710/1985: Contributions to encourage industrial production.
- Law 808/1985: Assistance for development and growth of aeronautical sector industries (Industry).
- Legge Finanziaria '87: Special rotating fund for technical innovation. Special fund for applied research, university buildings, etc.

The CNR report refereed to earlier[47] also lists an Institution of Ministry of Universities and Scientific & Technological Research, which has its operating costs paid by a "special fund." This fund also provides for capital expenditure on programs such as:

- CNR for Fellowships for Southern Italian graduates (as part of the Government's regional aid policy).
- Reform of Law 46/1982 and participation in international programs of research and innovation.
- Renewal of the Government's support for the International Center for Theoretical Physics.
- Research and growth of geothermal resources.
- Refinancing Law 30/1982 for renewable energy sources and for energy saving.
- Financing of ENEA.

On-going, multiyear activities requiring budgets to be authorized by law, and renewable annually in the Finance Law include (with anticipated changes for 1988-90):

- European COST program (+11 percent).
- Funding to CNR (+12 percent).
- National space program (-16 percent).
- Central Institute of Statistics (ISTAT) (+8 percent).
- Ratification and execution of agreement with ESA (+28 percent).
- Approval and execution of international agreement on energy (+5 percent).

National Research Council—The CNR currently receives about 20 percent of the total public sector funding. Its budget was increased by 19.2 percent for 1988, and its funds for the National Space Plan were doubled. It was due to receive additional funds for "10 new finalized projects," as well as special programs (Law 46/1986) for Southern Italy.

The initiation of the 10 "new third-generation finalized projects" will involve 1,200 new full-time staff, including 690 in CNR and 500 in companies and other participants. The 10 projects are:

- telecommunications,
- robotics,
- electronic technology,
- new materials,
- superconductivity and cryogenics,
- international collaboration,
- information technology,
- biotechnology,

[47] 1bid.

- applied chemistry, and
- construction.

These, presumably, are program initiatives coordinated by CNR.

Under triennial Law 46/1986, the growth of laboratories and personnel in Southern Italy should account for 40 percent of CNR's total expenditure in the early 1990s. The first planned agreements for investments in area, made between IRI (public), Olivetti & Fiat (private), and CNR (institutions), are in innovation technology and applied and developmental research.

Excluding university research, to which it contributes, CNR's research gives funding priority to the promotion of industrial activity (13.5 percent), human health (10.4 percent), and basic research (10.6 percent). By comparison, the state administration and public companies' figures for 1986 were: promotion of industrial activity (20.9 percent), defense (12.1 percent), and energy (12 percent).

National Space Plan—The National Space Plan (PSN) was formulated in 1979 to give greater support to this sector and to strengthen Italian participation in ESA, to whose budget it is the third largest contributor after France and Germany. Space activity is managed by CNR, based on a 5-year plan which it updates periodically. The third plan (1987-91) is in progress, with such programs as the telecommunications satellite (ITALSAT) the propulsion system of IRIS, the geodetic satellite (LAGEOS II), the tethered satellite, and the science satellite for SAX astronomy.

Over the 1987-91 period the proposed spending breakdown for both national and international programs is as follows:

- 30.5 percent-telecommunications satellites
- 21.4 percent—space structures & research satellites
- 9.2 percent-earth & environment observations
- 9.1 percent-space station
- 7.8 percent-propulsion
- 6.3 percent—space science
- 3.8 percent-feasibility studies for future projects
- *3.6* percent-Technological research
- 8.3 percent-Other activities

In 1987, space activity increased in importance, receiving 9.9 percent of public sector R&D funding, both through the NSP and the growing financial involvement of publicly owned companies.

National Committee for R&D of Nuclear & Alternative Energy—The activities of ENEA in 1988 fall within the fifth Five Year Plan, and most of its budget is spent in the energy sector. ENEA's budget has been cut by 18 percent, reflecting government indecision on energy policy. While awaiting the government's decisions, ENEA reorganized those parts of the plan concerned with fission. Other areas of activity include collaboration with CNR for the management and funding of the Finalized Project on Energy, the national research project in the Antarctic, and agrobiotechnoiogies.

Defense R&D

The defense budget in 1988 accounts for 2.3 percent of GDP, while defense R&D accounts for 12.1 percent of publicly funded R&D. The position of the Italian defense industry among the Western world's arms manufacturers is now well established, but the effort that brought it such prominence in the late 1970s and early 1980s has ended. Exports have peaked, though in 1986 they still accounted for around 60 percent of the industry's output, compared with roughly 40 percent for both France and Britain. Hopes in the defense industry are now pinned on the recently proposed and coordinated re-equipment program (mentioned earlier) in which defense spending is to increase by 60 percent over 10 years-provided Parliament endorses the plan.

The Defense Technical Scientific Council (DTSC) coordinates and directs research and experimental activities carried out on behalf of or by the three Armed Services. In particular, the DTSC:

- centralizes the direction of research of common interest to more than one Service;
- coordinates research of special interest to each Service;
- identifies research of common interest and provides guidelines for its execution; and
- promotes higher education courses for the three Services.

The Chairman of the DTSC reports to the Defense Chief of Staff. The DTSC has a Standing Committee, consisting of one general from each Service and its own secretariat, to define, plan, and supervise the research programs. A Standing Technical Secretariat is the working **body** that implements the Council's and the Committee's tasks. The DTSC also cooperates with other national research agencies, thereby ensuring cross-fertilization with the appropriate civil science and technology programs. The DTSC maintains three specialized facilities: the Center for Military Applications of Nuclear Energy, The Experimental Missiles Range managed jointly by the Navy and Air Force, and a Center for Technical and Scientific Documentation.

The DTSC is primarily concerned with inter-Service research requirements, and does not deal with development or production. The post of National Armaments Director, responsible to the Minister of Defense, was created to provide "one voice" within NATO and elsewhere, to speak with authority on the coordination and control of all activities within Italy's military procurement programs, including collaboration on research.

Research for military purposes is carried out within each Service by dedicated agencies, or through the auspices of the DTSC when there is a multi-service interest. Civil research agencies are used for the benefits of cross-fertilization and to influence the direction of civil programs which have a military application, as well as to use their resources and research skills.

International Collaboratiot—In the past decade, Italy has been involved in major collaborative military programs for all three Services, both within Europe on projects such as Tornado and Eurofighter, and elsewhere on projects such as AM-X with Brazil. Generally, Italy does not become the major partner unless the project was originally a national one, as with AM-X. Italy has also launched several national projects, such as the A-129 helicopter, and only later looked for partners. Now, however, it is unlikely that major new projects would be launched in isolation from the needs of NATO and members of the Alliance, or without first having been considered by the Independent European Programme Group.

SWEDISH POLICY FOR RESEARCH AND TECHNOLOGY

Background

Sweden accounts for 1 to 2 percent of the world's total resources for R&D, to which it commits about 2.7 percent of GDP. With its limited number of researchers, it is impossible for Sweden to conduct research in all fields of importance to industry and the community at large; flexibility, both in the use and direction of resources, and in the definition of priorities, is therefore crucial. Through regular Research Policy Bills the government gives the Riksdag[48] an overview of research and research training at post-secondary education level, of sectoral research, and of industrial research activities. The bills also guide the planning and development of research activities and general priorities.

The Swedes have a concept of sectoral research in which every government department, regional agency, and administration is responsible for its own future, and must therefore invest in the R&D needed for its future operations. This R&D is normally carried out by external partners; approximately 25 percent of all R&D is performed within the higher education system; the rest is performed by industry, national authorities, public, private, and cooperative research institutes, and independent consultants. The higher education system plays a much more prominent role in the performance of basic and applied research than in experimental development, but in industry the ratio of basic to applied research is put at 12/88. About half of the R&D undertaken by public authorities, institutes, and the like is research and half is experimental development.

The main objectives designated by the Riksdag in science and technology are to support the efforts of Swedish industry in strategic areas, and industry's technical renewal. The government and the Riksdag define broad areas of support and decide the balance between different research fields in a national perspective, leaving researchers to decide on the more detailed definition of priorities and the projects to be funded.

The political system (with only 7 prime ministers in the last 50 years) is noted for its stability and a

[48] Swedish Parliament.

strong social consensus that, together, promote the acceptance of structural change and positive adjustment of national policies. This flexibility is further enhanced by the organization of government into small, efficient departments oriented toward drafting legislation and toward political activities, with administrative work entrusted to autonomous agencies.

Emphasis is put on the search for new knowledge and its application to the benefit of society. A pro-science and technology consensus appears to exist among all political parties and trade unions. The Swedish view of the status of science is exemplified by the fact that the *Prime Minister chairs the Special Research Advisory Board* that serves as a conduit to politicians, eminent scientists, and the community; there is a consensus regarding the importance of science and technology as a strategic factor, rather than simply an enabling one—as an investment rather than a current expense.

Swedish Research and Technology Program Overview

Government Organizations and Coordination

There is no Ministry for Research in Sweden: *As a result of the widely adopted "sectoral research" model, each sector of society takes responsibility for the research required for both short- and long-term creation of knowledge. The* Swedish R&D organization is therefore sectorized, and each ministry has its own R&D organization. Most government departments have allocations for R&D; however, 74 percent of public grants are channeled through the "big three," the Ministry of Education and Cultural Affairs (30 percent), the Ministry of Defense (24 percent), and the Ministry of Industry, including state enterprises (20 percent). An analysis of total public R&D funding by socio-economic objective in 1986/87 showed "general advancement of knowledge" as the largest single objective at 43 percent, with defense the second largest at 26 percent (mainly development), energy and water at 6.2 percent, and the industrial activities at 5.7 percent. In the "general advancement of knowledge" by field of science, the top three were medical sciences, natural sciences, and engineering.

Since 1982 the coordination of R&D policy issues has been the responsibility of the Deputy Prime Minister, assisted by an Undersecretary of State in the Cabinet Office. When the Deputy became Prime Minister in 1986 he retained this role, thereby promoting a useful interchange in basic research between the universities and industry. The government has a Research Advisory Board, chaired by the Prime Minister, which interacts among politicians, researchers, and the community and keeps the government informed on research issues. It includes eminent researched in various fields and convenes larger groups to discuss R&D issues-often at the Prime Minister's summer residence.

The definition of priorities is crucial for smaller countries with limited resources, if they are to stay competitive in a rapidly changing world technological environment. In Sweden the Riksdag defined a number of priority fields in the Research Policy Acts of 1982 and 1984. By voting additional funds for R&D in the social sciences and humanities, the Riksdag noted the importance of R&D in those sectors that, although less immediately useful, are vital to a country's intellectual life.

It is accepted by the government and others that only by innovation can Sweden's economic prosperity be maintained. Other organizations involved in the planning and financing of research include the Research Councils, the Council for Planning and Coordination in Research (FRN), the National Board of Universities and Colleges (UHA), and the National Board for Technical Development (STU).

Research Councils—The Research Councils (RCs) administer flexible grants for basic research, 90 percent of which is conducted within the higher education system.[49] Three of the RCs, together with the FRN, come under the Ministry of Education and Cultural Affairs:

- Medical Research Council (MFR)
- Natural Science Research Council (NFR)
- Council for Research in the Humanities and Social Sciences (HSFR).

The Council for Forestry and Agricultural Research (SJFR) comes under the Ministry of Agriculture.

[49] Annagreta Dyring, "Swedish Research, Policy, Issues, Organization," transition by R. Tanner, Swedish Institute, Stockhold, 1985.

The task of the RCs is to encourage research both in new and established fields. Besides promoting rest arch of scientific importance, the RCs also encourage the dissemination of research that maybe important to the larger society. They allocate funds according to criteria that the researchers themselves define. The 3 RCs under the Ministry of Education and Cultural Affairs each have 11 members; the Chairman and 3 members are appointed by the government, while the other 7 are elected every three years by active researchers in the faculties. Members can serve up to 6 years; thus, except for the FRN, the majority are research representatives.

The RCs occupy a central position; their priorities carry weight, because they ultimately select among, and fund, new research projects. Professional chairs can be affiliated to the RCs, and RCs are also responsible for research appointments, postdoctoral fellowships, and post graduate appointments in subjects with heavy recruitment needs. The RCs also evaluate research.

