Chapter 3

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MANAGEMENT OF PROGRAMS AND FACILITIES

The system used by the Department of Defense (DoD) to run its technology base programs is dominated by two major characteristics that are practically unique among large technology-based organizations. First, the system is inherently decentralized, with planning and management dominated by a bottom-up approach. Second, it relies heavily (although not exclusively) on a large, diverse group of government owned and operated laboratories devoted to defense research.

Planning of technology base programs is done primarily by the Army, Navy, Air Force, DARPA (Defense Advanced Research Projects Agency) and the other defense agencies, and SDIO (the Strategic Defense Initiative Organization).* The Office of the Secretary of Defense (OSD) primarily serves as a monitor and data collector, deferring to these component organizations on matters of program direction. OSD collects budget requests and passes them to Congress; after the funding is approved, the component organizations run their own programs. Within OSD there is a hierarchy of oversight that inhibits rational integration of programs: the Services report atone level, DARPA reports one level up, and SDIO reports only to the Secretary of Defense. While not unique in running its programs this way, DoD follows a minority path. Most organizations exert much more top-down coordination and control over planning and management of technology programs.

The labs owned and run by DoD have two general shortcomings. First, most are not strictly laboratories and lack the multidisciplinary pool of talent necessary to be effective in developing a broad range of modem technology. Although they interact, they are generally independent of each other. Developing technology is not the only (or even the primary) mission of most of these labs, but access to that capability underlies the ability to perform other missions. Second, the government-owned, government-operated (GOGO) management arrangement has created many problems that impair the ability of the labs to function effectively. Other organizations structure their lab systems and lab management differently.

Worldwide, there are three major trends in the planning, management, and performance of technology development: top-down planning; centralized management; and collaboration. Moreover, among the governments of other industrialized nations there is a movement away from concentration on defense research and toward emphasizing civilian research that can be exploited for both economic and defense gains, as well as a movement away from government ownership of laboratories.

Department of Defense Technology Base Programs

The Department of Defense does not have a centralized system for strategic planning of technology base programs. It has a federated system in which the central authority-the Office of the Under Secretary of Defense for Acquisition-plays an advisory and coordination role, but either lacks or fails to exercise the power to make major decisions. Those decisions are made by the component organizations—the Services, DARPA, and SDIO. The planning process is both top-down and bottom-up, but it is clearly dominated by the bottom-up approach: most real decisions are made within the component organizations. OSD provides general guidance and reviews Service programs, but does not exercise any strong role in molding them. Attempts by OSD to mold programs (usually to keep to budget ceilings) are often viewed by the Services as uninformed, capricious, and arbitrary. This arrangement generally results in OSD not being able to guide or coordinate the technology base programs. However, OSD has in the past provided

[1] In fiscal year 1989 the three Services together will spend 40,2% of the technology base funding (6.1 plus 6.2 plus 6.3A). SDIO will spend 39.370; DARPA will get 13.8%; and the remaining 6.7% will be spent by the other defense agencies—the Defense Nuclear Agency, the Defense Communication Agency, the Defense Mapping Agency, the Defense Intelligence Agency, the Defense Logistics Agency, and the National Security Agency. Among the agencies, DARPA occupies a special place because of its role as a source of R&D to complement Service programs. Efforts of the other agencies tend to be more specialized.

leadership for some special cross-Service programs, such as VHSIC, MMIC, SEI, and STARS.*

This system is not necessarily bad, but it seems to be ineffective in producing a coherent technology base program. Those who believe OSD ought to provide strong leadership find the current system disappointing. To those who believe that OSD ought not to be controlling technology planning, it is the proper approach, even if OSD occasionally weighs in too heavily and disrupts programs. They believe that the users of technology—the Services-ought to plan and control its development, that giving too much power to OSD risks losing Service support for technology base programs, and that the Services are better able than OSD staff to preserve technology base funding.

Central planning and central management are two separate but related issues. Without top-down planning a program lacks, as DoD's currently does, a broad consistency of purpose and coordination to ensure that important areas are not left unaddressed, and that healthy competition among competing developments does not become wasteful duplication. Central management can help ensure that the results of central planning are carried out, but it can also result in control of programs by those least able to understand them.

Organizationally, the problems arise from two sources. First, OSD lacks either the ability or the will to exercise power over the Services. And second, there is no one individual or office that serves as a focal point and coordination center for the technology base programs of all the component organizations. This results in diffusing the power to plan and coordinate, and precludes establishing a high-level advocate for technology base programs who is free of competing interests. The Goldwater-Nichols reorganization changed the players and their titles, but did not correct these basic problems.

Within OSD, all technology base programs with *the exception of SDI* are the responsibility of the Undersecretary of Defense for Acquisition. This is shown schematically in figure 1. But the technology base is only one small part of what he is responsible for—he also oversees the rest of research, development, test, and evaluation (RDT&E) as well as all of procurement. DARPA reports directly to the Director of Defense Research and Engineering (DDR&E) for oversight, but oversight for the Army, Navy, and Air Force programs rests one level farther down the chain with the Deputy DDR&E for Research and Advanced Technology. The DDDR&E(R&AT) is the highest ranking official with responsibility only for technology base programs, but he only has responsibility for less than half the technology base. Thus, the Service programs are coordinated at the DDDR&E(R&AT) level, but they are coordinated with DARPA's program one level higher up the chain, and balanced with SDI only at the highest level. This produces a hierarchy of influence among these component organizations and a mismatch that makes it difficult to balance their demands.[3] Moreover, no one with the power to oversee the entire technology base program can be an advocate for it unencumbered by other, possibly conflicting, responsibilities.

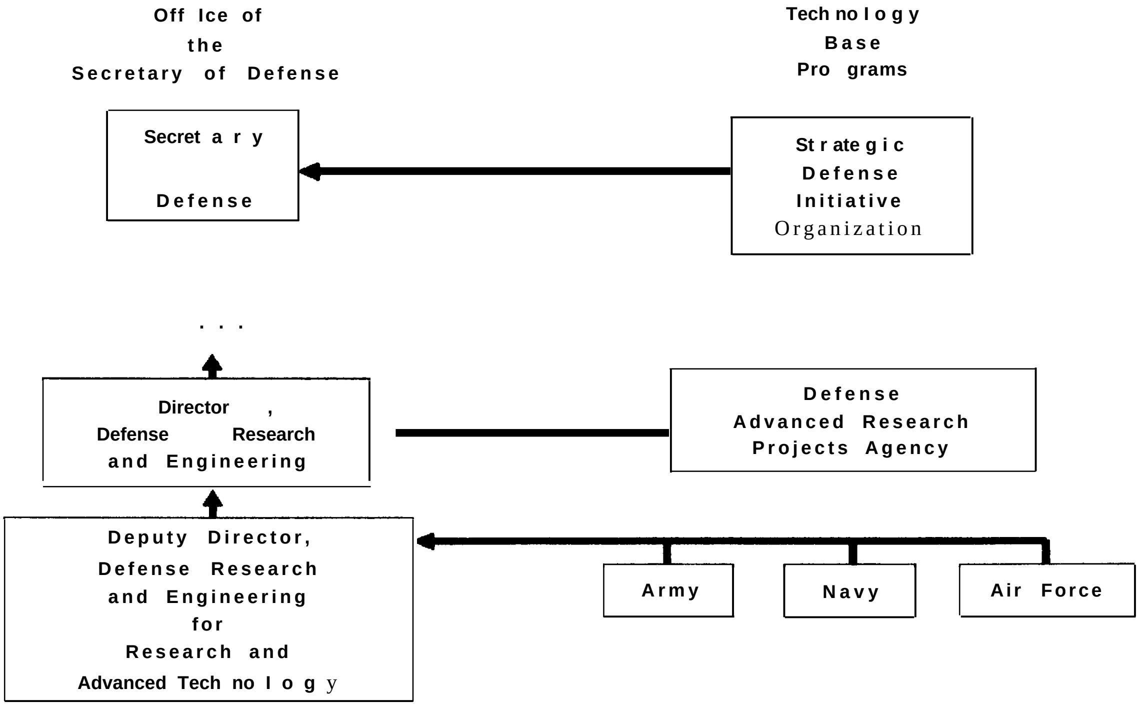
Overall goals for technology base programs are supposed to be specified in the annual Defense Guidance document. But in reality, the Defense Guidance devotes little space to the technology base, providing only very general guidance that can be used to justify just about anything the Services, DARPA, and SDIO want to do. The result is that these component organizations plan more or less independently, based on internally generated criteria, and link their plans to the general language of the Defense Guidance. The OSD review of Service plans is predominantly a data-gathering exercise with little real power exerted from OSD. And real coordination is hampered because DARPA and SDIO programs (which together account for over half of the funding) are considered only at higher levels. Thus the Services and agencies dominate the planning process.[4]

[2] Very High Speed Integrated Circuits; Monolithic Microwave Integrated Circuits; Software Engineering Institute; Software Technology for Adaptable, Reliable Systems.

