Chapter 9

Civilian Technology and Military Security

CONTENTS

Figures

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MILITARY ACCESS TO CIVILIAN TECHNOLOGY

This assessment was prompted by a concern on the part of the Congress that the defense technology base might be eroding in the United States. As a result, the Armed Services might be unable to retain a technological advantage over the Soviet Union and other possible adversaries in the future. This concern is closely related to two observations. First, certain high-technology industries-such as semiconductors and numerically controlled machine tools—have lost domestic market share to foreign competition. Some appear to have entered a cycle of decreased capitalization, weakened innovation, further loss of market share, and eventual loss of leading-edge capabilities, in both design and process technologies. As a result, U.S. military dependence on foreign civilian technology is increasing. The second observation is that the U.S. military appears less and less able to acquire the leading-edge technology that does exist. Such technologies may be available in the civilian sector of the domestic economy, but they are somehow beyond the reach of the Department of Defense (DoD).

Because of these concerns, OTA conducted policy-oriented case studies of three dual-use[1] technologies—fiber optics, software, and advanced polymer matrix composites (PMCs)—to assess the availability of civilian technology for military purposes and to analyze difficulties in the transition of technology between the civilian and military sectors of the U.S. economy. The case studies avoid extended technical description in favor of policy-relevant analysis of major issues confronting these high technology industries. For each case, the inquiry has addressed three central questions: **1) Are civilian high-technology industries (those critical to the military) eroding in the United States? 2) Do military technologies and their applications diverge significantly from their counterparts in the civilian sector of the economy? 3) What are the principal barriers, both technical and institutional, that inhibit military access to civilian technology and vice versa?** Each of these questions requires some amplification.

The rationale for the first question depends on the extent and nature of military dependence on civilian technology, both domestic and foreign. If it is possible and desirable for the defense industrial sector to develop and produce all technologies necessary for the Services, then the competitiveness of the civilian sector of the economy, while important for other reasons, would not be related to national security considerations, But if the defense industrial sector relies to any substantial extent on research and development (R&D), innovation, and production conducted in the civilian sector, then loss of commercial competitiveness in industries that develop technologies that are pervasive or enabling for military systems would have serious policy implications. A recent report on defense industrial competitiveness by the Under Secretary of Defense for Acquisition took this position.[2] It was also the primary concern of the Defense Science Board (DSB) when it recommended an industrial policy, which amounted to a strategy for economic defense of the domestic semiconductor industry.[3] In the case of semiconductors, the DSB argued in its report that eroding domestic capacity seriously jeopardizes our ability to build and field major weapons systems—unless the United States is willing to depend on foreign firms for strategically important technologies, materials, and devices in the future.

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[1] In this chapter the term ''dua]-u~" refers to technologies that can have multiple, significant applications to military systems, and that can be employed extensively in civilian industry as well.

[2] 'As a nation and as a continent, we no longer are totally self-sufficient in all essential materials or industries required to maintain a strong national defense . . . . Clearly, the Department of Defense cannot provide massive financial assistance for every American industry characterized by a lack of International competitiveness, nor can we effectively provide incentives for every manufacturing industry critical to our defense. " (Department of Defense, '' Bolstering Defense Industrial Competitiveness, " Report to the Secretary of Defense by the Under Secretary of Defense for Acquisition, July 1988, p. v.)

[3] 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.

These concerns have equally significant implications for emerging and fast-moving, high-technology industries such as fiber optics, software, and advanced composites. There is substantial evidence and widespread agreement among experts, for example, that the Japanese government and industry are already deeply engaged in the process of funding, researching, planning, and designing market-oriented applications for a wide range of fiber optic and photonic technologies. By contrast, many American firms appear to be waiting in the wings, biding their time, hoping for Federal assistance, and unwilling to commit substantial corporate funds for products that might not reach the market for 10 years. If fiber optic and photonic technologies do indeed supplant large portions of the consumer electronics and computer industries-as some analysts argue they will—the implications for the civilian side of the U.S. economy and its ability to supply the military will be enormous. For this reason, the case studies, which are located in a separate volume of appendies to this report, all address the question of the health of domestic industry, specifically analyzing the threat of destructive foreign competition now and in the future.

The purpose of the second question -concerning divergence and convergence in dual-use technology—is to make explicit the differences and similarities between military and civilian technologies and their various applications. As technological divergence between the two sectors increases, it becomes more difficult for the military to draw on the resources of the civilian sector of the economy. Absolute divergence between military and civilian technologies would mean that by far the largest portion of the technology and industrial bases in the United States and around the world would be unavailable to the military. This is clearly not the case. Indeed, a basic strength of the West is that technological innovation is rooted in society and not in the military. Nevertheless, there is a widespread belief among many defense planners and technologists that military and civilian technologies are inherently different, because weapons systems must push the outside envelope of performance, must be built to sustain battlefield environments, and are expected to survive up to several decades of readiness and training missions.

Critics of this position contend that it is possible to plan for convergence of military and civilian technologies, even in early development, by harmonizing otherwise divergent standards and specifications. They believe that much divergence is the result of a military fixation on achieving technical performance levels that may or may not be decisive in warfare or desirable from a training and maintenance perspective. They believe that civilian products can be as rugged as those built to military specification. There are, for example, few environments more hostile than the one under the hood of a car, where semiconductor devices are hard-mounted to the engine block.

Many observers agree that in any dual-use industry there will be strong convergence between the military and civilian technologies themselves, and potentially significant divergence when it comes to end-use. Clearly, there are military applications that will never find expression in civilian life, but at the same time it appears to be possible to substitute commercial off-the-shelf (COTS) products for Milspec items[4] in some of the most advanced weapons systems. But the relationship between civilian and military technologies is far more complex than arguments about the adoption of finished pieces of hardware can suggest. It is evident that civilian technology that could be important to the Armed Forces will be irrelevant if military officials—from general officers to program managers—reject suitable civilian parts in favor of items developed under contract with the government, And it is likely that Service acquisition managers will continue to resist civilian technology and components until the incentive system is changed. At present, many managers avoid new technologies available in the civilian sector, because the acquisition system forces them to assume responsibility when such a part or component fails, thereby jeopardizing their careers. Most prefer to use older technologies, waiting until the specifications, standards, research, and testing are complete—and the risk of failure is eliminated or can be transferred to another program.

[4] Milspec items are parts or systems formally specified in the body of Military Specifications and Standards published by the Department of Defense.

In the sphere of complex, information-intensive military systems—whether involving weapons or not—the utility of civilian technology and applications must be addressed case by case. For each of the cases in this report, an effort was made to analyze the extent of convergence and divergence of civilian and military technology, and to explore existing and potential areas of overlap. The case studies attempt to sort out the extent to which divergence is technologically necessary and the extent to which it is a product of military culture as well as economic incentives for the contract industries on which the Services depend.