Much international research cooperation is carried out under the auspices of the RCs. The Board for Space Activities (DFR), for example, funded both by the Ministry for Industry and the Ministry for Education and Cultural Affairs, is independently responsible for various national and international space programs, including Sweden's contribution to ESA. Other RC tasks include special investigatory assignments for the Government.

Council for Planning and Coordination of Research-The FRN's main task is to initiate and support research of great social importance, together with the RCs and sectoral bodies. While the basic RCs are dominated by researchers, the FRN is dominated by community representatives from the four main political parties, trade unions, the Swedish Employers Confederation, municipal authorities, and county councils; the government appoints the FRN chairman. The FRN's structure reflects its role of monitoring community research needs and starting new, probably multidisciplinary, research programs. The FRN's tasks also include distributing state grants for expensive scientific equipment, carrying out studies, and sponsoring the National Understanding of Science program.

*National **Board** for Technical Development—The STU* is the state agency that encourages industrial research and development. It is the only central body that both supports initiatives, and plans and advises on technical research and industrial development. Its contributions vary from long-range, broad-based research to technical development, the allocation of venture capital, advisory services, information distribution, and technology procurement. The predominant forms of support for technical R&D are both general and selective. Support is channeled through the STU (or the Industrial Development Fund for longer-term, high-risk projects) in response to proposals from companies and institutions. The support is general, in that anybody can apply for it, but selective, in the sense that awards are made after an evaluation by the funding agency. The STU cooperates closely with higher education establishments and provides much of their funding. Loan to large companies are restricted to projects where an exchange of knowledge with universities and research institutes is part of the program. The STU also has a program for the "Development of Knowledge" as well as its own Technical Research Council.

National Board for Universities and Colleges—The UHA, a Government agency subordinate to the Ministry of Education and Cultural Affairs, is concerned with coordinating and planning national higher education, research, and research training. It compiles documentation on which the government and the Riksdag base their decisions for developing resources for higher education and research. It submits annual budgetary requests to the government, based on the requests it receives from individual educational units and other authorities within its jurisdiction. Central planning of higher education, research, and research training in various fields is conducted by five sectoral UHA planning committees. In budgets since 1982, most education expenditure items have been cut, but not research and research training. Research and research training funds are distributed by the local higher education establishments, not the UHA.

Sectoral Research—Beside the above organizations, the sectorization of Swedish R&D has spawned special agencies for planning, financing, and sometimes performing R&D in various sectors. In some cases special bodies exist to coordinate research in a particular sector, while in others these activities are coordinated through the ministry concerned. There are some 100 sectoral bodies financing R&D, most of them small. Those with extensive R&D activities include the Council for Building Research (BFR), the National Board of

Education (SO), the National Defence Research Institute (FOA), the National Environment Protection Board (SNV), the Swedish Transport Research Board (TFB), and the Work Environmenrt Fund (ASF). The STU described earlier is an agency of particular importance for technological development, and is also a sectoral agency for industry. In its review the OECD,[50] while recognizing that a reasonable balance had been struck between long-term basic research and short-term sectoral research, advised the government not to establish any more specialized in-house R&D facilities for fear that they will isolate themselves from the university system and from strategic research, and be unable to show a correlation between success and funding.

The National Defense Research Institute is a joint sectoral agency responsible for planning and coordinating defense research and for conducting the bulk of its R&D. Its funding allocation is part of the annual defense budget, although long-term development guidelines are laid down in the defense policy decisions enacted at roughly 5-year intervals. FOA also receives an allocation through the Ministry for Foreign Affairs to finance documentation for arms limitation and control.

The National Board for Space Activities is responsible for state-funded space research. Its duties include initiating space R&D long-range analysis, distributing state grants for space research and space technology development, and supporting industrial development in the space sector, including Sweden's contribution to ESA and other international projects.

Sweden has few governmental R&D laboratories outside the system of higher education.

Industrial and Technical Council—An Industrial and Technical Council (ITC), attached to the Ministry of Industry, was set up in 1981 to represent educational, research, and industrial interests, and is designed to promote contacts between government, industry, and technical research. Other miniseries have similar units attached to them.

R&D Policy Formulation

The Role of Education—Higher education in Sweden is a public research resource, and *university researchers are civil servants.* Most basic research takes place within the higher education system and consists of general scientific development, problem-solving, and goal-oriented research. Most development work is done by industry. In the main, the state finances R&D through:

- permanent resources to the higher education system;
- project funding for the research councils; and
- project funding for the special sectoral agencies.

Decisions by the government and the Riksdag concerning higher education research essentially are based on the annual budget requests submitted by educational establishments and research councils. Although the state exercises no detailed control over basic research, except through the establishment and scope of professorial chairs, it issues directives for major sectoral measures whenever it deems the national coordination of R&D necessary. Loose control is maintained through the size of faculty grants and various funding items within them, and by the balance of funds between faculties.

For applied R&D fincanced by the sectoral agencies, the state sets the basic guidelines, based on social considerations of policy, priorities, and structural matters-after consultation with industry, researchers *and the unions.* Within the government, ministries prepare R&D proposals based on requests from authorities, committees, and their own R&D agencies. The government presents its R&D policies to the Riksdag in periodic research bills.

Research Bills—Generally, there is political unanimity concerning the direction of research policy. Various research policy reform measures were carried out in the 1970s to foster technical renewal in industry, encourage industry to increase its own basic research spending, finance institutional research through 5-year framework programs, and the like. To achieve a coherent research policy, the government's practice since 1982 has been to introduce a comprehensive research bill every 3 years. The first such Bill was introduced by the government in 1982, followed by another in 1984 which represented a broader approach across 10 departments. The third was presented in 1987.

[50] Organization for Economic Cooperation and Development, "Reviews of National Science and Technology Policy: Sweden," ISBN 92-64 (Paris: 1987).

The 1982 bill introduced measures concerned with the dissemination of research information, improving contacts between university and industry, evaluating research by research councils and sectoral agencies and, most importantly, improving research planning and coordination. The 1984 bill presented long-term plans from sectoral bodies, so that university research planning could include the sectoral agencies. The bill provided for strengthening research evaluation and, for the first time, defined priority areas across research fields. Industrial strategic priority areas in technical research had been adopted in an earlier act on industrial policy.

The 1984 Act put less emphasis on planning, but defined a number of main issues such as quality of research, working conditions of researchers, and the balance between resources for the sectoral agencies and resources for basic research. The need to strengthen basic research was given particular attention. Measures to improve recruitment of students to research training were established and a system of student grants introduced. In sectoral research, long-term development of knowledge and competence was given a higher priority. The long-term priorities of the 1982 Act remained unchanged, but special emphasis was put on environmental research, information technology, materials science, and biotechnology.

Civil R&D Activities

Universities and Colleges—Sweden is divided into six higher education planning regions, with the university being the main institution of higher education and research in each region. There are 34 state institutions for higher education in 21 cities and towns. Higher education units with permanent research organizations exist in seven cities: Stockholm, Uppsala, Linkoping, Lund, Goteborg, Umea, and Lulea. Faculty and sub-faculty boards plan the research training within their fields and supply the university senate with documentation on which to base its applications for funds, and decide the distribution and use of university or college resources. Some faculties have only one department, while others may have up to 40. Specialized groups that are more or less permanent conduct the research. There are also multidisciplinary projects.

Within the higher education system there has also been a growth of problem-oriented research involving researchers in several disciplines; the Riksdag specifies these "thematic programs." Several professorial chairs have been established for each theme, and a number of research centers have been formed at the universities and colleges involved, such as the Research Policy Program at Lund and the Interdisciplinary Centre at Goteborg.

As a result of the increase in research and research training resources in the 1980s, the higher education system has taken on a growing number of research assignments from industry and the sectoral agencies.

Institutes—By international standards Sweden does not have many state research institutes. It has been, and remains, a deliberate policy of the government and the Riksdag to gather R&D resources within the higher education systems. Research institutes remain an exception. The government has established a number of independent R&D agencies and institutes in specific fields. Usually these are interdisciplinary to benefit the principal customer, exploit the installation of special equipment, do specialized tasks, or meet the needs of a particular region. One such independent R&D institute is the aforementioned National Defense Research Institute, which conducts defense-related research in the natural sciences, engineering, behavioral sciences, and medicine.

Partly to assure development in certain areas, the government has sponsored special institutes and companies to conduct applied R&D. To avoid scattering R&D resources, the government and the Riksdag have recently been more reluctant to start research institutes outside the universities.

A number of "cooperative" research institutes funded equally by government and industry exist; they form a common platform for industry and the state to develop the competence of various sectors. (Other cooperative research, similarly funded, is carried out in universities without the formation of an institute.)

R&D *in Industry—As* mentioned earlier, only 12 percent of industrial R&D is estimated to be basic research. With companies funding virtually all of their own R&D, it is understandable that the bulk of it should be "experimental development," *The strict distinction between the R&D roles of industry and the public sector (including academia), necessitates close cooperation and transfer of R&D results. The development of good relations between university and industry is therefore very important to Sweden's technological and economic progress.* For many years, both imports and exports of high-technology products have grown more rapidly than those of other sectors; the success of industry must, therefore, depend on its ability to manage technology-related factors.

While industry does little basic research, the OECD Review[51] gives some significant figures for total R&D:

- it represents 10 percent of value added in industry;
- it is nearing 70 percent of all R&D in Sweden;
- about 95 percent of R&D is in firms with more than 500 employees-the five largest account for 37 percent, and the 10 largest for 55 percent. Some of the large companies have their own research councils;
- while R&D is mostly allocated to developing existing products, innovation is growing;
- in some industries, R&D is hampered by lack of manpower,
- R&D-based high technology firms are on the increase, but do not yet play a major role.

University/Industry Cooperation—Attitudes toward operation in both industry and the universities have changed since the early 1970s. There has been strong industry interest in specific programs launched by public agencies, promoted in part by the predominance of well-trained researchers in the universities, and in part by the need of companies for the continuous generation of knowledge. R&D-intensive industries, such as pharmaceuticals and electronics, are now establishing closer links with the universities.

In 1985, the UHA canvassed major companies to identify their graduate needs by qualification, and their preferences for content, kind, and location of education and research. Industry's suggestions included expanding engineering degree studies, producing more computer specialists and other graduates with computer science qualifications, increasing in-service training, offering better language teaching, increasing the interchange of qualified personnel between academia and industry, providing for better dissemination of R&D results, and encouraging wider sharing of specialized laboratories and expensive equipment.

Adapting the system of higher education to the community's rapidly changing educational needs has high priority in Sweden. The OECD Reviews* quoted the Undersecretary of State in the Ministry for Education and Cultural Affairs as saying, "Due to the size of the country and due to specific traditions in higher education, there are three different oriented-research systems which have to co-exist geographically on seven main campuses: first of all academic research; secondly, politically initiated sectoral or mission-oriented research in areas such as defence, health, environment, housing, etc; and thirdly, commercially initiated contract research towards sophisticated products in, for example, the pharmaceutical industry, metals and pulp, computers, telecommunications, etc. All these kinds of research have to be undertaken in the same physical environment and partly by the same people."

Since the mid- 1970s the trend has been for higher education to be job-oriented and framed in the manner of the technical universities or the business schools. By international standards, Swedish industry employs fewer postgraduates or PhDs than comparable countries, preferring instead to hire graduates and train inhouse. This has no doubt contributed to the paucity of basic research done in industry compared to the universities.

University-to-industry cooperation mainly occurs through government agencies responsible for R&D support of interest to Swedish industry; the most influential are the STU and the BFR. STU, for example, funds about 30 institutes in cooperative programs. Most institutes are-located at or close to a university and collaborate very closely with it. The financing of the institutes is regulated through long-term contracts between STU and an industrial consortium, on a 50/50 basis.

SUT also funds up to 500 researchers and up to 1,000 research students in information technology and other priority areas, thereby complementing the basic resources of the university system.

Other examples of university-industry cooperation include science parks, innovation centers. and foundations, all of which grew rapidly in the 1980s. Special arrangements have been adopted, one of which is an R&D center established within a

[51] Ibid.