[3] Manufacturing technology programs, vital to ensuring producibility of items, are accorded a generally lower level of oversight and advocacy than product technology programs.

[4] Top level planning is typically not done within the Services either; ideas come up from lower levels. However, in recent years the Services have been conducting high level studies of their future technology needs: Air Force Forecast 11; Navy 21; and Strategic Technology for the Army. The Air Force had been planning some of its technology base program around the results of Forecast 11.

Figure 1—A Hierarchy of Oversight



SOURCE: Office of Technology Assessment, 1989.

It is not the case that the Services do not talk to each other or to DARPA or SDIO. There is considerable coordination among projects having similar technical foci, but this occurs at the project level and not at the overall program level. There is much technical interchange but little programmatic coordination. OSD could exert strong influence at this level through its technology reviews, but it only conducts a few such reviews each year.

Because no single individual or office has responsibility for all technology base activities and only for the technology base, it is difficult to have a strong and consistent advocate for technology base both within the DoD bureaucracy and in relations with Congress and the Office of Management and Budget (OMB). (This problem is mirrored within the Services with similar results.) Nevertheless, OSD personnel spend a large part of their time defending technology base programs or answering congressional mail, leaving little time available to evaluate technology base programs. It is not surprising, therefore, that OSD and the Services do not have a systematic DoD-wide approach to evaluating technology base activities. Evaluating last year's programs is a key to planning next year's. If OSD personnel do not have the time to evaluate last year's programs, they lack a solid basis on which to judge Service plans for next year.

The structure of the bureaucracy is not the only contributor. The relationships among institutions within DoD also play a major role. The Services and DARPA have traditionally had the upper hand with OSD. SDIO was designed to be able to proceed without interference from OSD or the Services. Typically, this sort of "pecking order" will persist in the absence of positive actions to change it.

Personnel is another factor. Although OTA has encountered OSD staff who are competent, dedicated, and overworked, there is a consensus among experts that, like the labs, OSD suffers from restrictions that limit its ability to get and keep the best people. While experts are divided as to how to solve the problem, most agree that paying more and decreasing career restrictions would help. Some believe that the problems would be best solved by vesting power in a professional staff with long tenure, removing it from the hands of political appointees and other "short timers. " Others think that only a constant infusion of "new blood" will help: rearranging the system so that very capable managers could take such jobs for a fixed term (e.g., 4 years) and then return to industry.

Department of Defense Laboratories

Reports on the shortcomings of DoD laboratories go back at least 30 years. The mind-numbing array of specific issues that these earlier reports have raised can be captured by two fundamental questions:

- Does the DoD have the type and quality of laboratories it needs?
- Are the management arrangements under which these laboratories are run inhibiting their ability to perform as needed?

Type and Quality of Laboratories

To be precise, DoD has no laboratories. The Army, Navy, and Air Force departments own and operate a large number of research, development, and engineering (RD&E) centers, none of which are laboratories in the pure sense, i.e., institutions solely for conducting research. These centers perform a variety of functions ranging from research through full-scale development to occasional limited-scale manufacture of military equipment items. The mix of activities varies from center to center, with some—such as the Naval Research Laboratory and the Army's Harry Diamond Laboratory-being more heavily oriented toward research than others. As a shorthand, the term "defense laboratories" is used to refer to these government owned and operated RD&E centers.[5]

The structures of the defense laboratories-how big they are, what kind of work they do, etc.—have evolved historically, based in part on the different procurement systems of the three Services and the roles each has seen for its laboratories. These structures are quite different among the labs. However, the management arrangements and modes of operation—which are similar across all of them—are a consequence primarily of law and also of DoD and Service regulations.

Comparing the defense laboratories to other government R&D institutions is difficult because DoD's role as a large purchasing agency makes it almost unique within the government. NASA is perhaps the closest analog because it too purchases products of technology, but it also builds things and conducts research and space exploration. The national laboratories that support the Department of Energy (DOE) build nuclear weapons and pursue a broad base of research for the furtherance of science. Industry, which also runs laboratories, ultimately builds things.

Comparing DoD labs among themselves is also difficult because no two are really alike. They differ in three distinct dimensions: the subject areas they focus on; the mix among categories of work (6.1, 6.2, etc.); and the weighting of their missions among a number of basic tasks. In addition to conducting research and development, these tasks include:

- buying R&D from contractors and monitoring the contracts;
- advising program offices on responding to proposals from industry to do development and production work (i.e., acting as "smart buyers" of technology);
- providing a base of technical expertise and know-how that can be drawn upon to solve problems as they arise or to follow new areas of technology;
- training young officers in science and engineering;
- solving technology-based problems (or equipment-based problems) encountered by field commands; and
- designing and producing very small numbers of special purpose items 'needed by field commands.

They also differ in size, source of funding, and the orientations and "cultures" of the organizations they primarily work for.

[5] DoD is also supported by contractor owned and operated laboratories such as the John Hopkins University Applied Physics Lab and the MIT Lincoln Lab, and by national laboratories operated by contractors for DOE. For more information on the institutions that support the defense technology base see: *The Defense Technology Base: Introduction and Overview*, OTA-ISC-374 (Washington, DC: U.S. Government Printing Office, March 1988).

All of these differences make objective evaluations and comparative ratings of these institutions very difficult to perform. Most evaluations and comparisons appear to be subjective ones, even when performed by highly qualified individuals. For example, Service labs are frequently criticized for not doing top-flight science, especially when compared to national laboratories or major university laboratories; but performing scientific research is not the major mission of these facilities.

Nevertheless, there is a common thread among all the tasks the labs perform: they all require the laboratory to be a center of technical expertise. Most don't *require* the staff to be conducting research and contributing to the advancement of science or technology, but all *benefit* from a staff that has hands-on expertise: a staff member who is contributing to the leading edge is closer to it than one who is simply reading about it, and is more likely to get a seat at the table when the real experts meet.

There are three basic approaches to providing the research core of an R&D facility. The first is to build a large, diverse, multiprogram laboratory with a staff that does research in a broad range of disciplines. The DOE national laboratories fit this description, as do the corporate research centers of several very large corporations such as IBM, AT&T, and General Motors. These labs push forward the frontiers, provide a large pool of talent that can be directed and redirected to solve problems or follow new areas of technology, and provide a base of knowledge from which other labs can draw for more narrow applications. Staffs typically number well over 1,000 and are heavily weighted toward advanced degrees. The Naval Research Lab is the only DoD lab that fits this mold.

A second approach is to build labs with staffs of a few hundred that concentrate their efforts in one or a few areas. Several Army laboratories-Night Vision, Harry Diamond, Electronic Technology & Devices, etc.—are structured this way. These facilities can have programs that are at least as good as those of the multiprogram laboratories in a few selected areas. However, this focus is bought at the cost of loss of breadth and flexibility to respond to a broad range of problems. Moreover, as modem technology becomes more complex, even a single area of concentration can rest on a broad base of underlying disciplines. Size can constrain these laboratories from effectively pursuing their few areas of concentration and from shifting their focus. This problem of lack of critical mass is even more pronounced in the third type, the model followed by most Defense labs: a medium to large RD&E center with small cells of expertise embedded in it. These labs do not have in-house research as a focus, but as a supporting function. Hence the cells of expertise, however skillful and productive, tend to be narrow and thin: in some cases the departure of one or two key individuals could destroy that expertise.