The final question asked earlier, regarding impediments to military use of civilian technology, requires an analysis of the barriers to the fluid exchange of technology between the military and the civilian economies. When OTA began to investigate questions of dual-use technology, complementary complaints surfaced from within DoD and from civilian sector managers. Military technologists asserted that while there were many advanced and desirable technologies in the civil sector, the military encountered difficulties in gaining access to some of them. In addition, senior defense officials indicated that some military contractors had diversified into the civilian sector of the economy with the intention of getting out of the defense business altogether. These officials cited a need to reduce red tape and to make doing business with DoD more stable and predictable. The other side of the complaint—which first emerged from managers of small, entrepreneurial firms-was that doing business with the government involved difficult adjustments, including compliance with outdated military specifications, cumbersome auditing and reporting procedures, and possible compromise of proprietary information. They considered DoD to be a very difficult customer, often too costly to pursue for commercial purposes. The bottom line is that DoD may have to buy advanced technology from companies that do not need, or even particularly want, its business.

Accordingly, it is important to investigate the processes by which specific technologies move between the civilian and military sectors. The existence of significant barriers-whether technical or institutional in character-points to severe deficiencies in national security policy. If security rests to a large extent on the health of the domestic economy and its ability to produce technology and materiel for the national defense, then any substantial inability of the military to draw on civilian technology and industrial resources constitutes a serious and presumably unnecessary liability. If civilian high-technology industries erode significantly in the United States, or if the government loses the ability to exploit the civilian technology base efficiently, it amounts to the same thing. The OTA case studies specifically investigate the extent to which and under what conditions existing barriers are technical in nature, and the extent to which they are due to institutional considerations, including regulatory, legal, and administrative factors.

The focus on the problem of the transition of technology between the civil and military sectors of the economy served as a principal criterion for the selection of the three technology case studies in this reports Fiber optics is a high-technology industry that is well-established in the civilian sector, both domestically and internationally, but which has lagged significantly in the military sector where it has numerous potential applications. On the other hand, advanced polymer matrix composites were developed in the aerospace industry for military purposes. They have only begun to find markets in the civilian sector, even though they could be employed extensively in the construction, civilian aerospace, automotive, and medical instrumentation industries, among others. Finally, software is a case where the technology is advanced and resident in both sectors of the economy, but where each sector still encounters difficulty in drawing on the resources of the other.

[5] This chapter employs a research strategy based on the method of structured, focused comparison. See Alexander L. George, "Case Studies and Theory Development: The Method of Structured, Focused Comparison," in Paul Gordon Lauren (ed.), *Diplomacy. New Approaches in History, Theory, and Policy* (New York, NY: The Free Press, 1979), pp. 54-59. See also, Alexander L. George, "Case Studies and Theory Development," a paper presented to the Second Annual Symposium on Information Processing m Organizations, Carnegie Mellon University, Oct. 15-16, 1982, pp. 25-34.

[6] The following three sections present summaries of the results of each of the cases as they apply to the three principal questions addressed in this chapter. The reader is referred to Appendices D, E, and F in Volume 2 of this report for more in-depth analysis and documentation.

HEALTH OF THE DUAL-USE INDUSTRIES

Are civilian high-technology industries, those that are critical to the military, eroding in the United States'? The story is somewhat different for each of the three high-technology industries considered in this study.

Fiber Optics

Over the past decade, the fiber optics industry has realized tremendous growth, not only in production and sales, but also in the scope of the technology itself. It is a vital technology whose future patterns of development and diffusion have strong economic as well as military implications. Military planners recognize the technical superiority of fiber-based communication systems over those that employ coaxial cable or twisted copper wires. Many analysts believe that fiber optic and related photonic technologies will eventually exert an impact on the world economy comparable to that of the electronics revolution of the 1970s and 1980s.

The worldwide fiber optics industry is characterized by overcapacity and intense competition, with many advanced industrial nations already designating fiber optics as an essential national capability. By 1980, definite patterns had emerged in the way that OECD[7] member governments would respond to the strong growth potential of fiber optics markets. In the United States, large, vertically integrated firms like ITT and AT&T had begun to invest heavily in fiber optic R&D.[8] An early lead in fiber development was established by Coming Glass Works, which holds many of the most important patents in the field. Major cable makers were targeted for takeover by firms seeking to position themselves for future fiber optics business that had not been principally associated with the telecommunications industry.

In contrast to the United States, the Japanese government pursued a deliberate 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. NTT, MITI, and KDD[9] (the Japanese international communications agency) initiated a carefully orchestrated campaign. NTT (then an official government agency) led the effort, conducting and promoting fiber optic and optoelectronic research, working principally with three companies, Sumitomo, Furukawa, and Fujikura. At the same time, KDD set up a long-term program to develop all aspects of the technology necessary for submarine fiber optic systems. And MITI sponsored two substantial research projects, the Hi-OVIS program and the Optical Measurement and Control System R&D program. By the mid-1980s, 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.

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. 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. The PITs provide centralized planning and control of the telephone network and have supported the introduction of new technology into that network by sponsoring trials and demonstration projects. The present configuration of national policies would change dramatically if a pan-European policy develops in the future.

As a result of these differences in policy and approach, U.S. firms face stiff competition at

[6] The following three sections Present summaries of the results of each of the cases as they apply to the three principal questions addressed in this chapter. The reader is referred to Appendices D, E, and F in Volume 2 of this report for more in-depth analysis and documentation.

[7] OECD: Organization for Economic Cooperation and Development.

[8] International Telephone and Telegraph, and American Telephone and Telegraph.

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

home—while they are effectively barred from substantial penetration of some important foreign markets. Nevertheless, representatives of some American fiber and optoelectronic companies believe that the United States presently maintains a technological lead in virtually every area of fiber optics, but that this lead is eroding. The American position was established and is still based on intense competition for sales to American telephone companies. Some analysts believe that because the industry is robust, officials in Washington should stay on the sidelines and allow market forces to continue to strengthen an emerging industry in which the United States has already proven itself to be particularly sturdy and capable.

Many analysts are less optimistic about the competitive status of the fiber optics and optoelectronics industries in the United States. They believe that the success of the U.S. industry is by no means assured, but instead will hinge on a variety of critical factors. The most important of these are discussed briefly.

First, the future health of the U.S. fiber optics industry largely depends on the extent to which it can sell fiber and optoelectronic devices to the telecommunications companies. That business, in turn, depends on building fiber optic links to individual homes across the United States, Legislators and regulators have tended to shift responsibility for the national telecommunications infrastructure to market forces and to the courts. Some analysts believe that the present regulatory structure—one that effectively separates telephone from television delivery systems and inhibits the spread of telematic (online) services—retards the development of the optoelectronics industry in the United States. At the same time, huge, vertically integrated Japanese and European firms are gaining experience in the production and commercialization of large-scale fiber optic local area networks (LANs) in their home markets.