[52] Ibid.

university to promote contract research as well as industrial applications of new ideas. There are several such centers, often acting on behalf of the whole faculty, some of whom take the application to the pre-production stage. Another model is that of a transfer center established jointly by industry and the university, perhaps by way of a foundation. The most common arrangement is a foundation jointly created by a municipality or a county council, the county administrative board, a university or college, a chamber of commerce, some companies, and one of the industrial development boards. In the government's 1985-86 Budget Bill, special emphasis was laid on promoting the regional economic role of universities, with funds provided for support and dissemination of the technology and knowledge developed. A particularly novel arrangement is the venture in biotechnology carried out in the laboratories of the University of Uppsala, financed by STU, the university, and Pharmacia (a major pharmaceutical company) whereby Pharmacia employs the researchers but a special steering committee ensures that the results are open to all. Acknowledging that some cooperative arrangements may be more effective than others, the government has assigned to FRN the responsibility for evaluating each model.

Other initiatives to promote university/industry cooperation include:

- Adjunct or part-time professorships filled by scientists working outside the university system.
- A program under the government's Commission on University Cooperation with External Partners to make so-called "liaison researchers" from universities available to small and medium-sized companies. The Ministry of Education funds only the initial phase of a project, with regional organizations and the companies funding it thereafter.
- Contact offices at the technical universities to facilitate liaison with local industry. The Federation of Swedish Industries and some regional chambers of commerce have established their own contact offices at the universities of Stockholm, Uppsala, Lund, Linkoping, Umea, and Lulea.

Evaluation of R&D—Research is evaluated through peer review committees comprised of individuals with international experience and reputation. While such audits can help in assessing the quality of R&D, it may be that unless they knew the quality to be high, these international experts would be reluctant to accept the auditing task, as they would be unlikely to learn anything new. Sweden has some scientists of international repute, working in established centers of excellence; this preferential treatment of places and people of excellence may be considered elitist, but according to the OECD it appears to have served Sweden well. Sweden has been eminent for decades in such fields as ultracentrifuging in biochemistry, electrophoresis, exclusion chromatography, and the separation of large biomolecules, together with the enabling equipments in each field. Such success reflects both the persistence and perception of individuals and government support.

Defense R&D

Long-term direction for the defense program is provided by the Riksdag in 5-year defense resolutions, the last of which passed in June 1987. Annual budgets define priorities and identify changes. In 1986/87, defense programs accounted for 26 percent of government funded R&D of which, as in other industrial countries, the major portion was for product and project development rather than for basic research. Allocations Under ''defense R&D" on industrial development, since research contracts are placed with individual companies. Moreover, "common defense research" *as it is called, is closely connected with several other objectives such as space, energy, transport and communications, nature conservation, and public health and hospitals.* In a statement published by the Ministry of Finance, the civil functions for which the Ministry of Defense is responsible even included ecclesiastical preparedness.[53]

The FOA is the joint sectoral agency responsible for planning and coordinating defense research and conducting most of related R&D activities. In accordance with its policy of neutrality, Sweden retains a comprehensive defense industry capability, and can claim to be among the world leaders in several technologies. When capabilities are not domestically available, the freedom to manufacture imported systems and equipment under license or in joint ventures is inevitably sought.

[53] "The Swedish Budget 1988/89," A summary published by the Ministry of Finance, 1988.

International Collaboration—Swedish industry and its exports are highly specialized. Sweden has limited resources and cannot afford to develop a comprehensive range of complex technologies; therefore, it collaborates at all levels from individual researchers to government. International R&D cooperation includes exchanges of information, cooperation on individual projects and major research programs, coordination of research inputs, cooperation on research training, joint financing of research, and joint research institutions.

It is difficult for a small country to strike a balance in allocating its resources among national and international programs; tradeoffs have to be made among existing R&D programs, or at the expense of other sectors of society. For many years, the Swedish scientific community has been mainly responsible for achieving a sound and balanced international orientation for Swedish R&D; this has been a guiding principle of Swedish research policy. Decisions on participation in international programs hinge mainly on potential scientific returns, with special financial arrangements being made to allow participation in long-term European projects such as CERN, ESA, and cooperative fusion research. Though international research projects are also promoted by other motives such as industrial needs and policies in energy, trade, or development assistance, the importance of scientific value as a determining factor is likely to remain. Initiatives to increase international cooperation in research will largely continue to emanate from the scientists themselves; but the Prime Minister is actively involved in ensuring that costs and benefits are compatible with the government's integrated research policy.

Sweden also participates in international R&D under the aegis of such organizations as the United Nations UNESCO. It is involved in EUREKA and, though not a member of the EEC, is cooperating on ESPRIT, BRITE, and RACE, etc. through an agreement with the European Commission signed in January 1986. Sweden is an active participant in COST (European Cooperation in Scientific and Technical Research).

There is comprehensive R&D cooperation among Nordic countries funded through the budget of the Nordic Council of Ministers, and focusing on industrial technology. Substantial grants are channelled into technical and scientific cooperation by the Scandinavian Council for Applied Research (Nordforsk), the Nordic Industrial Fund, and under such project as Tele-X. Nordic R&D cooperation was strengthened by the establishment, in 1982, of the Nordic Research Council.

Bilateral research associations promoted by STU have been established with several countries, most notably France, Germany, and Japan, with extensive contact between individual researchers in the U.S. and elsewhere. The 1984 Research Act proposed that significant funds be allocated to enable researchers and students to work abroad, as well as to facilitate visits by foreign researchers to Swedish universities.

SUMMARY OF EUROPEAN COLLABORATIVE RESEARCH AND TECHNOLOGY

Background

Military Trends in Collaboration

Two diverse arguments support the current trend toward increased intra-European collaboration: first, the pressing need to improve NATO's military capability through a more efficient use of resources, and second, the political and commercial need to promote a stronger "European defense identity" within the Alliance and to maintain a viable "European armaments base."

Supporters of transatlantic cooperation emphasize the need for more efficient use of resources, while others emphasize the need to maintain a viable European defense industry. The need for Europe to export armaments and high-technology products figures strongly in arguments *for* European and *against* transatlantic cooperation, due in part to restrictive U.S. policies on technology transfer and third country sales.

In fact, both arguments are valid. The issue that brings both sides together is money. Real cost growth for military hardware can be more than 5 percent each year and the trend is expected to continue. Unfortunately, defense budgets are not growing to meet these increased costs. This has become a critical problem for the Alliance, which sees inevitable and unacceptable shortfalls in conventional capability, unless steps are taken to reduce armament costs.

While some rationalization is taking place, today's European defense industry is still fragmented and nationalistic, with manufacturers limited to smaller volume production that results in higher costs. In seeking a more cost-effective industrial policy through collaboration, Europe is trying to "put its house in order" and obtain more capability from its defense investments. A strong European defense industry will be better able to collaborate with the United States on more advanced programs, better placed to introduce European defense products to the U.S. market, and able to satisfy requirements for which European governments have in the part turned to the United States.

All European NATO governments today broadly support armaments collaboration, as the collective Ministerial Declaration and Decision Document, issued after the meeting of the Independent European Programme Group (IEPG) in November 1984, revealed.[54] To increase the benefits from armament collaboration these texts emphasized: 1) the importance of R&D collaboration to provide a basis for future collaboration on development; and 2) the need for staffs to work together from an early stage to see if needs could be harmonized.

The IEPG, whose task is to encourage European collaboration in defense research and procurement in a NATO framework, also called on nations not to launch projects that would duplicate others' efforts, and suggested that European governments be more willing to adopt equipment already in production in other Alliance countries, preferably European. *The commitment to collaboration is now registered strongly in national Defense White Papers,* and the intent of the IEPG Ministerial statements is reflected in national procedural documents that instruct MoD personnel to harmonize requirements, avoid duplication, and enhance coordination with the Allies' research and procurement programs.[55] Despite this commitment to collaborate wherever possible, there remains no directive in the U.K. MoD, for example, that European products be given priority in procurement; the principle of "the best equipment for the price" is still paramount.

The IEPG procurement concept models the U.S. style of competitive, consortium contracting, but on an international scale, not unlike the approach now being taken for "Nunn" programs. *Whether diverse industrial structures in individual European countries will allow such competition remains to be see, but the political will essential to success has been established.*

European Collaboration on Advanced Civil R&D

The growing concern in Europe over its technological future can be attributed to three factors: 1) the enormous impact of information technology; 2) the growing perception of advanced technology in strategic terms and the need for self-sufficiency; and 3) the severe "structural" handicaps to Europe's international competitiveness.

Europe's problem does not seem to lie in any critical shortage of basic technological resources, skills, or funds to support them, but in its failure to organize properly to exploit innovations to maximum commercial advantage. Some analysts suggest that Europe lacks high-technology companies big enough to challenge the largest U.S. or Japanese competitors internationally, but this argument does not stand close scrutiny. More plausible is the argument that the structure of Europe's industries has remained too rigid, with older companies slow to recognize that profitable growth requires worldwide marketing resources and a readiness to innovate. Many larger European companies still rely heavily on home markets that no longer provide economies of scale, or else they have traditionally set up operations dedicated to each national market. This contrasts sharply with the ways in which U.S. companies such as IBM, Hewlett-Packard, and Texas Instruments have organized on an EEC-wide basis to take advantage of the Common Market.

Breaking down the long-standing barriers that have isolated European companies from each other, as well as from other European national markets, is an explicit objective of the significant collaborative high-technology initiatives now being pursued. Industry, however, sees additional reasons for collaborating in research. One is that, as technologies converge, companies that once specialized in a single activity need to draw on a spectrum of

[54] Independent European Program Group, "Ministerial Declaration and Decision Document," reporting on first IEPG Ministerial Meeting, Nov. 22-23, 1984 (published in NATO *Review,* December *1984,* pp. *27-29).*

[55] Symposium *on* "A European Armaments Policy," Brussels, October 1979.

sciences to progress; innovation increasingly demands a multidisciplinary approach. The other is that as product life cycles shrink, the need for more frequent introduction of new ideas increases the costs and risks of research; companies can no longer afford to risk a generation gap in their products because of research failures.

As an inevitable step in the above process, *the Single European Act passed by the European Parliament provides the impetus and means to create an open market among EEC members by 1992. The* pace of European industrial integration is accelerating, driven by high-profile government publicity campaigns that "Europe is open for business" in 1992. Astute companies are preparing for 1992; if the internal barriers fall as planned, Europe will need to have in place an industrial structure that can exploit the increased opportunities.

The Impact of Collaborative Research on Future Defense Equipment

The political trend is for governments to reduce spending on defense R&D in real terms, encourage defense contractors to invest more, and put more emphasis on civil research and commercial applications.

The growing European collaborative civil research programs are explicitly directed towards civil commercial application, with little public recognition of their possible application to defense equipment. The dividing line between defense and civil R&D in the technologies appears to be fading, and only becomes marked when technologies are applied to products; at that stage, the trend is for funding to transition form government support to industry investment. *The European collaborative research civil programs clearly do have defense applications, but it appears to have been left to the industries involved to identify and exploit them; the* programs may not yet be sufficiently mature for such technologies to have been matched with defense equipment requirements.

Collaborative Military Programs

Overall Trends

From all that has been said and published, it is not the intention of the IEPG countries to encourage a form of European protectionism at the expense of U.S. defense companies; rather, a stronger and more coherent European industry is viewed both as insurance against waning U.S. attention to Europe, and as a step towards a stronger, more coherent industrial base throughout all of NATO, including the United States.

In fact, a significant impetus was given to transatlantic NATO collaboration by the Nunn-Roth-Warner Amendment to the fiscal 1986 Defense Authorization Bill. European governments and companies are now responding positively to Nunn program opportunities, and transatlantic consortia are forming at record pace; most major European defense contractors are involved in one or more projects listed as "Nunn Projects."

However, there are major European defense equipment programs provided for by Memoranda of Understanding (MoUs) between participating NATO nations, to which the U.S. Government is not a party-and in which U.S. companies can only hope for a minor or subcontracting role. Funding for such projects will come from the "D" element of government-funded defense R&D budgets, with little or no research directly applicable once the collaborative project stage has been reached. These joint programs are invariably run by companies formed specifically to manage them. Table G-1 presents a listing of the most important ones.

To this list of military projects can be added the civil aerospace Airbus program, managed by Airbus Industries on behalf of the U. K., French, German, and Spanish Governments.