In detail, the Army, Navy, and Air Force run their RD&E centers differently. But in general they all function the same way: technology generated in-house, in other Service labs, externally under contract, and any other place the staff has access to, is assimilated with the aim of transitioning it into the procurement system. The accumulated base of knowledge is used to advise the procurement officers regarding the technical qualities of various proposals to develop and build systems.

The central question is whether this system has been, and is really capable of, delivering the goods. Does the technology transit into and out of RD&E centers, and are the staffs up to the job? This is a very complex question requiring an intensive investigation, but it is absolutely key.

If the answer is "yes," Congress ought to stop worrying about the labs and let them get on with their work. Steps might be taken to make their jobs easier by easing management burdens. However, even if the labs are judged to be doing a good job, budget constraints may make it necessary to consider restructuring.

If the answer is "no," there area number of steps that might be taken to fix things. These range from taking steps to ease management problems (which will be discussed below) to drastic reorganization of the entire system. Some involve centralizing, consolidating, closing, and moving institutions. However, such steps have far-reaching consequences and can be nearly irreversible. They ought to be taken only after much deliberation. One approach would have each RD&E center include or be closely associated with a large multipurpose laboratory, the small cells of expertise being replaced by a large, diverse pool of technical talent. Clearly, doing so for each RD&E center would be prohibitively expensive. An alternative approach would be to provide each Service, or DoD as a whole, with a central corporate lab and tie the RD&E centers closely to it. The Naval Research Lab might be a model. Smaller labs of more limited scope are a second choice, but because they are inherently less flexible than multi-program labs, arrangements would have to be made either to shift their focus or close them down as the areas of technological interest shift. As an alternative to building up the research bases within the Services, greater use might be made of DOE national labs as technology bases for the Services. Consolidating facilities either within each Service or across Service lines under OSD could offset the cost of expanding the underlying labs. But this runs the risk of cutting the links of the RD&E centers to their parent buying commands and further restricting the transition of technology into the procurement system. Unless handled carefully, it could also sever the very important links of the labs to the field commands.

Management Structure of Laboratories

The problems that plague the Services' government-owned, government-operated laboratories (GOGOs) and the causes thereof have been extensively documented. They are inherent in the laws and regulations that govern the operations of these labs. While these laws and regulations have not changed greatly over decades, the trend within the last few years has been for their application to become more onerous, making the government labs less attractive places to work at a time when the market for technical talent has become much more competitive.

The difficulties fall into three related categories: problems in recruitment and retention; difficulties in conducting the day-to-day business transactions necessary to get the work done; and long delays in updating buildings and major equipment. The latter two are problems in their own right as well as contributors to personnel difficulties. Effective management is also impeded by funding that is often unpredictable and fluctuates from year to year.

Even premier laboratories, like the Naval Research Lab, are having difficulty attracting the best and the brightest. Many of the RD&E centers have all but given up trying: they now recruit from a small circle of mostly local schools and hope to "grow" their own in-house expertise. OTA's observations support the points made in earlier studies:

- most of the labs have difficulty hiring and retaining highly qualified personnel;
- the government is at a major disadvantage in competing with industry and academia; and
- the system makes it difficult to reward good performers, penalize the poor performers, or tie salary closely to performance.

The "NOSC/China Lake Experiment," in which the Navy loosened the salary structure for scientists and engineers at the Naval Ocean Systems Center and the Naval Weapons Center at China Lake, helped with recruiting and retention in the entry and midlevels. Similar novel approaches including salary structure and educational opportunities are under consideration by the Services. But since these do not raise the ceiling on salaries; they do little to solve the problem of attracting and retaining key senior people. Losing senior researchers is a double liability: exceptional senior people do exceptional work, and they also attract younger people, many of whom will accept otherwise less attractive work conditions in order to work with someone special.

Interesting work helps to attract and retain people. Good people stay if the work is challenging, if discretionary funding is available to allow them to "follow their noses," and if they have an opportunity to pursue a technical career without being sidetracked into management. But increasingly, technical people in Service labs can only get ahead if they become managers, and in those management jobs they spend an increasing amount of their time in administrative tasks and insulating their bench-level people from bureaucratic "paperwork" imposed from above.

At most DoD labs the Tehnical Director has little or no control over the most important support elements of his organization—the personnel office, the general counsel, the procurement office, etc., all of which report to parent commands. And construction of new facilities is handled out of military construction (MILCON) accounts for which the labs usually fight a difficult, and often losing, competition with a long list of other claimants. This results in obsolete facilities.

The Defense Science Board has recommended changing the laws and regulations that are causing the problems, loosening up the system to enable the Defense labs to compete more effectively. While this might be helpful, it would require a long list of changes in both legislation and government regulations. This involved agenda could be very difficult to complete. However, a congressional decision to treat the laboratories differently from other government offices might facilitate the changes.

An alternative would be to convert the labs to government-owned, contractor-operated (GOCO), or even to contractor owned and operated (COCO) facilities. This would seem an easy way out of the morass of government red tape. GOCOs do have greater management flexibility in personnel management, but the evidence for greater flexibility is ambiguous in areas other than personnel. GOCOs can pay higher salaries, can hire and fire more easily, and have much greater flexibility in rewarding good work and shifting personnel. They also display greater flexibility in shifting the focus of their work, and have some advantages-although not so dramatic—over GOGOs in their ability to purchase equipment and facilities.

DOE GOCOs appear to show a greater aggressiveness in seeking out and developing technology. And, at least in the design and manufacture of nuclear weapons, transition of technology into applications is more direct than it typically is in DoD. But this is not necessarily a consequence of their being GOCOs. Size, fill-spectrum stance, and research-oriented culture are all contributors. So is the relationship that has evolved between DOE and its labs: the missions of the labs have been construed in a very broad way, facilitating changes in program directions as technology evolves.

While there are some real advantages to converting to contractor operation, there are some important offsetting factors. No government-funded institution can escape oversight merely by converting to contractor operation. Funds derive from congressional appropriations, and Congress holds senior officials of sponsoring agencies accountable for their use. Thus, the tendency is for the government to impose on its contractor laboratories many of the same rules and regulations it lives under. Consequently, with time GOCO labs tend to become more like government-operated laboratories. Government rules under which the sponsoring agencies operate tend to be passed down to the contractors, so the GOCOs are not free of the majority of government impediments. Government policy appears to be that even though government regulations do not apply to GOCOs, GOCO practices ought to be consistent with them. OTA found that the perception of "red tape" and the burden of bureaucratic paperwork reaching down almost to the bench level was no different at GOGOs, GOCOs, and COCOS.

Although there have been many studies of government labs since the 1962 Bell Report, none have questioned its finding that there are "certain functions which should under no circumstances be contracted out. The management and control of the Federal research and development effort must be firmly in the hands of full-time government officials clearly responsible to the President and Congress."[6] There are some functions that are inherently governmental: passing them off to contractors would raise major questions. For example, being a smart buyer and advising a program office on the technical merits of proposals is probably not a responsibility that ought ultimately to be entrusted to a contractor, although today contractors are part of that process.

One advantage of government labs—and a major function—is that they can respond immediately to problems that emerge in the field. Staff can be ordered to stop whatever they are doing and turn their attention to the problem at hand. This would be more difficult for contractors to do, unless the contract had been carefully crafted to allow for the contingency.[7] At several contractor operated facilities OTA was told that response times would have to be measured in months, if not years.