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 services digital networks (ISDN), progress in this area is slow for 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 have advanced farther towards setting standards than has the United States, and that they may succeed in imposing de facto standards on the competition in the future.

Third, penetrating foreign markets-especially in Japan but also in some European countries-is still difficult for American firms. This disadvantage for U.S. companies is compounded because future expanded demand for fiber optic systems is expected to occur first in foreign markets, where domestic manufacturers are favored.

Fourth, most European producer nations and the Japanese Government have designated fiber optics as an essential technology of the future and they subsidize R&D in the optoelectronics field. In the United States, government assistance has been confined largely to the military, and U.S. companies have tended to pursue research and development on an ad hoc, isolated basis.

Finally, the United States 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. U.S. unilateral controls have tended to exclude U.S. firms from participating in some markets that are open to the European and Japanese competition. In addition, some foreign firms are reluctant to buy U.S.-made optoelectronic parts and components, because they fear that U.S. Government prohibitions against exporting goods to third-party countries will apply to them.

Software

Although the U.S. software industry currently dominates world markets, both technically and economically, its continued superiority will depend on a number of complex factors. The industry faces difficulties in meeting growing demand for all types of software-packaged, integrated systems, and custom-built. International competition is increasing as other nations—particularly Japan, France, the U. K., Korea, and India—establish software production capacity and seek to penetrate global software markets. U.S. software firms increasing y face tariffs and foreign trade policies that restrict imports of U.S.-developed software. Enforcement of intellectual property rights in international software trade is lax. And finally, as the world market continues to grow, its composition will undoubtedly change, and the demand for new types of software may create advantages for companies in foreign nations. These factors are addressed below.

The ability to meet the growing demand for software, and the ability of the United States to maintain its dominance of the software market, depends on the supply of computer programmers and the technology available to them. U.S. companies cannot meet the demand for software with the present number of computer programmers. The shortfall of software professionals in the United States is estimated at 50,000 to 100,000 and is forecast to grow steadily over the next decade. 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.

Many programming methods and practices used in U.S. industry today are primitive when compared to sophisticated software engineering techniques. The software development process can be improved through the use of formalized and automated engineering techniques. These support the iterative building and testing of software prototype systems, allow for the reuse of software components, and accommodate the complexity of software systems. Widespread use of these technologies in the United States is impeded by the existence of a large, embedded, heterogeneous software base.

The growing cost of software maintenance is directly related to the failure to recognize software engineering as a scientific discipline and to the lack of trained software engineers. Software maintenance—the modification of software to correct errors and to incorporate changes or enhancements—has become the primary cost in most software systems. Present estimates indicate that in fiscal year 1990, DoD will spend 80 percent of its $20 billion software budget on maintenance.

Approximately 40 percent of the packaged software[10] revenues earned by U.S. firms come from outside the United States. This share is threatened by the software industries in Japan, France, the U. K., Korea, India, Taiwan, and Singapore. Japan is the strongest competitor primarily because of its advanced hardware industry and the propensity to take advantage of standardized technologies and develop marketable products from them. A principal strength of the Japanese is the ability to close large portions of their domestic market to foreign products, and simultaneously to penetrate U.S. markets with systems software developed using U.S. standardized designs.

A comparison of the U.S. and Japanese industries shows that, while the level of software technology in both countries is similar, Japanese firms create more disciplined software engineering environments in which the use and production of tools is more widespread. As a result, Japanese programmers are much more productive than their U.S. counterparts. In contrast to the U.S. industry, Japanese software companies tend to invest more money in basic technology and to distribute this capitalization across the entire firm, rather than limiting it to particular software projects. Many Japanese companies view programming as an applied science. Their ‘‘software factories, ” which reuse approximately 30 percent of previously developed software, have an error rate one-tenth that of U.S. companies, and have the potential to produce lower cost and higher quality software.

As U.S. software companies operate in world markets, they are increasingly subjected to intellectual property violations and infringements. U.S. domestic intellectual property protections (copyrights. trademarks, trade secrets, and proprietary data) are insufficient to protect U.S. interests in many foreign nations, where the penalties for intellectual property infringement can be less than the resulting profits. This problem is most pronounced in less developed countries, which have little to lose and much to gain by not honoring U.S.

[10] Packaged software is software that is commercially developed and broadly marketed, as opposed to custom software, which is developed to meet the particular needs of a specific user.

regulations. Japan is also cited frequently for violations.

Additional economic loss for U.S. industry is attributed to the restrictive trade policies of many foreign nations, which serve to foster native software industries at the expense of U.S. firms. Import quotas, discriminatory taxes, local ownership requirements, embargoes, and preferential treatment for locally produced goods are among the common policies that discourage or preclude U.S. firms from seeking business. These practices are most pronounced in Brazil, India, Mexico, and Korea.

Polymer Matrix Composites

Although the U.S. DoD drives the development of composite materials technology (historically through its R&D funding and now through its aircraft/aerospace purchases), advanced composites is a global business conducted by companies (U.S. and foreign) with broad international interests.[11] Large chemical and petroleum companies are suppliers of fibers and composite parts around the globe.

The world PMC industry is extremely intertwined in terms of corporate vertical integration, integration with its major end-use market (the military aerospace prime contractors), and with multinational chemical and petroleum interests. Advanced composites are formed in a series of stages, each of which corresponds roughly to a different industry—raw materials, fiber preparation and shaping, and components for end-use.[12] In recent years, raw material suppliers such as Amoco, British Petroleum, Phillips, Shell, BASF, Ciba-Geigy, Du Pent, and Hercules have moved downstream into fibers and shapes, where there is more value added in the products. Most of these companies buy from, sell to, and compete with each other for business from military prime contractors. At the same time, defense aerospace companies, which had relied on specialized companies for part forming services, have moved upstream, making parts in-house and buying only the raw materials.

In this discussion, two distinct stages of corporate integration can be defined: material suppliers and end users (including intermediate material suppliers). Fibers are sold as standardized commodity materials. End users (and intermediate suppliers) develop individually tailored structures for each application. Because of this dichotomy, fiber suppliers conduct a different style of business, with different issues and concerns, from that of the end users.

Material Suppliers

Carbon fiber is a principal ingredient in the production of advanced PMCs. About 65 percent of the U.S. carbon fiber market is in the aerospace industry. Over half of the U.S. aerospace market for fiber is military. Defense applications are projected to grow by as much as 22 percent annually in the next few years. The U.S. military market is a primary target for foreign companies producing carbon fiber composites, because it is the largest, most advanced, and most attractive in terms of sales and profitability. The second largest market is in the Far East, where carbon fiber products are used to make sporting goods.