Perhaps the most visible example of collaboration among European companies is the European Fighter Aircraft. This program is experiencing all of the traditional problems surrounding joint R&D and production programs, such as equitable worksharing, cost control, project leadership and control—and overcoming national biases. How *the Europeans address (and overcome) these issues may be a good indicator of how well economic "integration" will work in 1992 and beyond.*

European Fighter Aircraft

Program Structure and Goal—The EFA program is a four-nation collaborative venture involving the United Kingdom, Germany, Italy, and Spain. An October 1986 MoU authorized a four-government management organization, the NATO European Fighter Management Agency (NEFMA), to be set up in Munich under the auspices of NATO. The organization is similar to the NATO Multi-Role

Table G-l--Major European Management Companies

Company	Project	Nations
1. Panavia	Tornado	United Kingdom, West Germany, Italy
2. Eurofighter & Eurojet	European Fighter Aircraft	United Kingdom, West Germany, Italy, Spain
3. E H Industries	E H-101 Helicopter	United Kingdom, Italy
4. Eurocopter	Light Attack Helo	United Kingdom, Italy
5. Joint European Helicopter	A-129 Light Attack Helicopter	Italy, United Kingdom, Netherlands, Spain
6. Euromissile	HOT, Milan, Roland	France, West Germany
7. Euromissile Dynamics Grp	TRIGAT	France, United Kingdom, West Germany
8. BBG	ASRAAM	United Kingdom, West Germany

combat Aircraft Development Agency (NAMMA), the Munich-based tri-government agency that oversees the Panavia Tornado program. Also Munich-based are the EFA manufacturers' consortium, Eurofighter Jagdflugzeug GmbH, consisting of British Aerospace, MBB, Aeritalia, and CASA; and the EJ-200 engine consortium, Eurojet Turbo, consisting of Rolls Royce, Motoren-und-Turbinen Union, Fiat, and Sener. Many leading electronics and equipment companies in the four countries have also either formed, or are forming, international consortia to bid for systems contracts for the project. The master contracts for the program, placed through NEFMA, go to Eurofighter and Eurojet, both of which started work ahead of the recent MoU and financed it themselves to save time.

The Chiefs of Air Staffs of the four countries met in Madrid in September 1987 and reaffirmed their air forces' requirements for a fighter to meet the air threat projected from the mid-1990s. They signed the European Staff Requirement for Development (ESR-D) and forwarded it to their respective governments, with the hope that an early decision would be made to proceed with full development. That commitment has now been made by the U. K., Germany, Italy under an MoU signed in May 1988, with Spain expected to sign later in the year.

The original, tentative national requirements for the EFA were United Kingdom and West Germany, 250 aircraft each, Italy, 165, and Spain, 100; but budget stringency has reduced the West German figure to 200 for planning purposes, and there is some doubt as to the firmness of the U.K. *S 250. The United Kingdom and West Germany each have a 33 percent share in the development program, while Italy and Spain have 21 percent and 13 percent, respectively. The initial commitment is to spend $3.5 billion on the development stage, which should be followed by a further $10 billion. *Each production aircraft is expected to cost* **$52** *million at today's prices,* but the final fixed-price figure will not be agreed until nine prototypes have been built for flight testing; each country will build at least one of the prototypes, with the first scheduled to fly in mid-1991. Production contracts are expected to be awarded in 1992 and 1993 after development has proceeded far enough to confirm that the aircraft meets its performance requirements, with introduction to service in 1996.

The program is ambitious in technological, economic, and political terms. In the new climate of fixed-price, competitive contracts-and with the specter of the Nimrod cost and schedule overruns to spur them on-the industrial partners are well aware of the challenges they face to keep costs in line and avoid the ever-present "alternative" to buy a U.S. aircraft (e.g., the Hornet 2000). In Britain, more than in the partner nations, the advantages of "going European" tend to be presented in terms of job creation, but the most compelling case for keeping the project "European" was to retain a cutting-edge technological capability. Cost, it seems, was not the over-riding factor in the commitment to EFA over such alternatives as the McDonnell Douglas Hornet 2000, even though the program is disrupting defense budgets in all the participating countries (the U.K. MoD has admitted that its share is only "affordable with difficulty"); and Germany has reportedly canceled nearly 200 defense projects to "make room for EFA" in its budget.

BAe Experimental Aircraft Programme (EAP)- BAe first flew its experimental demonstrator aircm the EAP, in 1986. Originally conceived as a technology demonstrator when U.K. industry's patience ran out after several years of MoD procrastination over the RAF's fighter requirements, it was also something of an "EFA trailblazer." Funded by BAe, Aeritalia, partner companies in the U. K., Germany, and Italy, and eventually by MoD, the EAP was designed and built remarkably quickly; it was developed to demonstrate "fly-by-wire" and other advanced technologies for eventual application on "the U.K. 'S next fighter aircraft." Only one aircraft was built. In June 1987 it was announced, ahead of the recent EFA MoU, that the EAP was to be further funded for use as a flying test-rig for the four-nation EFA development program. Additional funding was also expected to cover flight setting of the EJ 200 engine being developed by the Eurojet consortium.

Commercial Aspect—The original EAP had been funded to a much greater extent by industry than by the U.K. MoD (German and Italian MoDs had declined to contribute), with the participating companies hoping to secure favorable—or even monopolistic-positions once EFA was launched. However, after the U.K. government imposed its considerable political influence on the EFA project, all EFA bidding became competitive, with all bidders having an equal chance regardless of whether they had contributed significantly on EAP. This caused those companies that had contributed to doubt the wisdom of such up-front investments on major projects when governments denied them any competitive advantage for so doing. The companies now have to bid a firm fixed price for development, drawing on hard-won background knowledge, with the prospect of further competition for subsequent production-and no guaranteed share for the developer. There is little doubt that if the companies had not made such investments, but had left it to governments to act, the EFA project would not be as mature as it is.

Other EFA procurement rules include the need for all bids to be collaborative; bids from single companies which, on their own, have all of the necessary skills will be adjudged non-compliant—*even if lower priced. This* ruling has led to ad hoc or "pseudo" teamings, proliferation of so-called "expert' companies, and lengthy bid lists and evaluations. The EFA program is collaborative by government edict, and no country has been prepared to forego involvement in important high-technology areas; this has led to mixed teams, committee or "political" choice of program leadership, as the risk of longer schedules, increased costs, and technological compromise.

The Radar Battle—The EFA program, if seen as the last major European military aerospace program of this century, may also decide the future of some bidders in specific technical fields. The first equipment to be decided will be the radar, and only in the United Kingdom are two companies (Ferranti International and GEC-Marconi) fighting for their country's share of the EFA radar contract. Each of the other three countries has only allowed one of its companies to bid for the contract, under a "chosen instrument" policy. The radar, which is the biggest single item after the engines and airframe, should be worth $2 billion shared among the four nations; this is about the same as for the canceled GEC-Marconi Nimrod AEW aircraft.

Largely as a result of its experiences on Nimrod and the troubled Tornado Exohunder radar programs, GEC has opted for a low-risk solution for EFA, based on the technology of Hughes' APG 65; Ferranti has offered an all-European. European Collaborative Radar (ECR 90) solution based on its own technology. GEC, which believes that the next competition will be between Europe and the United States, apparently sees the competition's outcome as crucial to the structure of European airborne electronics companies. Ferranti, on the other hand, is more concerned with Europe's retention of high technology, and the ability to update it, free from possible U.S. embargoes.

Under its bidding rules, *Eurof`ighter has insisted on freedom to export all components of the aircraft.* Bidders for contracts have been warned that they must guarantee freedom to export the equipment they supply, or list in advance the countries to which it cannot be exported. European companies are bound only by their governments' adherence to the general Western ban on sensitive sales to the communist world. Although not formally directed at the United States, this rule reflects Europe's sensitivity to U.S. technology controls and will affect U.S. companies most. DoD's response to the situation was a draft MoU that called for a phased release of APG-65 technology conforming to EFA development milestones, and assurances of an equitable workshare for U.S. industry. The DoD also indicated its willingness to be flexible in working out its ground rules for export of the radar technology to non-EFA nations. It emphasized that EFA nations should meet their own inventory requirements before trying to export the aircraft-thereby deferring export license requests until around the year 2003.

European Space Program

The European Space Agency is currently considering its long-term objectives for a series of major projects, including: an upgraded version of Europe's launcher, Ariane-5; Columbus, intended to be Europe's contribution to the U.S. space station program; and the French-sponsored Hermes spaceplane. In the face of significant cost growth on existing programs, ESA is under pressure to redefine its long-term program which the U.K. Government has described as "over ambitious and beyond Europe's financial capacity-and has failed to show how private sector funding would be factored in to reduce dependence on government funding. " These concerns are beginning to be shared by others of the 13 ESA member states, and even the most optimistic are concerned that ESA may have proposed more than Europe can achieve. The concerns are two-fold: first, the cost of building the new infrastructure in space may prove to be beyond Europe's means; and second, inevitable cost increases in coming years will limit ESA's capacity to operate and maintain space hardware.

France and Germany are the largest contributors to ESA, with each providing roughly a quarter of the Agency's annual budget of about $1.7 billion. The French national space agency, CNES, has a budget of about $900 million, of which 40 percent is spent through ESA. With cost estimates for Ariane-5 and Columbus having risen by about 50 percent to around $4 billion for each project, and Hermes nearly doubling to about $5 billion since concept launch 3 years ago, agreement on all three projects would require ESA's annual budget to rise to $3 billion by the mid- 1900s, approximately one-quarter of the U.S. budget for civilian space science and technology.

In contrast to France's unwavering political and financial support for the three projects, including Hermes, Germany initially joined with the U.K. in calls for ESA to delay building the manned orbiter and to give more priority to the Columbus orbiting module project, led by Germany. The French position partly reflected anxieties about competition to the Hermes concept from the West German and British designs for spaceplanes known as Saenger and Hotol, especially as these two projects are now merged under an agreement between BAe and MBB. While France was prepared to increase its already significant financial support to ESA, the U.K. initially refused to increase its 10 percent contribution, insisting that the private sector should contribute. This argument was rebutted by the Director-General of ESA, who believed that the funding of pure science and research disciplines, such as telecommunications and Earth observation, was a matter for "society as a whole" and not private industry. Commercial spin offs from space are still relatively rare, the most obvious being launch facilities and telecommunications satellites; returns from investment in space projects over 20 years will not be attractive to industry, even though technologies from space programs are now being applied in such other industries as electronics and materials.

In April 1988 the United Kingdom reversed its earlier decision and agreed to participate in Columbus, although with a much smaller share than either France, Germany, or Italy. ESA assumed that Britain would make a major contribution to a special satellite called the Polar Platform until the U.K. Government switched the direction of its space policy in mid-1987 and then switched back again in 1988. The Polar Platform will carry radar sensors and other instruments for Earth monitoring, with the prospect that such remote sensing vehicles could spawn a new industry, providing oil companies and agricultural organizations with ground images for monitoring mineral deposits and crop growth. While the U.K.'s contribution and commitment to the European space program is smaller than the space community and its partners would have wished, the U.K. Government at least appears convinced that the program's objectives have been defined more realistically, thereby justifying its intransigence during the 1987 budget discussions.

European Advanced Civil Research Programs

Overview

After months of wrangling over the EC's budget for its framework of R&D collaborative programs, the EEC members finally agreed in September 1987 to spend 5.2 billion ECU ($6.8 billion) on technology collaboration over the next 5-years. Within that framework are several individual spending lines that include information technology, advanced telecommunications, biotechnology, alternative energy sources, environmental research, and nuclear safety. These subjects have their own specific research programs-ESPRIT, RACE, and BRITE-which will be defined and described later in this section.

The Commission does not fund EUREKA, which could itself approach $5 billion.

The September accord contained important conditions designed to meet the objections of the United Kingdom, the only member to refuse a scaled-down version of the Commission's original ambitious research budget first proposed 18 months earlier. Even now, there remain doubts as to how strictly one of the U.K. conditions wiIl be enforced, whereby 417 million ECU ($500 million) was held back pending clear evidence of progress on setting up practical spending controls for the entire EEC budget. The U.K. Government remains adamant that "expenditure on research cannot be separated from the overall question of total resources available and the disciplined identification of priorities for their allocation." Collaboration in advanced research is not without its problems, but the Europeans appear to be making good progress.