While all DoD labs could benefit from fewer restrictions, not all are equal candidates for conversion to GOCO status. Those that conduct in-house R&D would be better candidates than those that function primarily as "smart buyers." Similarly, those that cannot solve their management problems

[6] *Report to the President on Government Contracting for Research and Development*, reprinted in W.R. Nelson (cd.). The *Politics of Science* (New York, NY: Oxford University Press, 1968), p. 200.

[7] For example, level of effort support contracts.

within the government system would be more likely candidates for conversion than those whose managers believe they can.

Other Approaches

After examining a number of approaches used by other organizations to manage technology programs, some basic themes emerge that may be applicable to DoD management of its technology base programs and laboratories. First, in most governments and companies, R&D policy is approved at the upper levels of management and promulgated throughout the organization. Second, centralized control over research projects is the rule. It is supported by frequent reviews and combined with a readiness to cut losses when projects do not pan out and to buy technology outside the organization if that appears to be a more economic approach. Third, both public and private organizations are moving toward collaboration as a means of affording research of the magnitude dictated by modem technology. Finally, on a broader note, the Europeans appear to be moving toward the Japanese point of view that technology efforts ought to be focused on enhancing the economy: a strong high-tech economy will produce both more money available for defense and ‘‘spin-on” of technology for defense purposes.

For at least two decades the Europeans have been worried about their economic positions, particularly relative to the United States. But the emergence of Japan and other Asian nations as economic powers has greatly intensified their concerns. This has spurred efforts to integrate the European Community (EC), notably the movement to a “single Europe” in 1992. Moreover, as their fears of economic problems have increased, their anxiety over Soviet military power has receded. Hence the mood is to reduce the drain on the economy of defense oriented R&D, while increasing substantially research oriented toward civilian products. The Europeans are looking for ways to make defense R&D support civil production; defense labs are increasingly viewed as national assets that can be used to help make civilian industries productive. The trend appears to be to do research and exploratory development (the equivalent of 6.1 and 6.2) predominantly in civilian-oriented labs. Only in the advanced development stage would the work take on a more military-oriented cast. The prevailing philosophy appears to be that science and technology policy should be integrated whenever possible with economic and industrial policies. In this regard, the Europeans are moving away from the U.S. model and toward the Japanese model.

It is tempting to take the attitude that if our system has significant shortcomings we ought to adopt someone else’s. But this approach is fraught with peril. While there are important lessons to be learned-and these general themes appear to be worth considering-it is not necessarily true that DoD can simply adopt some other system as its own. All organizations are different, and they do not all see themselves as solving the same problems. Management approaches tend to be rooted in corporate ‘‘culture” at least as much as they are the result of dispassionate analysis. It is somewhat dangerous to adopt the attitude that what works for some other organization ought to work for DoD, For example, the sheer scope and size of DoD’s technology base activities dwarfs nearly every other organization examined, and might even rival the aggregate of them. Furthermore, it is not clear that other organizations are significantly more successful than DoD is in developing and nurturing technology and using it to good effect. The success story everyone immmeiately turns to is Japan. But Americans are not, and do not behave like, Japanese. And the Japanese seek to use technology somewhat differently than does DoD.

Planning and Priorities

In contrast to DoD, in which a laissez-faire approach and “bottom-up” planning predominates, most Western European governments set national civil and military R&D objectives from the top. Working through central committees or advisory panels, cabinet-level officials set priorities and ensure that the goals are translated into specific programs in either government or private laboratories. The technical experts are usually left free to determine the composition of the specific programs, but they must be able to justify program relevance to higher authorities. In addition, the European Community is exerting an increasing top-down influence on the member nations’ research programs. Exploiting allies’ work and avoiding duplication of effort is a growing theme. The Japanese approach is perhaps less formal, emphasizing government/industry consensus building and the role of industry, but ultimately major decisions are made by a central body.

Industry generally follows a somewhat similar centralized approach. Major corporations typically have central procedures for establishing business objectives, including identifying the key technologies that are expected to contribute. Once these selections are made, the component companies are free to decide how to pursue them. But corporate oversight typically remains continuous and close.

There has been strong criticism that U.S. defense R&D focuses too much on the near term, both in government and in the private sector. European companies are even more likely than U.S. companies to spend their R&D money for near-term applications. This trend has become more pronounced recently in both Europe and the United States as technology base expenditures have declined as a proportion of defense spending. In contrast, however, budgets for long-term research-particularly civil research-are increasing for many European countries and for the EC. This is tied to a perceived linkage between R&D, economic competitiveness, and prosperity. Governments are seeking to improve their industries' competitive positions by making civil research the driver and blurring the distinction between civil and military R&D. The Europeans' short-term focus and declining funding in defense research appears to be offset by a longer term focus and more generous funding for civil research. In Japan, the government role is greatest in long-term developments for which the risks are high and the payoffs not evident.

Growing fear of Japanese and U.S. industrial competition has fostered European interest in large-scale, centrally directed technological initiatives. These have been largely multinational in nature, such as ESPRIT, EUREKA, RACE, and BRITE,[8] although there have been single nation programs such as the U.K. Alvey program. These are modeled, in part, after a succession of U.S. initiatives—beginning with the Manhattan project—that, while not always successful, propelled technology forward. Large collaborative efforts are also employed by the Japanese, but their efforts tend to have more industry funding and less government money.

A similar approach currently in favor in Europe and to an increasing extent within U.S. industry is to employ special research teams, or "centers of excellence," often in collaboration with universities or potential competitors. These groups concentrate on technologies where a large critical mass of personnel and other resources, or interdisciplinary research, is considered essential. U.S. examples are SEMATECH, the Electric Power Research Institute, Semiconductor Research Cooperative, and the Microelectronics and Computer Technology Corp.

Management and Control

European governments not only plan their R&D programs centrally, they also manage the execution of those programs centrally. Large companies also tend to keep tight central control. In both cases, the trend is also toward centralized control of laboratories in an attempt to establish the optimum balance between generic research and product-oriented (or mission-oriented) research.

DoD's laboratory system is basically mission-oriented, with most laboratories dedicated to specific warfare specialties. Mission focus provides a closer link between technology and military applications, but it also encourages duplication in facilities, resources, and projects. European labs and programs are increasingly organized along technology, not mission lines. In France, Germany, and the United Kingdom the defense research activites are planned, organized, and managed by central authorities independent of service requirements and development activities. Centrally managed civil research programs are generally oriented around generic technologies. Similarly, EC programs are directed toward enabling technologies, with applications left to industry.

DoD's extensive network of government owned and operated laboratories is unique among Western defense establishments. With the exception of the United Kingdom, European governments own few, if any defense labs, and the British are in the midst of drastically consolidating their laboratory system. However, there are many more European government-owned and government-sponsored laboratories doing civil research.

[8] European Strategic Program for Research in Information Technology (ESPRIT); European Research Coordinating Agency (EUREKA); Research and Development in Advanced Communications for Europe (RACE); Basic Research into Industry Technology for Europe (BRITE).

Industry is generally moving in two directions. Most R&D is being moved out to the component companies. Some corporate research centers are being pruned back or even closed. As money gets tight, it is easy to view corporate research centers as expensive luxuries-''money Sinks ''-racier than as investments. But at the same time corporations are establishing corporate level centers of excellence in key technologies (or forming collaborative efforts in them). Technology is transferred to the product divisions, at least in part, by assigning personnel from the product divisions to temporary jobs in the central facilities and then moving them back to use and disseminate the technology they studied and helped develop. Industry is also moving in the direction of collaborative research, sharing the escalating costs of modem technology. This research is of necessity technology oriented, not mission oriented.

Collaboration, Coordination, and Technology Transfer

Collaboration in research is now a way of life. High costs and worldwide competitive pressures are forcing governments and industries to pool their resources. Collaborative projects play a central role in Japanese R&D. European governments and industries explored cooperative research in the 1970s and early 1980s, but in the mid 1980s growing concern that they were falling behind the United States and Japan led to a series of serious collaborative measures. Moreover, the European members of NATO, after more than 20 years of ad hoc collaboration on defense and other aerospace projects, are now working on establishing a coherent, systematic program of collaboration, Breaking down the long-standing barriers that have isolated European companies from each other and fragmented markets is an explicit objective of recent high-technology collaborative initiatives. In addition, European companies see that they each have to draw on a broader base of technology than was necessary in the past. Recognition that Germany's strong position in world trade is due, at least in part, to a collegial, collaborative relationship between industry, academia, and government also helped spur interest in collaboration.