Worldwide, carbon fiber capacity is twice the current market volume. Japan and the United States have about equal capacity. Japanese companies manufacture a carbon fiber precursor, which is then sold to U.S.-based carbon fiber suppliers (mainly Hercules), which is in turn the major supplier of fiber for military programs. At present, no Japanese carbon fiber is supplied directly to U.S. military programs.

U.S.-based industry is continuing to add carbon fiber capacity—about 1 million pounds in 1988. Accordingly, there is and will continue to be a great deal of excess capacity both in the United States and in world markets. While the United States has a large fiber overcapacity compared to domestic market requirements, most of the world excess capacity is concentrated in Japan.

1 [1]The discussion of PMCs draws on a previous OTA assessment. See U.S. Congress, Office of Technology Assessment, *Advance Design: New Structural Materials Technologies*, OTA-E-35 1 (Washington, DC: U.S. Government Printing Office, June 1988).

[12]In the manufacture of PMCs, highly processed carbon fibers are chemically treated and bonded With a matrix material. The material is shaped during this process which involves heating and compressing it into a mold. These shapes are then finished by machining, and become final products such as airplane wings and tennis rackets.

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. In addition, Japan does not have a domestic aircraft industry to which advanced PMCs could be sold, although it is trying to establish one through a joint venture with Boeing and through its decision to build the FSX fighter. Japanese companies are building a strong position worldwide in PMC technologies.

End Users

The United States leads the world in developing and using advanced PMC technology, based largely on the strength of its military aircraft and aerospace programs. Nevertheless, foreign commercial end users outside the aerospace industry are more active in experimenting with these new materials than are their U.S. counterparts. Western Europe leads the world in composite medical devices, partly because the regulatory environment controlling the use of new materials in the human body is less restrictive in Europe than in the United States. The EC is taking additional steps to commercialize advanced PMCs. For example, the EUREKA Carmat 2000 program proposes to spend $60 million through 1990 to develop advanced PMC automobile structures.

The U.S. market on the whole is projected to grow faster than the world market, based on the assumption that the military demand for PMCs will expand rapidly over the next 5 years. Although the number of U.S. military aircraft being built is declining, composites are replacing much of the metal on airplanes. For example, the F-16 has 260 pounds of advanced composites per aircraft, while the V-22, which recently moved into production, will have from 8,000 to 9,000 pounds per aircraft. However, growth is expected to level off in the middle 1990s as advanced PMCs move into all of the structures for which they are suited.

Foreign production of U.S. aircraft components is increasing, and manufacturing of composites for commercial aircraft is moving offshore in many cases. A significant number of foreign companies fabricate 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. Such sales enhance technology development in, and the potential economic competitiveness of, foreign-owned advanced composites businesses, possibly at the future expense of U.S.-owned firms.

In the past few years, participation of Western European-owned companies in the U.S. advanced PMC market has increased dramatically. This has largely taken 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, the Japanese have not sold any carbon fiber facilities. As a result of extensive acquisition of U.S. firms, foreign makers of advanced materials have entered the U.S. aerospace market and share the technology leadership that participants enjoy.

CONVERGENCE OF MILITARY AND CIVILIAN TECHNOLOGIES

Do military technologies and their applications diverge significantly from their counterparts in the civilian sector of the economy?

Fiber Optics

The distinction between tactical and fixed-plant fiber optic systems is important. Tactical systems require rapid mobility. Although fixed-plant systems are installed directly in the ground or in conduits, most tactical systems must be placed on the ground, strung above the ground, or deployed at sea. 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 that used in fixed-plant systems. While optical splicing may be used for many fixed applications, connectors are necessary due to the requirement for mobility in a tactical environment. And finally, batteries or other local sources of power are usually required to drive sources and repeaters in tactical systems. Generally speaking, shipboard fiber optic systems can be considered as fixed plant.

Do such differences between military and civilian applications translate into differences in the technology itself or in the way that R&D for fiber optics must be conducted? The answer is a qualified "No." For fixed-plant systems, military requirements would differ only marginally, if at all, from those used in private-sector businesses or for local area subscriber networks. For a large percentage of military applications—wiring the Pentagon, the DoD laboratories and R&D facilities, and the military bases—the technology is broadly available from the civilian sector. In addition, fiber optic systems deployed on ships would be similar to LANs now undergoing trials in the private sector in Japan and in the United States.

Optical sensors have enormous potential in a wide range of applications both military and civilian. Many of the major sensors used by the military-or under development—are analogous to those used in the civilian sector. One fiber optics group in the Navy has tested 54 different sensors developed for civilian purposes and found that most of them do not perform adequately in a military context. They concluded, however, that the civilian sensors should not be discarded and replaced by sensors built to military specification. Such specifications do not yet exist, and the process of writing them and getting them approved would take years. Instead, the group takes the approach of addressing the military requirement by modifying commercial products so that they are suitable for the particular military task for which they are envisioned.

Their objective is to use the existing technology—which they believe is far more advanced than that which the Services presently need. For example, industry already has endoscopic devices for looking into machinery and into places where electronics cannot be placed. This is not a new or radical technology. These devices represent basic technology with new applications. In this approach, DoD's challenge is to figure out how to take the technology that is available-not a radical departure from it—and use it in a military setting.

Despite the decidedly military character of the FOG-M missile,[13] 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 a volume of up to 2 million kilometers. There are special military requirements in the way that the fiber is wound on the spool, in the fiber design, and in the materials that are used to attach the fiber to the spool. But these do not translate into large differences from civilian technology, nor do they require significant changes in the way that R&D) is carried out. The military requirements can be met if civilian fiber companies are willing to develop the modifications.

Software

The software industry is increasingly divided into two camps, one that is dedicated to military interests and another that supplies the commercial world. These two sectors have been present since the birth of the industry, and exchange between the two was assumed to be the norm, not the exception. But there are significant indications that divergence between these groups is increasing, which may contribute to a weakening of the U.S. software technology base.

The underlying software technologies are very similar in both the military and civilian sectors, and divergence becomes noticeable only 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, such as personal computer (PC) based programs and office automation products.

Similarities in the applications of software are not limited to PC-based and systems software. Analogous applications of large-scale software systems also can be found in both sectors, including 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

[13] The Fiber Optic Guided Missile (FOG. M), now in full-scale engineering development, pays out optical fiber from a bobbin, enabling the battlefield operator to target the missile with a real-time video image emanating from a camera in the nose of the missile.

software that controls these systems. This is particularly true for large-scale, mission-critical applications in the DoD.

Thus, 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. The significance attached to software requirements by each sector, and whether they become rigid specifications or economic trade-offs, partially explains why there is little transfer of software between the military and civilian sectors in the embedded and large-scale applications.

Military requirements for custom-built and embedded software are generally far more rigid than civilian requirements. Once documented and approved in the design stage, specified requirements govern the subsequent development of the software.