The Joint Research Centers

The EC funds four laboratories of its own, known as Joint Research Centers (JRCs), at Ispra in Italy, Karlsruhe in West Germany, Petten in the Netherlands and Geel in Belgium. Whereas the JRCs were once the flagships of the EC's research effort, their direction, objectivity, and usefulness have recently been criticized to the extent that the EC is planning to tighten their management. Under proposals adopted by the Commission in October 1987, the JRCs will have to reduce their dependence on the EEC budget by 40 percent by 1991. The proposals envisage that 15 percent of the JRCs' resources should come from contract research for governments and companies by 1991, with a larger proportion coming from other Commission departments. The plan does not, however, envisage any cut in the JRCs' 690 million ECU allocation for the next 5 years under the EC's framework of research programs. The Commission has proposed a sweeping reform of the JRCs' objectives, mode of operation, and method of management Ispra, in particular, is reputed to need "a clean break with the practices of the past."

The 12 research ministers, however, were unable to accept the Commission's proposals; West Germany called for more details on how the JRC's performance would be monitored; the United Kingdom called for better control on areas where JRC work duplicates other EEC research; and West Germany, the United Kingdom, and The Netherlands thought the 40 percent reduction in dependence on the EEC R&D budget by 1991 did not go far or fast enough. Ministers did agree, however, that the JRCs should have more autonomy and less interference from Brussels.

Eureka

Originally conceived by France as a riposte to President Reagan's Strategic Defense Initiative, the European Research C(K)oordinating Agency program was launched in mid-1985 as a joint European program to strengthen non-military technologies, by jointly funded collaboration between European companies on civil projects with clear market applications. As stated by the Declaration of Hanover, the criteria for EUREKA projects are that they "will serve civilian purposes and be directed both at private and public sector markets." The sponsors are the 12 EEC governments, the Brussels Commission, plus Austria, Finland, Norway, Sweden, Switzerland, Turkey, and Iceland. The *aim of the* program is to improve Europe's competitiveness in world markets in civil applications of new technologies by encouraging technical and industrial collaboration.

Projects are underway in information technology, telecommunications, robotics, materials, advanced manufacturing, biotechnology, marine technology, and lasers, as well as in environmental protection and transport technologies. Companies identify topics and market opportunities on which they wish to collaborate, then seek collaborative partners, with governments acting as "barrier-busters" wherever obstacles to collaboration and trade occur. EUREKA status is granted to a project by agreement between governments of all companies involved, and the EUREKA Ministers' Conference is notified. EUREKA has no central fund instead, governments have promised national support for approved projects.

With a further 58 newly-agreed EUREKA projects announced at the September 1987 Ministers' Conference, *the number of agreed projects is* 165, *with a total value of at least $4.8 billion.* A recent survey of the management needs of EUREKA participants showed that some companies were experiencing difficulties, with the underlying factors being company size and collaborative experience. The U.K. Government believes that EUREKA has confirmed both the need for, and the feasibility of, cooperation between business and scientific communities across national frontiers in Europe. EUREKA has given companies the opportunity to request support from governments and the Brussels Commis sion. These measures should influence the framework for collaboration and thereby accelerate efforts to: establish joint industrial standards at an early stage, eliminate existing technical obstacles to trade (e.g., mutual recognition of inspection procedures and certificates), and open up the system of public procurement.

Esprit

The European Strategic Program for Research in Information Technology (ESPRIT) was launched by the EEC in February 1984 to encourage collaboration among companies, universities, and research institutes in different EEC countries on a wide variety of Information Technology (IT) topics. The program was conceived out of concern over Europe's poor IT competitiveness on the part of the Brussels Commission and the Round Table of 12 leading European IT companies (GEC, ICL, Plessey, Bull, CGE, Thomson, AEG, Nixdorf, Siemens, Olivetti, Stet, and Philips).

ESPRIT involves joint precompetitive research that, while not intended to generate commercial products directly, may lead to further collaboration. The program was initially set to run for 5 years with a budget of 1.5 billion ECU, half of which is provided by the EEC and half by the participating organizations, in support of 227 projects (from over 1,000 proposals). Five areas of IT are covered: microelectronics, software, advanced information processing, office systems and computer integrated manufacture. ESPRIT is a program of directed research based on published work programs, organized on an annual cycle that includes strategy and project reviews. Management involves the Commission, the Round Table, an ESPRIT Advisory Board, and the ESPRIT Management Committee.

The program is open to companies, academia, and research bodies, public or private. Each project must include companies from at least two member states, but there is no formal prohibition of subsidiaries of multinationals, provided the research is carried out within the Community. Intellectual Property Rights (IPR) arrangements provide that "foreground information" is owned by the contractor generating the information; however, *IPR must be made available on a royalty-free basis to others in the consortium and to those doing complementary work. The same* rules apply to background information provided the contractor is free to disclose. There is a general injunction on the owner to exploit results, subject to conditions of disclosure and the owner's commercial interests.

Since most of the first-phase projects last for 5 years, until the end of 1989, it is too early to judge whether the program has met its three objectives: to boost cross-border cooperation, to develop industrially important new technologies, and to create EC-wide standards for IT products. Even so, the Commission feels it is time to start looking for results, and an *independent technology audit will be conducted later in 1988.* According to ESPRIT's annual report, by the end of 1987 and 227 projects had produced 143 results of "industrial significance," 27 had contributed to products on the market, 44 were in products under development, 44 had been transferred outside ESPRIT, and 28 had contributed to an international standard. About 5 percent of the projects had been scrapped or merged. Specific achievements noted were:

- The high-speed chip or transputer, developed by INMOS of the U.K. Thorn EMI (INMOS') parent company) worked with the French electronics group, Telmat, to produce two low-cost supercomputers (the Parsys 1000 and T-Node) incorporating transputers. They provide around half the performance of the fastest computers in the world—made by Cray Research-at a tenth of the price. Although the transputer required only 4 billion ECU from ESPRIT for the precompetitive research, Thorn EMI needed to invest substantially more to bring it to the market.
- As a catalyst for forming standards, ESPRIT has created a type of software, Communications Network for Manufacturing Applications (CNMA), that allows different kinds of robots to work together in an automated factory. It is compatible with, but wider-ranging than, a similar standard developed in the United States by General Motors, and is already used by BAe to build Airbus wings, and by BMW at its Revensberg plant.
- The same kind of strategic value, this time in office systems, lies in a development called office Document Architecture (ODA), a way of formatting documents so that they can pass easily from one kind of desktop computer to another, thereby making it more difficult for a

dominant supplier to comer the European market. Another ODA allows the same flexibility for mixed text, image, and voice data. ODA was accepted by the International Standards Organization in late 1987.

In monetary terms, the package the Commission recommended for ESPRIT II was roughly double the size of ESPRITI. The program, which the Commission adopted in July 1987 and the European Community Research Ministers approved the following April, benefits from a 1.5 billion ECU cash injection that industry will match. This second phase of ESPRIT (1987-1991), the largest single project in the EEC's R&D framework program, will concentrate on the use and integration of IT, computer-integrated manufacturing, and application-specific integrated circuits. Over 1,000 proposals were again received and final decisions on successful bids were to be made in mid-1988. However, the joint bid by Europe's three leading computer groups, Siemens, Bull, and ICL, for an 85 million ECU program focusing on basic designs for the next generation of computers is one of the most ambitious schemes planned under ESPRIT 11 and "will need a lot of discussion," according to the Head of the Commission's IT Directorate; but the timeliness of the bid's objectives is not in doubt if Europe is to be competitive in IT in the next century.

One source of the success of ESPRIT has been the strength of basic IT research knowledge and skills present in European universities and research institutions. There is a clear need to maintain and increase these resources in Europe and, to this end, ESPRIT II will include a new element—the Basic Research Action-to promote collaborative basic research in selected IT areas most likely to create future breakthroughs. Research should be clearly upstream of ESPRIT precompetitive R&D in microelectronics, IT processing systems, and IT applications, and should be potentially relevant to long-term industrial objectives. Some 70 million ECU have been set aside for the basic research actions, which should be aimed at:

- optical computing, electronic properties of organic materials, quantum electronics, low-temperature electronics in superconductivity;
- formal methods in software engineering, computational logic and algebra, functional logic and object-oriented programming languages, distributed algorithms and protocols, dependability, complexity, parallel systems, databases; and
- learning, knowledge representation, non-standard approaches to logic, reasoning, speech and natural language, higher-level vision, multisensory fusion, perceptual-motor coordination, autonomous systems, symbolic and sub-symbolic computation, and human-computer interaction.

The above list is not exhaustive; proposals for research across disciplines, areas, and topics are encouraged. ESPRIT rules require that consortia must consist of at least two organizations from different member countries but, unlike the main program, industry participation in the Basic Research Actions is welcome but not a requirement.

RACE

Research and Development in Advanced Communications for Europe (RACE) is a strategic, market-responsive R&D program intended to lay the groundwork for a new generation of optical-fiber broadband communications systems to come into service throughout Europe during the 1990s. The aim is to achieve common standards and help European manufacturers gain a lead in advanced telecommunications products. An initial 1-year definition phase began in January 1986, with 31 projects costing 50 million ECU split between the Commission, manufacturers, and national telecommunications authorities. The Commission was seeking 800 million ECU in support of a second or main 5-year phase to develop technologies and specifications and test prototype systems. The Community's contribution to this main phase is 550 million ECU, matched by an equal contribution from the industrial participants in the program.

BRITE

Launched in 1985 as a 4-year program to increase the use of advanced technologies in the traditional sectors of industry, the Basic Research into Industry Technology for Europe (BRITE) program has already achieved a climate of cooperation in industrial technology, leading potentially to a new competitiveness for European industries. R&D carried out under BRITE must have a clear industrial potential and be precompetitive. The scope of the program includes:

. reliability, wear and deterioration;

- laser technology and its application, and other new methods of metal shaping and forming;
- joining techniques;
- new testing methods including Ion-destructive testing (NDT), on-line and computer-aided testing;
- CAD/CAM and mathematical models;
- new materials, in particular polymers, composites and others with special properties;
- membrane science and technology, and problems in electrochemistry; and
- catalysis and particle technology.

Precompetitive technical R&D, including pilot and demonstration projects in new production technologies suitable for products made from flexible materials, is sought in three main areas:

- automated handling of flexible materials and articles made from them;
- automated joining of flexible materials and their assembly into finished products; and
- integration of the above technologies together with others leading to flexible sequential automated manufacture, with particular emphasis on the need to accommodate multi-product manufacture and model changes.

The rules for funding and participation in BRITE are similar to those for ESPRIT

In September 1987, the EEC approved 112 new projects for BRITE, selected out of 471 research proposals submitted from more than 2,200 different organizations. The 112 projects will involve 573 participants from the 12 member states, 60 percent of them industrial companies, 25 percent research institutes, and the rest universities. Out of these, 46 projects were to receive Community finding up to a total of 45 million ECU once contracts were signed. The remaining 66 projects were to receive up to 60 million ECU as soon as the member states agreed on the revised BRITE program to be submitted by the Commission.

Among typical cross-border projects is a Dutch chemical manufacturer teamed with laser specialists in the United Kingdom to develop optical recording materials based on polymers. Unlike existing photographic films, these new materials would need no chemical processing and would be erasable. Other projects include the use of CAD/CAM in shipbuilding, and the use of lasers to treat alloys in steam and gas turbines to reduce wear and increase resistance to corrosion.

Some Reactions to the "Technology Push"

Though the United Kingdom was widely criticized in 1987 for single-handedly obstructing the EC's proposed research package, enthusiasm in other governments was reported as "appearing to be slackening" as they reevaluated technology and industry policies. While programs such as ESPRIT, RACE, BRITE, and EUREKA symbolized an almost obsessive drive to strengthen technological performance, complaints were heard that the Commission was interested only in more research spending. The mood today is increasingly typified by that of the U.K. Government, which accords *higher priority to promoting the use of the new technologies than to aiding the companies that supply them.* In West Germany, the change is thought even more pronounced, with Bonn appearing relaxed to the point of indifference—even with an "information technology" trade deficit. A senior Economics Ministry official reportedly believed that West Germany should concentrate on traditional industries where it has proven strengths, rather than pour money into glamorous new technologies where the risks were high and commercial rewards uncertain. Siemens, too, apparently insisted that it was right to be cautious, when "new technologies like robotics were supposed to become big business but never took off." In France, the government appears more concerned to acquire international market share for its high-technology companies, than to promote technological advances for their own sake.