U.S. companies are not only engaging in collaborative programs at home, they are also joining with European (and Japanese) companies in various ventures.

Applications: Transitioning Technology From Lab to Products

DoD has been criticized both for leaving technology in the lab too long, resulting in obsolete weapons, and for rushing it prematurely into production—which creates unreliable products. Neither allegation is without foundation. Technology transition is one of the most difficult problems of development. European governments and industries appear to be no better at technology transition than DoD is. Japan appears to have a unique success at transitioning technology rapidly and effectively from the lab into production. The Europeans appear to be studying and beginning to apply the Japanese experience. Teams of researchers, designers, engineers, manufacturing specialists, and even marketers are being brought together early in the life of a product in order to perform in parallel what usually gets done sequentially. The parallel development of process (manufacturing) technology and product technology is considered a particularly important factor.

Examples of the close relationship that is essential between research staff and those who develop specifications exist in all successful companies; but in large and diverse government organizations the liaison and communication that is required may be jeopardized by interdepartmental rivalries and parochialism which only strong management and direction can dispel. In DoD, requirements for new systems are set by the Service buying commands, and development is done by industry. These are obliged by law to stay at arms length; the government labs provide the primary link between them—and the labs are not always successful.

GETTING TECHNOLOGY INTO THE FIELD

Government officials and others have expressed concern and frustration over the age of technology in fielded U.S. systems, particularly those just beginning to roll off assembly lines. Comparisons usually take two forms. First, government and industry researchers have laboratory developments that are clearly superior to what is going into the field.

Second, dual-use technology in defense systems often lags significantly behind what is available in the consumer markets, and by the time a system has been in the field for 5 to 10 years it can seem outdated compared to what Ford or Radio Shack is selling.

Technology in production will always lag behind technology in the lab. Taking developments off the bench, engineering them into real systems, and getting those systems into production is a time-consuming process for military and civilian manufacturers, as well as for movie producers, think tanks, book publishers, and many other enterprises. Indeed, very little legislation moves instantaneously from brain storm to law. Major military systems are generally much more complicated than civilian products, and hence the product cycles are much longer.[9] In addition, the process of getting approval to begin a military project is generally considerably longer than the equivalent process in the consumer sector. Furthermore, military systems have long lives, and dealing with frequent updates is a logistical nightmare, so it is not surprising that changes occur much less frequently than the typical yearly changes in consumer products. It appears to make sense to change the current model Toyota because of a relatively small change in engine technology. (Indeed, it helps sales to tell consumers that this year's model is "all new" and "innovative," and technology is often changed just to enhance marketing.) But it makes absolutely no sense to rebuild the entire fleet of tanks every year to take similar changes into account. The problems of maintaining different equipment types in the field mean that decisions to update part of the total inventory, while often made, are not taken lightly. Finally, DoD is not in the business of developing and fielding technology for technology's sake; its job is to get better capabilities into the field in a reasonable time at a reasonable cost. Up to a point, it is not unreasonable to argue that new technology ought to buy its way onto a system.

Military-specific technology is usually the pacing technology for entire systems, determining the schedule for getting the system into the field and controlling the rate at which the dual-use technologies in the system get fielded. The entire acquisition system is geared to the pace set by these military technologies. It is often the case that after a system design is frozen, the commercial counterparts of technology embedded in it continue to move forward, sometimes dramatically, resulting in several generations of products before the military system is produced. This produces military systems that are not as advanced as some commercial products; but if responding to rapid changes in dual-use technology were to prevent freezing the design of a system long enough to get it into production, none of the technology would ever get produced.

Thus, while it can be misleading to compare fielded military technology to laboratory technology or selected consumer technology, it is important to ask whether new technology can get more quickly and more effectively into the field. (It is also legitimate to ask why the military cannot have the same products—like radios, CRT displays, trucks, and clothing—that consumers can go out and buy.)

The problem of getting new technology into the field is not that the United States is unable to develop new technologies with military relevance. It is rather a problem of the transition of that technology into engineering, the time needed to begin manufacture, and the rate at which new systems are built. It can be improved in three general areas: improving the insertion of new technology into acquisition programs (i.e., the transition from technology base to engineering and production); improving the acquisition process that engineers and produces systems; and improving the affordability of systems so that they can be bought more rapidly.

Technology Insertion

The technology development and system acquisition processes are largely (but certainly not completely) separate. Technology base work takes place in a variety of institutions, including some companies that ultimately build systems. Engineering and production are done in private companies (not always the same ones that did the technology base work) under the supervision of DoD program managers. This causes a major bottleneck at the point at which technology moves from technology base to acquisition. Several mechanisms exist to bridge this gap: general technical interchanges

[9] In commercial products, complexity is usually the enemy, something to be managed carefully.

between Service lab people and industry; IR&D and contract research that involve some companies in a development; involvement of lab people with the program offices (part of the "smart buyer role"); and formalized Service transition programs.

Many studies of the transition issue seem to agree that nonsystem-specific prototyping, pursued with 6.3A funds, presents the greatest opportunity to improve technology insertion. It has the potential to solve two problems. By demonstrating feasibility, these advanced technology demonstrations help reduce the high risk carried by some technical developments. And they help correct overoptimism by demonstrating the limitations in the current state of the art. Overoptimism leads to promising too much, which in turn leads to disappointing systems and to lengthy and costly redesign efforts. The new emphasis within DARPA on prototyping is apparently an attempt to ease the transition into system design of technology developed under DARPA programs. DARPA has always been the focus of technology that does not fit neatly into what the Services want to do. However, if the Services do not take DARPA seriously, it is not at all clear that DARPA's prototyping effort will have any use.

Acquisition

In searching for the causes of delays, the acquisition process has been the primary candidate, Even when the system is working smoothly it seems to take a long time to move programs through; but it usually is not working smoothly. And when it bogs down, delays lead to further delays through escalating costs, compensatory stretch outs, and time-consuming attempts to fix any particular program's specific problems. While the consensus is that the system is in trouble, it has weathered study after study without apparent improvement,

Several studies have found that acquisition (advanced development, full-scale development, and production) takes longer than it used to. But the data are not all that clear: there is certainly no obvious trend toward rapidly increasing times. It does take longer in the 1980s than it did in the 1950s or 1960s, but there is not enough data to discern clear trends over the past decade. Studies of fighter aircraft procurement, the most-studied system type, conclude that whatever increases have occurred are in the front-end decision process and in production, not in full-scale engineering development. Data on other systems are less conclusive.

It is generally held that commercial industry completes programs more rapidly than does DoD, but there are significant differences between government and industry that make it possible for industry to avoid many of the basic problems that plague DoD acquisition. These basic problems are "built into the system," they are consequences of the characteristics of U.S. Government. For example, canceling a program that has grown too much in cost or schedule to be profitable is easier than canceling one that, despite schedule slippages and cost overruns, is judged essential for national security.

But enhancing national security is not the Nation's only goal. Goals like fairness, environmental protection, equal opportunity, jobs, and competition all figure into how both Congress and the Administration judge defense procurement programs. DoD itself has goals it must pursue in addition to managing programs efficiently: maintaining the defense industrial base, ensuring that the most efficient producer does not drive the others out of business (contrary to what industry would do), etc. Government is not solely concerned that a program provide the best capability at the lowest cost most quickly. Moreover, the political process in both branches of government-the tug and pull over resources and goals-introduces uncertainty into programs, even when Congress and high-level executive offices do not micromanage programs.