The need for specific performance and operational characteristics is evident in many DoD mission-critical systems. It is necessary to require nearly 100 percent reliability for a missile guidance system or multi-level security in a networked defense communications system. But when these requirements are transferred unnecessarily to other military systems, the cost of development increases and the ability to use analogous civilian applications or commercially developed software diminishes.

Many of the requirements often identified as unique to military applications—for example, multi-level security, data encryption, interoperability, survivability, and high reliability—are equally appropriate in banking, insurance, commercial flight control, and other civilian applications. Indeed, many features incorporated into military systems could be transferred to civilian applications and vice versa. But while these features are desirable and appropriate in civilian applications, their implementation would be based on economic and risk analysis. In the civilian sector, if the cost of implementing a requirement exceeds the expected return, then the requirement is usually deleted or deferred. This analysis and design-to-cost approach rarely occurs in military software acquisitions, although similar accommodations will be more likely if military software costs continue to escalate.

A more recent divergence between the military and civilian sectors of the software industry relates to the military's mandated use of a single high-order language, Ada, in its mission-critical software systems. DoD's sponsorship of Ada began in 1974 when the ''software crisis" was first recognized and acknowledged to have potentially serious consequences for the military's ability to maintain and operate its many computer systems. In 1983, Ada was approved as a standard by the American National Standards Institute (ANSI) and by DoD as Military Standard (MIL-STD) 1815A. By 1987, Ada was approved as an International Standards Organization (IS0) 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 considered to be best for that particular application—whether it be COBOL, a fourth generation language, or any other computer language, 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 of, or ability to, incorporate commercially developed, non-Ada software into its computer systems.

Polymer Matrix Composites

There is both convergence and divergence in military and civilian applications of advanced PMC technology. In general, military and civilian markets have different technical and cost criteria for the selection of materials and process technologies. Convergence and divergence occur simultaneously in different aspects of the PMC industry and its markets.

Various segments of civilian and military markets place different emphasis on performance and cost. In the 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.

Although general functional requirements (e.g., low weight, high strength for primary structures, lower strength for secondary and nonstructural parts) lead to convergence between the military and commercial aircraft sectors, the stringent mission requirements for military aircraft drive the use of advanced composites in the military. 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 strength-to-weight ratio.

The use of lower cost materials (such as glass-reinforced composites, or fiberglass) in general means more weight and lower performance in the traditional aerospace sense. Industry representatives assert that battlefield conditions require that weapons systems weigh less. That was the initial reason for the attractiveness of composites, particularly graphite-reinforced composites. While lower costs are desirable in the military aerospace sector, performance remains the main driver.

According to advanced PMC industry representatives, cost currently limits market growth and the transfer of high-performance military PMC technology to the commercial sector. Carbon fiber is priced at about $15 to $20 per pound. Chemically treated fiber, called prepreg, sells for $35 to $40 per pound; and the cost of finished aircraft structural components is between $250 and $600 per pound. Aluminum structures cost about $85 a pound, including 2 hours of labor and $5 of material. Some 70 to 80 percent of the cost of a finished advanced PMC part is due to fabrication costs.

Many developments have wide applicability across both the civilian and the military arenas. There is synergism between military and commercial aircraft production in resins and fibers, the way materials are stitched together, and the way they are used. For military and commercial aircraft, the structures made from composites (e.g., wings, tail, 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.

However, military requirements may make it necessary to modify the fabrication process. For example, pultrusion is typically used in the commercial market to form beams. Military applications need superior load-carrying capacity, so that for military applications the pultrusion process must be modified to impart different properties to the fabricated part.

From abroad perspective, the military community often requires custom-made hardware, while commercial industries look for 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.

Military and commercial aircraft both experience similar environmental conditions, and thus 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, there are some major differences related to peak G-loading and maneuverability, repair strategies, stealth, radiation hardening, and design temperatures.

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

BARRIERS BETWEEN THE CIVILIAN AND MILITARY SECTORS

What are the principal barriers, both technical and institutional, that inhibit military access to civilian technology and vice versa?

Fiber Optics

In order to do any substantial amount of business with the DoD, fiber optics companies have found it necessary to create a separate corporate division. 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 one of government-subsidized research and regulated profit margins.

The question of how to specify fiberoptic 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. 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[14] in a field that is changing from month to month. The alternative is to adopt performance standards essentially specifying, in a general way, the characteristics that a part or component must meet, and then leaving it to industry to figure out the specifics. This would, however, make it more difficult to conduct competitive procurements. The range of competing designs might be very wide, and it would be necessary to trade off price against quality.

Industry executives suggest that the military generally does not recognize the capabilities of the commercial sector. From the industrial perspective, this is due to "the momentum factor" and "cultural conservatism" in the military, two substantial barriers to the large-scale introduction of fiber optic technology. The former proposes that the Services have committed themselves to older communications and sensing technologies, many of which are not compatible with fiber optic systems. According to the latter, 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.

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 resides—in the absence of performance, design, and testing specifications. These are considered essential to the acquisition process.

By insisting on the use of existing specifications, the military can create barriers to the introduction of a new technology—for example, when a large civil-sector company attempts to install a standard fiber optic telecommunications system for a military base. DoD could procure regular commercial products, since there are no special military requirements. But it is very difficult to install such a system on a base. If there are no existing military specifications and standards, DoD is reluctant to buy a system. If there are military specifications, they are unlikely to correspond to existing commercial products, because civilian technology probably advanced while the military specifications were being written and approved. In this case, the Defense Department will end up paying more for a less capable system than would a commercial purchaser. Somehow, DoD must learn to make decisions about what it wants—either by writing specifications, modifying specifications, or carrying out procurements without specifications-in a matter of a few months.

[14] In general, ''prescriptive standards'' specify how something is to be made or what it is to be made from. In contrast, 'performance standards'' specify only the resulting capability or performance level to be achieved.

Industry executives and analysts point to several key reasons why some optoelectronics and fiber optics firms have difficulty in selling their products to DoD, and others are reluctant to do business at all. Those most often cited include: 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.

In a somewhat ironic case, a fiber optics company licensed its technology from a university research program funded by DoD, and is now unwilling to do business with the government. It is a small, highly profitable company that is limited in the extent of money and technology that it can leverage for any given purpose. Its executives are very reluctant to take contracts with DoD, because they cannot afford to hire specialists who can respond to DoD regulations, contracting procedures, auditing practices, and other requirements. They are unable to support the cost of research and gearing up for production, unless there is a definite market for the product in question and the opportunity to realize substantial profits.

In the civil sector, a company can develop long-term relationships with its suppliers and customers. Government notions of fairness and competition rules make it difficult to sustain such relationships, as does the turnover of contracting personnel.

A second major problem, cited by some industry analysts, is that government procurement officers and regulations do not recognize the extent to which fiber optic and optoelectronic technologies are driven by R&D activity. Government agents tend to demand as many data rights as they can get in any given contract. 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 process information.