These trends simply reflect the gradual recognition in Europe that *achieving a commanding technological position, on its own, does not guarantee high profits; innovation quickly becomes subject to intense competition in which even the most successful companies can sustain heavy losses.* European participation in the U.S. Strategic Defense Initiative typifies the mood, being described as "at best of dubious commercial value, and at worst as a wasteful diversion of scarce resources. " Even the recent weakness of the U.S. economy was seen as a counter to the theory that a sound economy and commanding technological skills went hand-in-hand. In Europe there has been a general shift towards deregulation, privatization, and other policies geared to enhancing the role of market forces. In the EEC the completion of the Single Market by

1992 now commands a high priority, and industry is being encouraged to put its own house in order, assume more independence from government support, and respond to the influence of market forces.

In reality, today's trend can be seen as a healthy correction to reduce reliance on costly, often ineffective, technology-push policies and given greater scope to the stimulus of market pull.

Appendix H

Strategic Technology Management in Japan: Commercial-Military Comparisons

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Appendix H
Strategic Technology Management in Japan: Commercial-Military Comparisons

SUMMARY

The salient points of Japan's overall research and development (R&D) efforts that have particular importance to the defense sector include:

- *Emphasis on private sector activity. The* private sector seines as the main player in R&D expenditures. Its time horizon is fixed on the long term and management strategies, which emphasize broad analyses of the effects of technological applications on corporate goals.
- *Limited government role. The* government role as an initiator is most prominent when risks are highest and the potential payoffs are not immediately evident. Nevertheless, once a budding technology appears more attractive than present endeavors, R&D is assigned to the private sector. Government strategies assess the role of technology in terms of its impact on the national economy.
- *Strong institutional and informal integration of government and business R&D.* Government and business interact at several formal and informal levels and, in doing so, reach a consensus on R&D directions. While the private and public sectors do not necessarily see eye to eye on all major issues, there is nevertheless a greater degree of cooperation and coordination than is evident in other countries. Moreover, by detailing their own employees to various agencies, government ministries themselves encourage the integration of perspectives and a comprehensive outlook on technology.
- *Emphasis on dual **use** technologies with multiple applications.* Advanced technologies with a single or limited application are not as attractive as those offering multiple applications. The R&D management process tends to weed out technologies with limited applications or defer their development. While spinoffs are desirable, an equally important consideration is "spin-on": applying technology to producing new products or even industries. The close integration of business and government, along with an emphasis on focusing R&D efforts on the 'private sector, help assure the development and utilization of dual-use technologies. It is not a case of developing, say, a process or product in a government military laboratory and then attempting to find applications in commercial fields. To a large extent, military and commercial interests are merged by the institutional structures and management attitudes evident in business and government.
- *An emphasis on research collaboration.* In both military and civilian fields, R&D that is particularly far-reaching tends to organize around private-sector consortia that combine cross-fertilization in the early stages with the benefits of free competition at the point of development. Collaboration is not the sole means of bringing technology into commercial or military marketplaces, but it does play a crucial role.

INTRODUCTION

Although defense R&D expenditures still account for only a small part of Japan's annual budgets, the government is strongly emphasizing the development of indigenous weapons systems and the utilization of domestic technologies for defense applications. The defense policymaking establishment recognizes that Japan's capability to defend itself against potential threats, particularly in the face of a weakening U.S. presence in Asia and a decline of American economic power, rests on its ability to field superior technology in the form of advanced weapons systems. The 1988 issue of "Defense of Japan," the annual statement of defense policies, issued with cabinet approval, declares that:

> It is particularly important to continue efforts to maintain **and** improve the technological standards related to military equipment required for national defense in years to come. Japan is the second largest economic power in the Free World and has a high level of industrial technology capable of independently carrying out research and development projects in the field of high technology. The Defense Agency is conducting research and development by taking advantage of technological expertise accumulated in the private sector. It has been increasingly necessary

for the country to direct more positive efforts to research and development on equipment.[1]

Japanese defense technology strategies are intertwined with a broader process of technology management within government and industry that emphasizes the nurturing of dual-use technologies to assure Japan's security in the broadest sense during the coming century. To understand the thrust of Japanese defense technology management, it is essential to look beyond narrow definitions of defense and security. One must examine the roles and perceptions of a range of business and government interests in formulating and implementing technology management policies as part of a larger economic strategy. The importance given to developing dual-use technologies with multiple applications demonstrates that Japanese technology policies are developed and implemented in a way that merges economic, security, and industrial considerations. As a result, the line between purely defense and civilian technologies is consciously blurred.

This paper examines the mechanisms and policies that result in this policy mix by reviewing: 1) the most important player in Japanese research, the private sector; 2) the nature of industry-government interaction in R&D; 3) the players and processes in defense decisionmaking; and 4) the research patterns evident in commercial research that are manifested in defense-related efforts, as well as the specialized role of defense research offices.

R&D IN THE PRIVATE SECTOR

Japanese management of defense-related technology must be seen in the context of overall R&D in Japan and particularly in terms of the role of industry and government-industry collaboration in achieving targeted goals. In Japan the private sector dominates R&D. Only recently have economic, political and institutional constraints on defense spending moderated sufficiently to identify a more specific defense component in those efforts.

The United States still spends more in the aggregate on R&D than Japan does. Nevertheless, Japan now spends a higher portion of its GNP than the United States does-2.8 percent for Japan, compared to 2.7 percent for the United States in 1985. The Japanese Government estimates that this will increase to 3.4 percent of Japan's GNP by 1990 and 5.3 percent by 2000, compared with 2.9 percent and 3.4 percent for the United States over the same period?

Approximately 50 percent of all U.S. R&D spending is related directly to the military (estimates go as high as 70 percent). The percentage for Japan is far smaller (although increasing) with 80 to 90 percent of all funds-government and private sector combined—directed toward commercial applications. Private sector R&D dominates the Japanese technology process. Whereas half of all U.S. research is funded by the government, approximately 75 to 80 percent of total Japanese R&D allocations reside in the private sector.[3]

These factors have been cited to account for Japan's efficiency in applying new or improved technologies to products. But it is not a matter of funding alone. Business and government give priority to projects that will provide a net technological gain to the domestic economy and/or serve as a source of innovation for other industries and sectors. If the collective evaluation of industry, government, or an individual company is that the potential payoffs are likely to be very significant, investors and researchers will accept an even longer period for the technology to mature. Innovation is viewed not simply as a means of achieving economic breakthroughs, but as a process to be incorporated into every phase of development and production. Japanese firms will invest in a series of incremental improvements in products despite the costs, while U.S. firms often pursue more sweeping—perhaps elusive-breakthroughs.

A basic difference between the United States and Japan is that in Japan engineers, researchers, and other technical specialists are involved both in choosing among potential research projects and in participating in the design and development of new products from the outset. Production and manufacturing considerations are accounted for in the

[1] "Defense of Japan, 1988" (Tokyo: Japan Times, 1988), pp. 135, 136.

[2] Jon K.T. Choy, "Technological Innovation in Japan and the United States," *The World* and/, November 1988, pp. 171-172. The budget for the Technical Research and Development Institute (TRDI), the research and development arm of the Japan Defense Agency, accounts for just 5 percent of total government R&D expenditures. Research in private firms accounts for the remainder of total defense-related R&D.

[3] Ibid., p. 172.

development and design stages virtually from the initial consideration of a promising technology all the way through the production phase. Their incorporation into product design necessitates fewer costly and time-consuming modifications later on. It is still difficult to determine if the same can be said without qualification in defense production, but it would not be surprising if similar attitudes and practices prevailed.

Another fundamental but often overlooked point is that Japanese firms that do not necessarily lead in underlying technologies may still excel in process technology, the mundane but essential capability to produce goods more efficiently than other competitors. Again, this is attributable in part to close cooperation and collaboration among designers and production personnel at the earliest phase of product development.

A final characteristic is top management's commitment to promote technological advances within their companies. While participation of senior managers and corporate officials varies from one firm to another, there is widespread awareness of the need for continuing research. Failing projects can be quickly dropped, and those who first supported them suffer no adverse consequences. Further, research results circulate throughout corporations, extending even to sales and marketing divisions.[4]

R&D IN THE PUBLIC SECTOR

In terms of government funding, the Science and Technology Agency (STA), Ministry of International Trade and Industry (MITI) and Ministry of Education constitute the three largest players in Japan's government-directed research and development. (This paper will focus on the first two. The size of the Education Ministry's budget is partly attributable to its responsibility for managing educational research facilities.) Total government R&D funding will reach 41.71 trillion yen ($8.92 billion) during the current fiscal year, with STA and MITI accounting for 4,431 billion and 4,221 billion yen respectively (see table H-l).

A broad consensus on the value of R&D exists in Japan, one that provides a stable environment for pursuing long-term goals. Bureaucratic organization and more politically oriented activities help assure the preservation and continual assessment of that consensus. STA, for example, is organized under the office of the prime minister, while MITI's research programs report directly to the head of the ministry. At the broadest level, scientific research trends are monitored and influenced by advisory councils associated with the office of the prime minister. These councils fulfill multiple roles, including facilitating cabinet-wide consensus on appropriate government policies and allocation of resources, and legitimizing initiatives developed in the private or public sector by publicly endorsing them. Council reports can often stimulate progress in specific fields. Space exploration, for example, has become a national priority in part because of the role played by these advisory councils in articulating government visions and stirring the national imagination.

Government laboratories and research institutes fulfill a variety of roles in the Japanese R&D process. While government facilities may serve as creators of new technologies or initiators of larger research projects, that is not their main purpose. Rather, such facilities serve to verify, through testing, results achieved in private labs and to carry research to a point where it becomes more economical to turn it over to private-sector facilities. Given these roles, which industry and government clearly understand, it is understandable that considerable business-government interaction takes place at the level of individual researchers, their supervisors, and the directors of respective facilities.

Despite the efficacy of Japanese R&D efforts, the process is not faultless. Inter-ministerial integration and cooperation are not always as thorough as they could be. There have been instances in which ministries have competed against one another for prominent roles in research initiatives, forcing political compromises that wastefully duplicated efforts-c ompetition over budgets for space activities comes to mind. Important initiatives can fail, even when there is a clear consensus of views in government and industry. An aerospace effort in the 1950s, for example, produced the YS-11, a small passenger aircraft intended for commercial use that fell far short of expectations.

[4]Shogo Sakakura of the Japan Society of Science Policy and Research Management details these and other characteristics of Japanese research management in "A Fact Finding Survey of Researc h Management in Private Research Institutes," MIT- Japan Science and Technology program Paper No. 88-12, Massachusetts Institute of Technology, 1988.

Table H-l–Japanese Government, Science and Technology Budget Allocations Fiscal Year 1988 (mIllions of yen)

Ministry/agency	Total allocations	Percentage change from previous year
Education	812,954	4.2
Science and technology agency	430,955	1.3
International trade and Industry	221226	-0.1
Japan defense agency	82,700	11.6
Agriculture, forestry, fisheries	66,642	-0.2
Health and welfare	44,059	10.8
Posts and telecommunications	30,729	4.3
Transportation	14,627	0.8
Environmental protection agency	7,752	-2.0
Foreign affairs	6,417	1.9
Others	14,894	0.6
Total	1,706,504	3.1

SOURCE: Ministry of International Trade end Industry, Agency of Industrial Science and Technology,

By the same token, a nationwide or govemment-wide consensus on the value of defense production and research for the economy does not necessarily exist While it has been argue-d here that the country has embarked on a policy emphasizing domestic research and development of ‘advanced weapons systems, that policy is not accepted. The Ministry of Finance retains as-an article of faith the philosophy that virtually any spending on defense comes at the expense of the economy (thus necessitating active lobbying by industry to convince the ministry of the domestic economic value of, say, an indigenous fighter-support aircraft). A number of major research efforts within the civilian ministries and agencies have clear potential for military applications. Among them ‘are artificial intelligence research, high performance plastics, fine ceramics, advanced alloys, jet engine research, and deepsea mining systems, to mention only a few. Although both the public and private sectors are examining possible military applications, the projects nevertheless are justified ‘primarily on the ‘basis of their expected beneficed- impact ‘on the civilian economy.