The structure of the DoD acquisition system is much more cumbersome than that of private sector companies. That structure is, in part, determined by government's size and unique role. DoD program managers are accountable to five or six layers of bureaucracy up to the Secretary of Defense. These layers typically have extensive horizontal structure, so the program manager (PM) has to satisfy a large number of people, many of whom have power over his or her program but no responsibility for it. To complicate matters further, the PM reports up one chain for oversight of the program, and up another for the planning, programming, and budgeting system which is responsible for determining the funding for the program. But this involvement of the OSD bureaucracy, as well as that of OMB and

Congress, is part of the checks and balances on the expenditures of billions of dollars.

While industry shares many of DoD's problems, it has a very strong incentive to manage successfully: failure could mean bankruptcy. In many instances industry works under a simpler system involving a direct link between the program manager and a high company official having the authority to make decisions, settle disputes, and insulate the PM from external pressures. The PM has responsibility for the program: if it fails it is his fault and his job may be at stake. The DoD PM typically has to obtain several levels of approval for any action; there are many people who, in trying to ensure that the PM does not fail spectacularly, will also prevent him or her from succeeding spectacularly.

Several factors are major contributors to delays in programs: the sequential processes of requirements generation, resource allocation, and system selection; program variability (or instability) caused by many players making changes; bureaucratic paralysis; inappropriate organization for defense procurement; and the quality and incentive structure for procurement personnel. Underlying these are the basic structure of the government, the nature of the bureaucracy, the organization of the DoD procurement system, and the conservative risk-averse nature of government organizations.

Requirements generation and resource allocation involve the Services, OSD, OMB, and ultimately Congress. They are highly political, which often leads to overpromising in order to get program approval. Overpromising leads to cost growth and schedule slippage. But the system makes it easier to readjust the program to these realities rather than to go back and question the requirements that produced them in the first place.

Constant changes in defense acquisition programs are commonplace, leading to cost increases and schedule slippages. Variability results from the requirements process, the risks inherent in new technology, the political/budgetary process, and personnel turnover. While the disruptions caused by these factors can be somewhat controlled, the underlying causes cannot be eliminated.

Baselining-a form of contract between program managers and their Services-was developed to limit changes in programs. But making baselining work requires giving program managers more authority over their programs than they now have. Neither program managers nor Services can control budgets or other changes and conditions imposed by OSD, OMB, and Congress. Moreover, external factors that affect a program-like threat, doctrine, and resources— will cause changes in the program no matter how well it is managed.

However, Congress, OSD, and OMB can decide to limit their direct involvement in a program (or Congress can decide for the others). But, at least in the case of Congress, this would involve giving up power which it jealously guards. Congress has already agreed, in principle, to relax oversight for a few major acquisition programs, which would require reauthorization only at significant milestones rather than annually. As yet, none of these milestone authorizations have been submitted to, or approved by, Congress. Not all members are likely to agree that efficient functioning of defense acquisition programs is more important than other issues they are concerned with, including the (possibly shifting) interests of their constituents. The budget process specified by the 1974 Budget and Impoundment Control Act and public Law 99-177 (Gramm-Rudman-Hollings) increases Congress' incentives to keep control of as many budget items as possible so that it can engineer the budget levels it agrees to.

Perhaps the most discussed problem is the bureaucratic burden individuals and companies must struggle through in order to do their jobs. A 1977 Defense Science Board (DSB) panel concluded that increases in acquisition times are all bureaucratic: 'it does not take any longer to do something, it just takes longer to obtain the necessary approvals and acquire funding . . . ." The program manager's job has become increasingly complicated, accompanied by lengthening time to complete contracting actions and increased regulation, oversight, and auditing of contractors. The overall perception is that of increasing regulatory and bureaucratic burden, but studies have found the picture to be unclear. While some indicators of burden have been clearly increasing, others have remained the same or declined. Moreover, measuring the effects of regulatory and bureaucratic activity is even more difficult than measuring the activity itself. For example, estimates of the added costs due to regulations and bureaucracy range from 5 to 200 percent!

This "red tape" is unambiguously greater in government than it is in private industry. What in industry can be a straightforward, one-step, project initiation process involving the manager and a high corporate officer is in DoD a two-step process involving the PM, a committee within DoD,[10] and Congress. Both the DSB and the Packard Commission recommended bringing the system closer to an industrial model in this regard, and the Goldwater-Nichols Act tried to implement that.

Since the bureaucratic burden arises in part from government attempts to have programs satisfy goals other than getting the job done most efficiently, solutions can be of two types: those that try to streamline the system without changing its mix of goals; and those that seek to change the balance among goals, particularly the balance between having an efficient and successful program and satisfying all the other government goals. One suggested solution is to review all the regulations to determine whether each is still necessary and whether the aggregate could be streamlined somehow, a daunting task in its own right. Another suggestion is to shift the burden of proof from the PM to those who would slow down the project, making the PM innocent until proven guilty. For example, a competition advocate would have to show that the program was insufficiently competitive or that taking measures to enhance competition was important enough under the circumstances to warrant tampering with the program. But some higher authority would have to be responsible for balancing these claims against the interests of the PM who would always be served by ignoring them.

Some DoD programs do better than most: "black" programs (so it is said), and other special high-priority programs. This success is due in part to their high-priority which affords them high-level attention. Clearly, all DoD programs could not be treated that way or the system would overload. These programs also get special exemptions from various regulations, Granting similar exemptions to all programs would nullify the regulations, defeating the purposes for which they exist.

There has been widespread concern about the process that produces PMs and their chief assistants. These people are either military officers or civil servants. In 1986 the average tenure of PMs was about 2 years. This makes it difficult to give them real power over programs that run many times that long, and creates incentives for them to sacrifice long-term performance in order to look good on their watch. The military personnel usually, but not always, rotate rapidly in and out of the jobs in 2 to 3 years. They do not always have prior experience or relevant training. Many of the civil servants do not rotate, and "remain for so long that they resist innovation and change."[11]

Affordability

One of the major contributors to delays in getting new technology into the field is the cost of modem development and procurement programs and the resultant program stretchouts and low buy rates. Almost all important systems cost enough to get close scrutiny by OSD and Congress. The battles are fought each year. The result is often that the funding requested by the program is reduced (in some cases dramatically), which slows the development pace and slips the date at which production is initiated.

Once the program is in production, DoD's tendency is to reduce the funding below what had been projected, in order to keep as many programs alive as possible. This leads to buying fewer of any particular item per year, which has two major consequences. First, obviously the slower the rate at which a system is bought the longer it will take to get the capability into the field. It may not delay Initial Operating Capability, but it will certainly delay the date at which a significant capability is fielded. Second, providing insufficient funds to procure at planned rates raises the unit costs, which further decreases the number that can be bought per year.

[10] The Defense Acquisition Board, and perhaps others.

[11] J. Ronald Fox and James L. Field, The *Defense Management Challenge: Weapons Acquisition* (Boston, MA: Harvard Business School Press, 1988), p. 312.

DUAL-USE INDUSTRIES

Most of the technology that is engineered into defense systems is still developed in the "defense world" of DoD's laboratories and contractors. This is particularly true of the exotic technologies that are the centerpieces of advanced designs. But increasingly, building those systems depends on developments that take place in the civilian sector, a civilian sector that is driven by the international marketplace. This was dramatically illustrated by events during the first week of November 1988. A company called Avtex, which manufactured rayon fibers for the apparel industry, announced that it was shutting its doors in response to foreign competition in the clothing business. This sent shock-waves through DoD and NASA when it was discovered that Avtex was the only producer of fibers that were critical to the production of missiles and rockets. While other sources could be qualified, and other fibers might be found to substitute for the rayon that Avtex made, that process would take longer than the period of time the available supply of rayon would support production. Negotiations were soon completed to keep Avtex open.