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. If the company has not worked with DoD in the past or if the military segment of the business is small, many executives tend to skirt the problem by avoiding government contracts.

A third major impediment between DoD and civil-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 in part a consequence of the divergence of business practices in the military and civilian sectors of the economy. and partly a result of inflexibility on the part of government. To do substantial business with DoD, managers 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 that do not make sense in the context of civil-sector business.

Software

Despite similarities in the technologies available to the civilian and military software sectors, differences in their respective acquisition strategies obstruct the exchange of software technologies and applications. Persistent barriers to the transfer of technology, methodologies, and products between military and civilian interests are identified below.

In 1987, a DSB task force reported that both technical and management problems are evident in military software development, with the latter being more significant.[15] These management problems relate to the manner in which DoD procures software, and they represent major barriers to the exchange of software technology between the civilian sector and DoD.

According to industry representatives, the principal problem is the bureaucracy and administrative overhead associated with DoD acquisition procedures. The requirements regarding procurement, design, development, and maintenance of DoD software are set forth in DoD-STD 2167A. As a government review mechanism, DoD-STD 2167A references and directly or indirectly requires compliance with many additional standards, directives, data item descriptions, and Federal Acquisition

[15] Defense Science Board, "Report of the DSB 1987 Summer Study on Technology Base Management," prepared for the Office of the Under Secretary of Defense for Acquisition, December 1987.

Regulations (FAR). As is true of fiber optics companies, in an attempt to comply with contractual obligations, commercial software vendors must employ specialists who are fluent in military regulations, government reviews, documentation, and accounting procedures. These requirements and associated legal issues have forced many DoD contractors to establish autonomous divisions for conducting business with the government. As a result, few civilian software firms regularly contract with DoD.

Defense Department acquisition procedures and contracting practices limit the number of potential vendors and discourage established contractors who already work for the military. Civilian firms that contract with DoD receive no guarantee of a continued relationship with the government, achieve poor profit margins, and often lose the rights-in-data to their software.

Although software firms guard proprietary information closely, this property is often transferred—by contract—to the government. Despite the flexibility allowed government contracting officers to negotiate less-than-exclusive rights to data in software acquisitions, commercial venders generally lose most, if not all, of their intellectual property rights to the software they develop. The government's claim to unlimited data rights is based on the notion that these rights protect the government and ensure public dissemination of publicly sponsored research efforts. In negotiating for unlimited rights to data for its software, the government achieves the ability to maintain and modify its software systems in the future. This practice is intended to ensure fair competition for future software maintenance and reprocurement contracts. Some analysts assert, however, that such policies weaken DoD's ability to negotiate for the best software at competitive prices, because they drive away potential bidders.

Ada has been cited by some civilian software firms as a barrier to doing business with DoD. The directive stating that Ada shall be the "single, common, computer programming language" used in command and control, intelligence, and weapons systems may help in the long run to alleviate the military's software crisis. But because of its relative immaturity, the number of software firms proficient in Ada is limited. The mandate to use Ada appears to reduce 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 much, too early. Although the requirement to use Ada for mission-critical applications was arguably premature in 1983, developments associated with Ada have advanced significantly since that time. But many commercial vendors, with the exception of those in the avionics industry, still take a wait-and-see attitude about Ada.

The merits of a single, standardized language, such as Ada, will continue to be debated. Ada's 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 its portability among diverse computer architectures. Additionally, because it was standardized early and trademarked, there are no incompatible dialects of the language; such dialects tend to decrease the reliability and complicate the maintenance of software systems. These characteristics have the potential to 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 DoD is the single largest consumer of software and is committed to the use of Ada, the language will be an important factor in future software technologies. Its potential, though, conflicts with the current situation in which many military mission-critical applications are required to be implemented in Ada, while similar civilian applications will continue to be developed in the language deemed best for each particular project.

Polymer Matrix Composites

Advanced composites technology was first applied in the military sector. 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.

As in the other industries under review, military contracting and accounting procedures, and the potential loss of proprietary rights and patentability, may be the costs of participation in the military composites market. Loss of data rights 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 losses inhibits the flow of technology between the defense and commercial sectors. Indeed, technology developed in the commercial half of a company may not be shared with the military half due to proprietary concerns.

These barriers represent inhibitions, but not prohibitions, to 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.

Government business rules and regulations have inhibited the transfer of PMC technologies from the commercial sector into military applications. For example, in 1978 ACF Industries successfully developed an inexpensive glass-fiber composite railroad car based on aerospace technology. 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 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 the government accounting compliance requirements met with stiff resistance. The commercial sector subcontractors expressed reluctance to participate on this project, because of the required forms, audits, and the justification of overheads.

In addition, personnel working on highly classified programs sometimes cannot obtain clearance to share nonsensitive information such as generic materials and process technology data. This 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.

The DoD has similar problems internally. Some analysts are concerned that there may be 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 the "white" technology base.

Industry representatives indicate that the pressure to share data in military markets to reduce costs conflicts with their competitive instincts. Some companies feel that information disclosed to the government would become public and might be used by their competitors in a different market. Nevertheless, some sharing of materials databases is necessary to reduce the currently excessive costs of R&D and processing.

Aircraft manufacturers, parts fabricators, and material companies that contract directly with DoD (or that take subcontracts) often set up separate divisions to comply with government regulations and procedures. Although personnel can be transferred from the commercial divisions or hired from other defense contractors, industry analysts state that everybody in the defense division eventually thinks "government contracting. " The overhead charged by that division is typically a great deal higher than that charged by the rest of the company.

SUMMARY OF CASE STUDIES

The case studies send mixed signals about the overall health of the three industries. Each exhibits different strengths and vulnerabilities. The U.S. optical fiber industry is strong today, but it is concentrated in two large companies. These companies face daunting competition in the future, both from the EC and from Japan. In software, U.S. companies clearly lead the world in both sales and technology leadership. But the competition—especially from Japan—is closing the gap, and the United States is experiencing a growing shortage of software engineers. The U.S. PMC industry is strong and thoroughly internationalized. It is also extremely dependent on the Defense Department. DoD has supported PMC technology because it is both pervasive and enabling for a large number of military systems. But the cost to DoD is very great. To date, there is little indication that U.S.-based producers are willing or able to diversify into civilian markets, so long as a lucrative military market exists.

For each of the three technologies, a high degree of technological convergence between civilian and military applications is evident. There are also some applications that are unique to the military for each of the technologies. There is, however, significant divergence between the military and civilian economic sectors for each industry, and this occurs for reasons that are not directly related to the technology itself. In the fiber optics industry, the civilian sector is far in advance of the military in most areas. The software industry is increasingly divided into two camps--one that serves the military and one that does not. Such divergence is rooted largely in differences in the way that military and civilian business is conducted. Of the three technologies, advanced materials shows the greatest divergence between military and civilian applications. There are significant differences in the molecular structure of each end-product because each PMC material must be individually designed. However, automation of the production process and dissemination of data bases would certainly reduce costs and aid in diffusing PMC technology into a variety of civilian applications.