RESEARCH COLLABORATION

Selective collaborative research, particularly in the precompetitive phase, plays an important role in realizing technological gains ‘n the public and private sectors. Although widespread, collaborative research is not necessarily the rule in Japan. The nature, timing and participants of collaborative efforts vary from one field to the next. Nevertheless, collaboration features prominently in Japanese efforts to bring technology to the marketplace. Informal and formal structures and processes tend to identify promising research fields or trends. Once government and industry agree on more specific avenues of research, the establishment of a govern ment-industry venture or a government-sanctioned research consortium often follows. As research proceeds, greater competition is introduced to hasten the introduction of a product to the marketplaces

Interviews with corporate figures suggest that many companies are less committed to the consortium approach than they might have been in earlier decades. Officials argue that important resources are being diverted from corporations to government-sanctioned efforts, with insufficient evidence that programs will produce short- or long-term gains. Some firms suggest that their own resources are sufficient to stimulate technical advances; while not resenting the government's role, they believe it should be reduced or that government should intervene in other ways. But, out of deference to government and a fear that they will miss out on technical developments, these same companies continue to participate in these consortia.

This situation is not likely to change soon. In defense technology, for example, there are a large number of industry consortia including those in composite materials, advanced turboprop research and fighter aircraft. (In some cases, companies will pursue their own R&D projects, with implicit recognition by the Japanese defense bureaucracy that ultimately the project will be funded by the government when it has reached a certain level of maturity or that costs will be recovered by industry through procurement contracts.) Japanese managers feel that the market is too competitive to risk a totally independent course of action. Certain projects, such

[5] For an analysis Of collaborative research in Japan, see Richard J. Samuels, “Research Collaboration in Japan,” MIT-Japan Science and Technology Program Paper No. 87-02, Massachusetts Institute of Technology, 1987.

as the FSX,[6] are seen literally as once-in-a-lifetime opportunities that, if neglected, could lead to the complete loss of important capabilities. Cost is another factor favoring cooperation, especially in large-scale projects originating in, but not necessarily limited to, the defense field.

DEFENSE DECISIONMAKING

It is in this environment that Japan establishes its defense policies. As was noted earlier, defense issues have assumed greater prominence in policymaking circles in recent decades. Nevertheless, Japanese defense policymaking remains constrained and is subject to negotiation among competing interests. Historical and institutional factors help explain this situation. For example, broad defense policies-hence, decisions about allocating national resources to major defense R&D programs- are not the sole domain of the Japan Defense Agency (JDA). JDA is not as autonomous or influential within the Japanese government bureaucracy as the Department of Defense is in the United States. Budget constraints have remained severe throughout the postwar era. Until recently, popular and political support within Japan for defense was muted, curtailing the agency's relative influence within government. The agency has been unable until recently to attract Japan's most promising college graduates, most of whom preferred joining more prestigious government ministries, including Ministry of Finance (MoF) and MITT.

Institutional factors also influence JDA's role as one among many in determining defense policies. Multiple players with differing agendas and perspectives interact to generate policies that can be accepted by the government as a whole. While different agencies' interests often compete with one another, this process nevertheless contributes to the formation of policies with widespread government support Interagency negotiation of defense policies tends to integrate economic, security, and industrial policy perspectives.

The most direct form of influence over defense policies is the budgetary power of the Ministry of Finance. On the assumption that the growth of defense budgets represents a drag on the economy, the MoF has used its considerable influence to restrict such growth. In recent years, however, defense proponents have been successful in securing spending increases far higher, on a percentage basis, than those for specific agencies and for the budget as a whole.

Despite this new influence, major defense policy decisions are only recommended by JDA, subject to the approval of the Security Council of Japan, a formal body chaired by the prime minister that includes the ministers of finance, international trade and industry, and foreign affairs, along with such officials as the director general of the Economic Planning Agency (EPA). The Security Council, which replaced the weaker National Defense Council in July 1986, is the final arbiter of such policies as the agency's 5-year procurement plans. The Security Council's influence means that much of Japan's defense policymaking process is intertwined with non-defense interests. Put differently, diverse and wide-ranging interests influence defense policymaking through organs such as the Security Council. These interests include domestic industrial concerns (as represented by MITI), fiscal and monetary interests (represented by MoF), and macroeconomic policy outlooks (in the form of EPA interests). MITT's aircraft and ordnance division is particularly influential in Japanese procurement decisions.

This influence by other ministries and interests in defense policymaking is exhibited within JDA itself. Many key positions there are occupied by officials detailed from other ministries. The director general of the procurement bureau usually is a MITI representative with experience in the ministry's aircraft and ordnance division. The internal finance bureau is staffed by an MoF employee. While this might have drawbacks from JDA's perspective, it also means that by virtue of their service within JDA, a growing cadre of government officials have been integrated into the defense policymaking process.

THE TECHNICAL RESEARCH AND DEVELOPMENT INSTITUTE

It is within this context that the Technical Research and Development Institute (TRDI) operates. Organized as a division within JDA, TRDI is the agency's primary research organization. It is headed by a civilian who oversees three administra-

[6] Fighter Support Experimental.

Table H-2-TRDI Research Facilities

First Research Center
- First division: Explosives; ammunition; small arms; artillery
- Second division: Armor; anti/ballistic structures
- Third division: Camouflage; parachutes.
- Fourth division: Hydrodynamics; battleship technology (structures, noise reduction).

Second Research Center
- First division: Communications; computer applications; information systems integration
- Second division: Radar; electronic warfare; microwave antennas/components
- Third division: Electro-optical systems; infrared systems

Third Research Center
- First division: FSX aerodynamics, stability/control, structure and system integration; helicopters; missiles, remotety piloted vehicles.
- Second division: air breathing/rocket propulsion systems
- Third division: Missile guidance; fire control systems; sensors; navigation systems

Fourth Research Center
- First division: Mine warfare; protective structures
- Second division: Transmissions, suspension systems, engines, and other vehicle subsystems
- Test division: Vehicle testing (tanks)

Fifth Research Center
- First division: Sonar; underwater acoustics
- Second division: Torpedoes; mines
- Field test/evaluation division: Torpedo, mine testing
- Kawasaki branch: Shipboard degassing; magnetic sensors

SOURCE: SOURCE: "Defense of Japan, 1988."

tive departments, along with four uniformed directors who supervise R&D in ground, naval and air systems, as well as precision guided munitions. Research centers sponsor technological research projects, including survey research and test and evaluation to enable further development on specific systems. Authorized manpower is 1,179, including 256 uniformed personnel rotated from the three branches of the Self-Defense Forces. TRDI maintains five research facilities in Japan to test and evaluate a broad range of weapons systems and technologies (see table H-2 for a complete list of the facilities and their areas of research). The Institute has no prototype manufacturing capabilities, relying instead on private sector capacities.[7]

The R&D component of the Japanese defense budget has grown at over 10 percent annually for the last five fiscal years. TRDI's total budget in fiscal year 1988 (April 1, 1988- March 31, 1989) came to 481.8 billion, ($682 million at current exchange rates), or approximately 2.21 percent of Japan's total defense budget. JDA's fiscal year 1989 preliminary budget request, submitted to the Ministry of Finance in July 1988, included a 12.9 percent increase for TRDI over the previous year's request.[8] Table H-3 shows the growth in TRDI spending, in recent years, as a percent of the total defense budget.

As a matter of policy, JDA seeks to continue its upward R&D spending trend and boost total R&D expenditures to 2.5 percent of the defense budget by the end of fiscal year 1991. Much of this is reflected in decisions to proceed with "big ticket" items for the three services. Major projects include the SSM-1 surface-to-surface missile (from which antiship and other derivatives are anticipated); a new main battle tank to succeed older, domestically developed models; the XSH-60J antisubmarine helicopter, a codevelopment project with the United States designed to replace outdated aircraft; and last, but certainly not least, the FSX next-generation fighter-support aircraft, another codevelopment effort, led by Mitsubishi Heavy Industries from Japan and General Dynamics from the United States. JDA and TRDI also have proposed four specific technology areas for codevelopment projects with the United States. In October 1988, the two countries initialed an agreement to co-develop new missile guidance technology.[9]

Throughout much of its early postwar experience, the bulk of the TRDI research effort was directed toward reinventing the military technology wheel. With limited resources, bureaucratic constraints, a lack of popular support, and other factors hindering R&D efforts, the organization was not capable of launching high-risk projects of its own accord. That situation has begun to change in recent years. With greater public acceptance of defense policies in Japan, TRDI has been able to recruit promising technical graduates from leading educational institutions.

TRDI was established to develop independent weapons development capabilities and enhance the growth of the domestic arms industry. It began with a philosophy of moderating direct participation in

[7] "Defense of Japan 1988," op. cit., footnote 1, p" 137.

[8] Ibid., pp. 137, 312; *Kokubo* (*National* Defense), vol. 37, No. 10, October 1988, p. 102.

[9] "Defense of Japan 1988," op. Cit., footnote 1, pp. 138-145; Kyodo Economic NewsWire, Oct. 6, 1988. The phrase "codeveloped" often is used in Japan in reference to modification programs involving, for example, changes to a U.S. airframe or other structure to accommodate introduction of Japanese electronics. The missile homing project, however, does appear to involve more fundamental efforts.

Table Technlcal Research and Development Institute Expenditures as a Percent of Total Defense Spending, Fiscal Years 1968-88

Fiscal Year	Percent
1968	2.01
1976	1.21
1984	1.49
1985	1.84
1986	1.95
1987	2.08
1988	2.21
1991 (goal)	2.50

SOURCE: Boei Kenkyukai, Boeicho, *Jieitai* (Tokyo, 1988), pp. 289-293

defense-related R&D, partly to minimize budget outlays and partly on the assumption that defense spending constituted a burden on the civilian sector and should be limited.[10] For these reasons, TRDI until now has viewed its defense technology spending in light of its impact on the domestic economic and technology base. The Institute does not necessarily target the development of technologies to field specific weapons systems.[11] A consistent criterion for selecting and nurturing technologies has been the impact of any given technology on the commercial sector. The chances that such a technology will be targeted for development are greater if it contributes to the overall industrial base and provides opportunities for other spinoffs. For example, the emphasis placed on radar development reflects industry and government interests as wide-ranging as phased array systems for fighter aircraft, 360° radar for commercial airports, and collision avoidance systems for automobiles. Composite materials is another field offering similarly diverse applications.

Thus, an important element of the Japanese strategy is much like one used in drafting professional football players. Rather than find the best player for a specific position, TRDI often "drafts" the best technology available at the time regardless of the position it plays. What matters is that it is capable of benefiting the "team" over the long run.

The U.S. security guarantee, of course, contributes to a situation in which Japan has more flexibility to make such decisions. In assessing this approach for the United States, it is important to keep these comparisons in context. Allowing for contextual differences, however, does not make the underlying principle any less valid for foreign observers.

The combination of a government attitude that defense spending is a drain on the civilian economy and the emphasis on broad technologies has led to government-business cooperation in defense areas. TRDI works with industry formally and informally. In many cases, the organization simply monitors research already under way in private companies. In others, it carries out preliminary research that it ultimately hands over to the private sector, once it has reached a stage where risks have been reduced and the technology has proven itself. The development of the F-1 fighter support aircraft, SSM-1 cruise missile, and T-2 trainer all illustrate that pattern.

These patterns were reinforced by a July 1987 reorganization that totally eliminated minor research programs that could be pursued more effectively by private research facilities. In addition, TRDI's role was defined to include research that lacks an immediately identifiable demand in commercial sectors. This could be an important development for TRDI's institutional role, perhaps representing a judgment by JDA that fielding advanced weapons systems will require selective development of specialized technologies with primarily military applications.