High-technology industries are becoming increasingly internationalized: foreign companies and multinationals are technology drivers. Large international markets generate huge amounts of capital that fuel research and development into new products and underlying technologies. The defense components of these markets are often small, giving DoD little or no leverage over the directions developments will take. DoD has to choose between playing a follower role, or spending large amounts of money to keep a competitive leading edge capability in defense laboratories and industries. But because of the cost of developing modem technology, it seems unlikely that DoD can afford to develop all the technology it needs in parallel with the civilian sector. Dependence on the private sector is not all bad: commercial development of technology is a basic strength of the industrialized, noncommunist world. Failure to exploit developments in the civilian sector would be throwing away a major advantage over the Soviets. But relying on the private sector means that defense development and production will depend increasingly on the health of the civilian sector and on the ability of DoD and its contractors to gain access to the products of the civilian sector. Thus DoD faces two challenges: maintaining access to the technology developed in the commercial sector, and coping with the international nature of that sector.

DoD and Congress face three generic problems. The first is keeping dual-use companies interested in doing defense work. Some are leaving the defense business. Others have technology that DoD could use, but are reluctant to get into the defense business. These attitudes are based primarily on perceptions of the difficulties of doing business with the government, and the problems of doing business in both sectors simultaneously. Second, high-technology industries are moving offshore due to foreign competition. Some have almost vanished, others are on the way. Furthermore, it seems likely that in the future some new technology-based industries will develop in other nations and never take root here. Careful balance will be necessary to nurture U.S. industries while maintaining access to foreign technology. Congress will have to consider U.S. trade and industry policy carefully. Third, entire industries, individual companies, and the many-stepped trails that lead from raw materials to finished components cross many national borders. In many cases, it is nearly impossible to determine what a U.S. company is, while in others it is difficult to separate U.S. companies from their foreign partners. Congress will have to come to grips with the meaning of foreign ownership and foreign siting for the availability of technology, as well as with how dependent the United States can afford to be on foreign sources. These international relationships will complicate attempts to protect U.S. supply sources.

Barriers Between Civilian and Military Industry

Since World War II, the U.S. economy has evolved relatively separate military and commercial sectors. They have different business practices, one dictated by government regulations and procurement practices and the other flowing from the marketplace. In recent years the *international* market has had a considerable effect on shaping the latter.

Government practices have made it increasingly difficult for DoD to obtain state-of-the-art technology in areas where civilian industries are leading, making defense business unattractive to innovative companies and contributing to traditional suppliers leaving the defense business. Many firms that are not heavily involved in defense business are reluctant to deal with the government because they consider it to be a bad customer. Moreover, many do not need DoD's business and can simply opt out. The barriers are not technological, but legal, institutional, and administrative. Some are the direct result of legislation, others flow from DoD regulations, including overly cautious interpretations of laws. Some commercial firms cite excessive regulation, burdensome auditing and reporting requirements, compromise of trade secrets, and loss of data rights. Large defense companies have similar complaints, but have adjusted to working under these conditions. But for smaller companies, getting into the defense business means heavy investment and reorientation of business practices.

A company can organize to do business in either sector, but can rarely do both under one administrative roof. Companies that do business in both sectors typically have separate divisions that are organized differently and almost never share staff, production and research facilities, data, and accounting procedures. These differences are profound. In large aerospace companies the commercial side responds to market conditions, whereas the military side responds to Service programs, government regulations, and the Federal budget. Their planning is "slaved" to the Federal planning and budgeting cycle. Corporate structures and rules tend to mirror those of DoD and tend to pass government encumbrances down to lower level suppliers. Companies doing government contract work have to keep their books in formats that are compatible with government auditing rules and procedures.

Following these and other government rules adds to the costs of doing business, costs that can legitimately be passed on to the government customer. Tighter control of the defense business ultimately translates into higher costs to DoD. The United States is apparently willing to bear this increased cost as the price of other benefits-for example, knowledge that the government is trying to keep the process honest. However, imposing the same rules on dual-use industries has other, fartherreaching effects. It makes them reluctant to do business with DoD and encumbers their products with additional costs that may adversely affect their international competitive positions. When dealing in both sectors, companies can accept either the higher cost of following government business procedures, or the higher costs of maintaining two separate business practices-one for government business and one for other business. With some exceptions, DoD product specifications are also seen as encumbrances; characteristics that are of no value in the commercial marketplace are engineered into the products for sale to DoD.

Government contracts regulate profits, creating a business environment very different from that in which most high-technology companies deal. These companies are used to investing heavily in R&D, recovering their investments through large profits, and then reinvesting in the next generation of product. Moreover, their customers see only the product, whereas DoD insists on knowing how the product was made. Defense contractors get by on small profits, in part because much of their R&D costs are covered either by contract or IR&D recovery. But dual-use companies qualify for little if any IR&D recovery and are reluctant to do contract R&D. The government owns the rights to data generated by contract R&D so that it can keep the subsequent phases of a project competitive by making a data package available to all bidders. But companies that live by their innovation in the commercial market see this process as offering their trade secrets to the competition. DoD procedures provide the winner of a development contract poor profit margins, no guarantee of a continuing relationship with DoD, and little incentive to innovate and provide a superior product.

Some industries, like advanced composites, are currently so closely tied to the defense business that they are apparently willing to live with these problems. But they worry that their competitive position may be damaged as the commercial market develops. At the other extreme, the companies that produce fiber optics are reluctant to get involved in a defense market they see as always being a small part of their business: they do not necessarily see the potential payoff as worth the aggravation.

While the small amount of military fiber optics business might be seen as evidence that the industry is not really important to defense, some within the DoD see it as a critical new technology for future systems, one in which defense could gain tremendously just by exploiting what has been and is being developed in the commercial sector. But DoD has been generally slow in adopting fiber optic technology. Program managers have much to lose by inserting risky new technologies which may delay schedules and increase costs, but little to gain because the advantages of the substitution will usually become apparent only on someone else's watch.

In the software industry, the divergence between government and commercial practices has been enough to produce separate defense and commercial businesses that often do not share technology. The procedures, policies, and management of large-scale systems in the military and civilian sectors diverge starting with requirements definition, continuing in the development or acquisition of software, and throughout the entire life cycle of the software. This restricts the flow of leading-edge technology from defense into the commercial sector and reduces DoD access to readily available commercial products. Most of the differences can be attributed to the policies, regulations, standards, and directives mandated by DoD. DoD software requirements are more rigid than their commercial counterparts. Defense systems tend to be overwhelmingly custom built, while commercial systems will use as much off-the-shelf technology as possible. Software companies are particularly concerned about data rights, which they see as critical to competitiveness. Companies are reluctant to deal under DoD restrictions; in their eyes the government would be taking and possibly giving to their competitors the very basis of their business.

International Competitiveness and the Health of U.S. Industries

The Department of Defense has been concerned for some time about the implications for defense of deteriorating competitive positions of U.S. manufacturing companies in the international market.[12] The government is also concerned from a wider perspective that this trend is weakening and undermining the U.S. economy. DoD shares the concern that a weakening economy and a drain of resources into purchases of foreign goods will reduce money available to produce defense equipment, but its primary concern is the continuing availability of necessary items and technology.

The government does not as yet have a policy regarding dependence on foreign sources for defense material and technology, let alone a game plan for implementing such a policy. The Undersecretary of Defense for Acquisition has recommended a plan to bolster defense-related manufacturing in the United States.[13] The report detailing that plan does not make a statement on how much foreign dependence is tolerable, although it does imply that some is unavoidable.

The complexity of the problem is illustrated by the issue of cooperative development and production of defense equipment with the European NATO Allies. It has been long-standing U.S. policy to encourage multinational procurement of similar defense equipment to foster commonality, to get the best equipment into the forces of all the Allies, to save money, and recently, to exploit a broad multinational technology base. In recent years the Defense Department has made great progress in generating international memoranda of understanding for joint development, with the help of initiatives like the Nunn Amendment. But as the Europeans have become more interested in cooperative developments, they have also sought a greater share in generating the technology and a larger market share for their defense industries. Interest by U.S. compa-

12For examples, see Defense Science Board, "Report of the Defense Science Board Task Force on Defense Semiconductor Dependency," prepared for the Office of the Under Secretary of Defense for Acquisition, February 1987; Report to the Secretary of Defense by the Under Secretary for Acquisition, "Bolstering Defense Industrial Competitiveness: Preserving Our Heritage, the Industrial Base, Securing Our Future" (Washington, DC: Department of Defense, 1988); and Martin Libicki, *Industrial Strength Defense: A Disquisition on Manufacturing, Surge, and War* (Washington, DC: National Defense University, 1986). See also, U.S. Congress, Office of Technology Assessment, *Paying the Bill: Manufacturing and Americans Trade Deficit,* OTA-ITE-390 (Springfield, VA: National Technical Information Service, June 1988).