In each of the cases reviewed, the barriers that exist between the military and civilian sectors of the economy are due largely to differences in organization, administration, and business practices, rather than to differences in the technologies themselves. Indeed, this is a principal finding of this study. The reality—that the military often buys less than state-of-the-art technology—is disturbing, both from a national security perspective and in terms of the kind of efficiency that is associated with good government. As we have seen, many companies that produce fiber optic and optoelectronic technologies are reluctant to do business with the government. Barriers to the participation of civilian sector companies appear to be largely generic across many industries. In the case of software, DoD simply does not have access to the best and most advanced civilian talent and products, and there is very little synergy between the military and civilian components of this critical high-technology industry. Advanced composites offer a different view of the same sorts of problems. Because the industry was developed largely by military aerospace companies and other DoD contractors, it makes sense to look for a ‘‘spin-off” effect. However, U.S.-based firms that do significant business in advanced composites with the DoD have generally not been successful in marketing their products in a nondefense context.

FINDINGS

The general findings of the case studies are presented below. While they are based on the three cases, they have wider implications for the defense technology base and for other high-technology industries. Detailed findings that are more specific to the individual technologies are presented in the particular case studies, located in Volume 2 of this report.

Overall Findings

1. Two relatively separate economic sectors have evolved in the post-World War II period, one military and the other commercial. Business practices in the two diverge significantly, and substantial barriers impede the transfer of advanced technology between one sector and the other.

2. Nevertheless, the ability of the military to achieve and maintain leading-edge technology in the future will depend in many cases on the health of the corresponding industry in the commercial sector of the economy. Machine tools and semiconductors are well-documented examples.

3. The barriers that stand between the military and the commercial high-technology sectors are largely due to legal, institutional, and administrative factors, and are not inherent in the technologies themselves.

4. The United States is failing to develop and/or maintain a competitive commercial base for some technologies that are important or even essential to military procurement. It is likely that DoD either will have to turn increasingly to foreign suppliers to achieve or maintain state-of-the-art capacities in such areas, or will pay a high price to maintain in-house capacities.

5. Longstanding industrial and trade policies may have to be reformed if the United States is to achieve and/or maintain world-class industrial capacity in support of certain essential dual-use technologies.

Findings Relevant to the Department of Defense

1. DoD faces two central problems in the area of dual-use technology. First, government procurement practices make it increasingly difficult for DoD to obtain state-of-the-art technology in areas where the private civilian sector is leading. Second, certain essential high-technology industries are weak in the United States, and others may not be located herein the future.

2. Due to the magnitude of the investment that is required to create advanced technological capability in a number of critical areas, DoD cannot afford to finance advanced technology and product development across the full spectrum of technologies that are important to the military. Instead, it must rely on innovation and R&D in the civilian sector to pull some technologies forward.

3. Initiatives to increase DoD's access to and use of commercial technology have tended to fail in the past, largely because they did not address institutional and structural factors.

4. Many firms are reluctant to do business with DoD because they consider the government to be a bad customer. Some commercial firms cite excessive regulation, burdensome auditing and reporting requirements, damaging competitive procurement practices, rigid military specifications, compromise of proprietary information, loss of data rights, and corporate "culture shock" as reasons not to seek DoD business. Some of these problems might be resolved through DoD or congressional action. Others are probably inherent in any industry-govemment relationship,

5. The recent expansion of special access or "black" programs reflects both an effort to increase technological security and an attempt to circumvent burdensome regulation and congressional oversight. Because they are highly classified, such programs present additional barriers to companies that are not ordinarily engaged in defense work.

Findings Relevant to the Defense Industrial Sector

1. In many high-technology areas, the defense industries no longer lead the commercial sector, and the disparity may be increasing.

2. The defense industrial sector has been shaped by an ad hoc—yet extensive—system of regulation and defense industrial policies that has tended to stifle innovation and creativity over time. These include nearly 400 different regulatory requirements in the FAR alone, extreme and uncoordinated government auditing activity, and pervasive overspecification of developmental items. Some were established pursuant to acts of Congress; others are the result of internal DoD practices.

3. Congressional attempts to reform DoD and the defense industries may be inappropriately aimed at fixing an archaic military-industrial structure that is out of step with a world economy radically transformed by intense international competition. Comprehensive restructuring and elimination of inefficient elements and practices within DoD may be necessary.

4. Strategic planning in the largest defense prime contractors is based on the assumption that doing business with the government is a slow and ponderous process, and that it is not likely to get better. For better or worse, corporate planning is married to the DoD planning and budgeting cycle.

Findings Relevant to Congress

1. Congress plays a major role in shaping the acquisition process, and with it, DoD's access to both the defense-specific and commercial technology bases. But the acquisition system has built up over time, and overriding national goals often conflict with the particular program-specific objectives of defense acquisition. These national goals include efforts to ensure fairness, access for small and minority firms, environmental protection, competition, and the best product obtainable with the taxpayers' money.

2. The opportunity to interpret and amplify the intent of Congress exists at many levels—in OSD, in the Services, in the large prime contractors, and at the sub-tiers-and is often acted on, particularly where criminal sanctions might be imposed. The

result is a risk-averse, highly conservative defense industrial sector that has trouble taking advantage of rapid technological change in the commercial sector.

3. The structure of the large defense companies complements the legal, administrative, and bureaucratic form of the government. Such structures are imposed on the defense firms by acts of Congress, by DoD regulations, by military specifications, and by auditing requirements. Every aspect of business in these companies conforms to and is enforced by such bureaucratic and administrative controls. Making the defense industries more efficient and accountable might entail radical alteration of the legal and institutional structures that shape the DoD.

Findings Relevant to Civilian Industry

1. In many dual-use, high-technology industries, the civilian sector leads the defense industries. This civilian capacity may or may not be located in the United States.

2. A company can organize to do business in either the military or in the civilian sector of a high-technology industry, but it is extremely difficult to do both under one administrative roof. Companies that work in both sectors typically have separate divisions that are organized, administered, and staffed differently. In that case, the two divisions usually cannot share staff, production lines, laboratory facilities, data, research, accounting procedures, and other administrative systems.

3. These differences are profound. In large aerospace companies, for example, the commercial side of the firm responds to market conditions, whereas the military side of the house responds to the nature of the threat, to government directives, and to the federal budget. Executives and engineers transferred from a military to a commercial division often experience a prolonged period of culture shock and some are unable to make the adjustment. This is the opposite of the situation in civilian industry, where the chief executive officers of Fortune 500 companies are increasingly interchangeable.