At the same time, a flexible approach was emphasized to incorporate commercial technology in military systems-all with the ultimate aim of making Japan equal or superior to other countries in terms of its defense technology base.[12] This outlook is summarized in the current white paper:

[10] For a discussion of the origins and early projects of TRDI, see Boei Kenkyukai, Boeicho, *Jieitai* (Tokyo: *1988)*, pp. 269 ff. (Transl: Defense Research Committee, Japan Defense Agency, *Self-Defense Forces).*

[11] Indeed, JDA has been accused of foregoing the acquisition of systems readily available from foreign suppliers until TRDI could develop the domestic technology necessary to produce a comparable *system, thus* enhancing domestic industry capabilities as well as spinoff/spin-on opportunities. Despite the high priority given by the Ground Self-Defense Forces to fielding advanced tanks, for example, deployment was delayed until a purely domestic *model was developed to* TRDI's satisfaction. Journalistic accounts of the Japanese procurement system also accused the government of delaying consideration of short range surface-to-air missile systems for air base defenses until the Tan- SAM was fully developed. More recently, industry backers of a domestic fighter- support aircraft to replace aging F-is called in 1987 for further feasibility studies and/or the development of a domestic prototype aircraft with the tacit support of the Air Self-Defense Forces, when it appeared that then-JDA director general Kurihara would decide in favor of an codevelopment project with the United States or the acquisition of an American aircraft.

[12] "Defense of Japan, 1987" (Tokyo: Japan Times, 1987), p. 140.

> The Defense Agency will positively utilize the private sector's technology on the basis of its excellent **technology in the field of microelectronics and new materials including ceramics and composite** materials. F reticularly in the area of basic research the Defense Agency will rely heavily on the technology pooled in the private sector. Furthermore, the Defense Agency, carrying out a technological research project to integrate private technology into future high-technology equipment, will build **it up as a system that will meet the unique operational requirements** of this country. Accordingly, the De**fense Agency will achieve effective improvement of** superior equipment capable of competing with **technological standards of** foreign countries.[13]

Institutional and informal mechanisms comparable to those outlined reinforce the use of commercial capabilities for defense in both research and manufacturing. Close links plus the overriding philosophy emphasizing commercial benefits/inputs help assure, first, that military-related research benefits the commercial sector (spinoffs) and, second, that commercial, off-the-shelf technologies are employed as much as possible in military systems (i.e., spin-ens). Even in the case of purely military technologies, TRDI can be expected to continue relying on private-sector development. Business and government will look to these technologies for maximum utilization in defense and commercial applications as well.

PRIVATE SECTOR INTERACTION

The private sector helps to develop a consensus on overall R&D trends, as well as sponsoring specific projects through individual company contacts and various industry associations. The most influential of these groups is probably the Defense Production Committee (DPC) of Keidanren-the Federation of Economic Organizations.[14] The DPC consists of about 10 percent of Keidanren's total membership of 800 industrial companies and over 100 financial institutions.

The DPC's officiate serves functions include:

- compiling basic data on defense production,
- collecting and exchanging information relating to defense production developments and trends among its members,
- promoting cooperation among defense contractors, and
- coordinating defense and non-defense industries and interests.

A fifth, unofficial purpose of DPC is to promote its members' interests among government agencies and policymakers. Given these objectives, it is not surprising that the DPC plays a significant role as a forum for discussion and dissent among contractors on defense issues. The committee will refuse to take stands where industry-wide concurrence is impossible or temporarily beyond reach, but it will promote positions on which there is clearcut consensus. The group issues an annual report on defense-related issues and has consistently favored higher domestic production rates and indigenous weapons development. Most recently, the group called on the government to allocate greater budgetary resources to defense-related R&D, supporting JDA's target level of 2.5 percent of the total defense budget.[15]

Since its establishment in 1952, virtually every DPC chairman has come from Mitsubishi Heavy Industries. While it is beyond the scope of this report to examine the implications of that dominance, it is worth noting that such consistency has given Mitsubishi a means of assuring its preeminent status as Japan's number one defense contractor by projecting its views of defense issues on the domestic industry as a whole.

Other groups playing comparable roles include the Japan Ordnance Association, the Society of Japanese Aerospace Companies (SJAC) and the Japan Shipbuilding Industry Association. In addition, the Japan Technology Association was created in 1980 with the support of commercial firms such as Sony and Honda Motors. These associations, along with other industry interests such as trading companies, can play significant role at the formative stage of major policies, in part because of the lack of

[13] "Defense of Japan, 1988," op. cit., footnote 1, p. 136.

[14] A dated, but still largely accurate, portrayal of the Defense Production Committee in *action is* David Hopper, "Defense Policy and the Business Community: The Keidanren Defense Production Committee," in James Buck (cd.), *The Modern Japanese* Military *System* (Beverly Hills: 197S), pp. 113-'148.

[15] For other Keidanren DPC perspectives, see Editorial Committee, Asagumo Shimbunsha, "Sobi Nenkan,]988," Tokyo, 1988, p. 479. The Japan Ordnance Association expresses its policy positions on pp. 480-482.

outside, independent consultants available to U.S. government agencies to address pending issues.

Senior executives of leading defense contractors who are also officials of these associations routinely serve on key advisory panels for MITI, the defense agency, and other government agencies. These panels, like the Defense Science Board in the United States, are an important conduit of information and influence between business and government. Moreover, it is not uncommon for major companies to provide JDA with technical analyses of competing weapons systems for use in determining a final selection for procurement. Governments in other countries also frequently turn to private interests for such analyses, although Japan lacks the Booz-Allens or RAND Corporations that normally would provide these analyses in the United States. However, since these Japanese firms also act ultimately as the developers, manufacturers, or agents for procuring these systems, their involvement in such fundamental activities gives them significant opportunities to shape the course of future policies in a manner that serves private sector interests. In R&D projects, it also allows them insights into government perspectives that might otherwise be limited or unavailable altogether.

Influence and interaction of industry is further strengthened by the increasingly common practice among major defense contractors, industry associations, and trading companies of hiring retired senior JDA and SDF personnel as advisers in defense matters. This does not differ markedly from practices in the United States, except to the extent that such relationships are usually the result of a 1onger-term interaction than might be evident in the U.S. experience. Furthermore, potential access to higher levels of government is greater if the new adviser retired from a senior position after serving in several ministries throughout his career.

Companies frequently attempt to anticipate major policy developments by forming informal study groups on specific issues. For example, the aerospace department of a major trading company might collect data and examine satellite utilization and technology to identify potential business opportunities. Participants would include representatives from comparable divisions of other companies; by informal agreement, a lower mid-level executive from the organizing company would supervise the group. Government officials might participate informally. If lower-ranking staff identified significant opportunities, the head of the trading company's aerospace department might also become involved. At that point, the focus would shift to one or more of the industry associations, and the participants of the study group would disband.

Such early interfirm cooperation can consolidate industry perceptions toward emerging business opportunities, and help identify specific roles for individual companies once projects move into research, development, and production phases. Firms continue to participate in these arrangements because they want to secure some portion of the business resulting from a major procurement decision. The Japanese defense market is an oligopoly, and government procurement decisions reinforce a pattern in which only a few firms can develop specific manufacturing and production capabilities. Given that situation, no one firm will secure the lion's share of a major procurement order. Their participation in the ways outlined above can help them at least a part of the business.

A point to note is that firms at this stage are not necessarily approaching these areas in terms of their potential for military business per se. Instead, they identify and analyze business opportunities in terms of their overall relationship to a company's strategic plans. It has been noted that in the United States the Defense Department fields weapons, not technology. In Japan, on the other hand, where commercial and civil ministry interests are very important, it is safe to say that JDA fields neither technology nor weapons, but products. This is partly because, unlike in the United States, Japan has few out-and-out defense contractors. Mitsubishi Heavy Industries, for example, secures on average about 25 percent of JDA's total annual procurement budgets, which amounts to only 15 percent of its total sales. Distribution of JDA contracts diversifies dramatically once MHI's share is accounted for. Of major contractors, only one, Japan Aviation Company, depends virtually entirely on defense contracts for survival.

Firms are diversifying to emphasize defense-related sales. Thus MHI's 15 percent of sales in the defense field has grown from just over 7 percent a decade ago. Nissan Motors now officially describes itself as a defense contractor in its corporate charter. As was mentioned previously, firms as diverse as Sony and Honda are keenly interested in defense sales and applications for existing and new technologies. But rather than looking at defense as a new field requiring different marketing strategies, Japanese companies are incorporating their defense strategies as new components of broader commercial plans, emphasizing maximum gains regardless of technology or product.

SELF-IMAGE, EXTERNAL EVALUATIONS AND) IMPLICATIONS

Japanese policymakers and observers alike increasingly view the country's technological capabilities as second only to those of the United States, and even then just barely second in terms of many specific technologies. The 1987 STA white paper concludes that within the past two decades, Japan's inherent technological strength and its potential for future technological development relative to the United States surpassed those of West Germany, France, and the United Kingdom.[16] A recent assessment of Japan's future role in the world, "Nihon no Sentaku" (Japan's Choices), completed by a MITI-sanctioned commission, determined that Japan leads the United States in many critical fields and is closing ground on virtually every other technology that will prove important in the coming century: space communications, launch vehicles, robotics, large-scale integrated circuits, civil aerospace, biotechnology, and artificial intelligence, to name only a few.[17] In its 1984 report on industry-to-industry arms cooperation, the U.S. Defense Science Board concurred that Japanese dual-use technologies offer great potential for advanced U.S. systems. A subsequent DoD task force identified a more specific range of technologies.[18]

These assessments represent an increasing appreciation of Japan's capabilities abroad. They are even more significant in demonstrating Japanese confidence—hitherto restrained-that it has the ability to lead the world in technologies with both commercial and military applications. Of itself, this development should not necessarily cause concern to the United States and other allies of Japan. It could even be viewed as a ringing endorsement of the economic and political systems that assisted such strides through generous technology transfers, a security guarantee that freed resources for commercial gain, and assurances of political stability through a democratic form of government. There have been signs that the effort will have payoffs in the form of U.S.-Japan cooperation. The two countries concluded agreements in November 1983 to allow military technology exchanges, and in 1987 Japan agreed to participate in the Strategic Defense Initiative (SDI). (The first SDI contract involving a Japanese firm was signed recently.) Furthermore, the two countries have embarked on a less heralded project, the development of a new missile homing system, that could be an even more promising augur of things to come.

Nevertheless, it is important to view the Japanese R&D effort in perspective. Japan equates technological advancement with its chances for future survival. The 1987 STA white paper concluded that virtually half of all Japanese economic growth in the 15 years since the oil shocks was attributable to advances in the domestic technological base, compared with 20 percent at most for the United States.[19] (It is safe to say that, in terms of defense outlays, much of the growth on the Japanese side would be attributed to the dual-use, multiple application strategy that has discouraged a focus on strictly military technologies. For the United States, one might conclude excessive attention to strictly military R&D has been a drag on the economy.) These gains have resulted in productivity improvements and the creation of new demand for products that simply did not exist a decade ago. Small wonder the government places a heavy emphasis on maintaining this pace to assure the future vitality of the Japanese economy.

The United States has concluded that its chances for continued global influence rest in large part on the health of its technological base. A critical element in this strategy, however, is the assumption that allied cooperation and technology exchanges

16 Science and Technology Agency, "Kagaku Gijutsu Hakusho 1987" (Science and Technology White Paper), pp. 40-42.

17 Ministry of International Trade Industry, "Nihon no Sentaku," Tokyo, 1988, pp. 184-193.

18 Defense Science Board, "Report of the Defense science Board Task Force on industry-to-Industry Armaments Cooperation, Phase II: Japan," prepared for the Of@ of the Under Secretary for Research and Engineering, 1984, pp. 15-17. U.S. Department of Defense. Office of the Under Secretary of Defense (Acquisition), Research and Advanced Technology, "Electro-Optics and Millimeter- Wave Technology in Japan," 1987, pp. 3-1,4-4.

19 *Science and Technology in Japan*, vol. 7, No. 26, June 1988.

are essential to assure mutual survival. One must ask if Japan, with its emphasis on retaining technology to assure its own survival, shares that assumption. The answer to that question could have profound implications for this country's relations with Japan in the coming decades.