13&x "Bolstering Defense Industrial Competitiveness, " Op. cit., footnote 12.

nies in joint ventures with Europeans has been spurred, in part, by fears that several trends in European thinking could sharply curtail their sales in Europe. Thus, the cooperative programs are a two-edged sword helping U.S. sales in Europe while stimulating European sales to the United States; and helping U.S. defense policy in general, while both helping and hindering the maintenance of the U.S. defense industrial technology base. Crafting a workable policy will be a tricky job.

There are three basic policy choices:

- demand that anything that goes into defense equipment be built in the U.S. from U. S.-sourced components, taking whatever measures are necessary to ensure that all the necessary industries are alive and well in the United States;
- let the market dictate which industries will be healthy in the United States and look only for the best deals wherever they can be found worldwide; or
- choose some industries that have to be located in the United States, take appropriate measures to ensure that, and let the rest go with the market.

The first and third require some sort of intervention in the international economy, either supporting the international competitiveness of U.S. companies or protecting, supporting, and subsidizing U.S. companies that cannot otherwise survive. Another approach is to design nothing into U.S. defense systems that cannot be domestically sourced. But this cuts off a great deal of modern technology, a Western strength. In making these choices, the United States will have to decide how dependent we can afford to be, and how much independence we are willing to pay for. If the United States demands self-sufficiency without taking measures to keep U.S. companies alive and competitive, the list of technologies available for defense systems is likely to decrease as time goes on.

It will be necessary to decide how to treat dependence on various nations. There are significant differences in being dependent on Canada (already defined as part of the North American industrial base), Britain, our other NATO allies, Mexico, Japan, Korea, etc. U.S. and Canadian companies are closely intertwined. Despite the recent controversy over the trade agreement and other arguments, we are each other’s largest trading partners. Canada is also a NATO ally with a common security interest. The chances of being cut off from Canadian sources either by policy or by hostile act are minimal. We are also close to our European Allies; much of our defense equipment is bought to defend them. But we are separated from Europe by an ocean, and they have not always supported U.S. military actions. Other nations are much less tightly tied to the United States.

The high-technology economy is an international one and responds to international market forces. These forces are likely to continue to move industries offshore despite U.S. efforts to will (or legislate) them to stay. In the vast majority of cases, defense business is far too small to provide the necessary clout, particularly when faced with other nations that manipulate their civilian markets to keep their companies healthy. Competition comes from Japan, the smaller Asian nations—Korea, Taiwan, Singapore, etc—and Western Europe. The Europeans are taking dramatic steps to improve their international competitive position, particularly in high technology industries. These include the economic integration of the EC in 1992, and the funding and encouragement of large cooperative R&D projects.

Although all industries are different, the plight of the fiber optics industry is illustrative. While healthy in the United States, it faces increasingly stiff competition at home and continuing difficulties abroad stemming from limited access to foreign markets. Both the Europeans and the Japanese are making major pushes in fiber optics and photonics in general. U.S. technology and production costs are at least competitive. But while U.S. producers have been largely excluded from some important foreign markets, the U.S. market remains open to foreign vendors. Japanese companies can sell in foreign markets at low prices because their government has discouraged foreign competition in Japan where prices are kept artificially high. The closed domestic market supports overseas competitiveness.

The U.S. software industry faces a different sort of challenge. It is currently strong and competitive, but the rapid growth in worldwide demand for software threatens to outstrip the capacity of U.S. firms to meet it, leaving a large opening for foreign firms to penetrate the market. Japan, France, the United Kingdom, Korea, Singapore, Taiwan, and India have the capacity to penetrate the global market. And many of these nations have trade policies that either discourage sales by U.S. companies or fail to protect the intellectual property rights of those companies: "pirated" software is becoming a major problem. Moreover, the Japanese are making rapid strides in turning software design from art to manufacture, building software factories to increase productivity dramatically.

Internationalization of Industries

Efforts to protect and nurture U.S. companies will be complicated by trends toward internationalization in high-technology industries. Examples are found in the advanced composites industry in which many of the firms that appear to be American—because they have American names or U.S. facilities—are actually owned by foreign companies and in the fiber optics business where international joint ventures are used to get into otherwise closed markets. International ownership, vertical and horizontal integration, and international siting make it difficult to define in any convincing way what an American company is. Moreover, the sequence of steps that leads to a final product often crosses international boundaries many times and shifts as prices and availability of components shifts. Is a Pontiac built in Korea any more or less an American product than a Honda made in the United States or a Chevrolet/Toyota assembled in California from U.S. and Japanese parts?

Difficulties in identifying U.S. companies will produce difficulties in writing legislation to protect them or establishing DoD policy to encourage the growth of important domestic industries. Foreign plants owned by U.S companies, U.S. plants owned by foreign companies, joint ownership, and joint ventures all offer different sets of problems.

Formulating Policy

These trends toward internationalization will complicate difficult issues that Congress and the Administration are already facing. Paramount among these is to decide whether the U.S. Government will play a major role in encouraging and supporting U.S. commercial business and industry, or whether—almost unique among the governments of major nations—it will continue to remain more or less aloof, confining its activities to a few international trade negotiations. Other governments encourage the development of commercial technology and associated industry, help to foster a domestic situation conducive to growth, and support aggressive overseas marketing.

Having decided government's role, the next issue would be to define goals. These might include:

- keeping key nondefense manufacture and development in the United States,
- keeping manufacture and development in the hands of U.S.-based (or U.S.-owned) companies;
- preserving some portion of the U.S. market for U.S.-based (or U.S.-owned) companies; and
- gaining access to foreign markets for U.S. firms.

Defining such goals will entail arriving at a working definition of a U.S. company, or at least of how location and ownership affect U.S. national security interests.

It would be necessary to decide how large a role defense needs would play in deciding which industries are in need of government attention. This decision would have to balance the problems of foreign dependence against the risk of diminished access to foreign technology and manufacture. It would also have to consider how much the United States is willing to pay to buy domestically that which may be available at a lower price elsewhere. The lessons of "low-priced oil" from the Persian Gulf are instructive here. Determining the acceptable degree of offshore dependence for defense equipment will necessitate deciding the level of componentry which DoD would have to specify as coming from domestic sources. For example, is it sufficient to require that systems or subsystems be domestically sourced, or does DoD have to assure that some or all of the components are made in the U. S. A.? This decision would dictate the level at which DoD would need visibility into the manufacturing process and have to keep a data base on suppliers.

Whatever the goals are, Congress will have to decide what levers can be pulled to make those attainable. In most cases, simply controlling defense procurement will not be enough to influence the industry: it may ultimately lead to an inefficient, backward, protected industry that is incapable of competing on the world market. Such an industry might only be capable of providing DoD with obsolete technology or overpriced products. The government has the option of getting more deeply involved in stimulating the development of technology for commercial ends, including making government R&D facilities more available and providing greater incentives for corporate investment. Yet another option is to formulate a strategy—as Japan and other nations have—for controlling access to critical U.S. commercial markets in order to preserve and support domestic industrial capabilities. A third policy lever that can be manipulated, but not totally controlled, is the cost and availability of capital for conducting R&D. Major technological developments are capital intensive, with costs measured in the hundreds of millions to billions of dollars. European and Japanese companies pay less to borrow money than do U.S. companies—far less in the case of the Japanese. This allows them to carry on more projects simultaneously, and to sell the resultant products at lower prices than those of their U.S. competitors, putting U.S. companies at a competitive disadvantage.