4. Many entrepreneurial civilian companies—large and small alike-are unable and/or unwilling to conduct business with DoD because of the heavy investment and reorientation in business practices necessary to meet DoD requirements.

5. Antitrust policy and a rigid regulatory framework in some high-technology areas is adversely affecting the competitiveness of U.S. industry. Faced with foreign competition—specifically, with governments that act to create advantages for their firms in the U.S. market—U.S. firms may well fail to compete successfully with foreign businesses that are presently gaining experience in these areas.

POLICY CONSIDERATIONS FOR CONGRESS

The policy discussion that follows is divided into two areas. The first deals with the question of **military dependence on foreign civilian technology.** It is addressed because an increasing number of domestic high-technology industries that are important to the military are losing technology leadership and market share to foreign competition. The military response has been to buy materiel from high-technology firms located abroad. The second area focuses on the problem of **inadequate military access to civilian technology in the United States.** In many industries, the military could improve its access to civilian technology substantially, but Congress would have to make changes in the procurement system to stimulate DoD demand for civilian products and to make it easier for civilian companies to do business with DoD.

Military Dependence on Foreign Technology

The U.S. strategy of developing and fielding better military technology than that of potential adversaries requires that the DoD have access to many technologies that are sold primarily in civilian markets. The technologies of microelectronics, for example, and those contemplated for optoelectronics, require enormous and continuous investments in R&D and production facilities. These investments will be made only by companies that expect to sell the resulting products in a civilian market that is many times larger than defense purchases. That market is generally one that innovates more rapidly, because intense competition has compressed the product life cycle, forcing the incorporation of technological advances at the earliest possible date. In most cases, DoD cannot afford to pay the price associated with this kind of R&D and is unable to induce private industry to develop it with the promise of future orders. Therefore, if the Defense

Department wants to acquire state-of-the-art technologies in these fields, it must purchase them from companies that are producing for, and selling to, a large civilian market.

Although it may be very important to U.S. national security that the Defense Department have access to such technologies, DoD can do very little to influence the location, ownership, capitalization, and fundamental directions of the commercial technologies and industries that it needs. These are driven, instead, by domestic and international market forces, financial opportunity, and the trade and industrial policies of OECD and other producer nations. The corporate structure that prevails will ultimately be determined by fierce international competition for civilian markets and by the national trade policies of self-interested individual trading nations.

Two policy problems arise in this context. First, there are unmistakable signs that participation by U.S. companies in the high-technology sector of the international economy is weakening in important respects. Significant loss of capacity by U.S. companies in these dual-use industries could ultimately undermine our basic military strategy of countering superior numbers of enemy troops and equipment with superior technology. The second problem, which follows from the first, is that DoD is becoming increasingly dependent on advanced technology and products that are developed abroad or by foreign-owned companies located in the United States. Although DoD does not maintain systematic records on the amount of foreign content in U.S. weapons systems, military and civilian officials agree that it is significant and growing. Failure to address these problems would eventually leave the U.S. military vulnerable to the self-interested actions of other nations upon whose technology the U.S. may depend.

There are no easy solutions. DoD is a small and relatively insignificant customer when compared to aggregate consumer demand in most high-technology, civilian-based industries. Accordingly, a requirement that DoD systems contain products made only by U.S.-owned companies located in the United States would exert little influence on the international marketplace. Instead, such a mandate would be likely to produce a number of unintended and dangerous consequences. It would, for example, limit access to advanced foreign technology, heighten tensions with our allies and trading partners, and create financial and administrative havoc in the defense sector of the U.S. economy. The resulting industries would have small, assured markets, and accordingly, little incentive to press toward the cutting edge of international technological competition.

If Congress wishes to address this problem, it will find that the issues of eroding dual-use industries and military dependence on foreign firms extend well beyond the purview of the DoD as well as the jurisdictions of the Armed Services committees of both Houses. This is because the environment in which policy must operate is the civilian sector of the international high-technology economy. DoD does not have the competence, the resources, or the policy levers to approach the situation in a comprehensive manner. At best, it can attempt band-aid solutions, such as funding Sematech and research into high definition television. What DoD might usefully do is to help establish parameters for the kinds of dependence that would be more or less acceptable, even if it cannot take meaningful steps to address the underlying causes of foreign dependence. Similarly, the Armed Services committees are constrained by custom and by the limits of their jurisdictions. As a result, few if any policy choices are available without the cooperation of the tax and trade policy committees which most affect the rules by which companies compete in America. Nevertheless, the nation and the Congress have a national security interest at stake, because it is unlikely that DoD, acting alone, will be able to keep pace with worldwide technological developments and avoid foreign dependence.

Policy makers will have to start with a clear conception of what a U.S. corporation or industry is, and will have to distinguish between the question of ownership and that of location of manufacturing facilities. Figure 10 indicates four different combinations, each of which suggests the need for a different policy response. In case 1, the simplest case, a corporation or industry is largely owned by U.S. interests and conducts most of its R&D and manufacturing operations in the United States. From a military perspective, this is the ideal situation, and it was, in fact, a characteristic condition in the immediate post-WWII era. At the other extreme, case 4, a corporation or industry is owned by foreign interests and is physically located abroad. Here, a flexible policy is needed that can calibrate the degrees of risk associated both with different supplier nations and with specific technologies of military significance. It would, of course, be necessary to make adjustments as international trading and military relationships evolve.

Cases 2 and 3 suggest intermediate possibilities. From a military perspective, case 2 (U.S.-based and foreign-owned) generally represents the more acceptable condition, because the corporation and most of its employees would be subject to the laws of the United States and could be required to give priority to U.S. national security needs in a crisis. But from an economic perspective, creating incentives for foreign-owned companies to locate manufacturing and R&D facilities in the United States might enhance or detract from the competitiveness of U.S.-owned companies with plants in foreign nations. There are competing interests at stake in these situations, but it is not necessarily a zero-sum game.

It is necessary, moreover, to distinguish between companies that merely assemble parts into finished products and those that actually conduct R&D and manufacturing operations in the United States. The former contribute far less to the U.S. defense technology base. In addition, DoD may need access to R&D and manufacturing facilities. While many analysts contend that the most efficient businesses colocate R&D and production facilities, the two are quite clearly separable. For example, Honda makes and sells cars in the United States but conducts research in Japan. And Coming Glass Works manufactures optical fiber in Australia but designs it in the United States. It would be important to consider that foreign-owned firms might produce less advanced technologies in the United States, saving the leading-edge R&D and production for their home bases. Care would have to be taken in connection with any policy that seeks to encourage foreign-owned firms to establish R&D and production facilities in the United States.

To the extent feasible, DoD would naturally prefer to minimize foreign dependence in dual-use industries that are important to the military (as in case 1). However, doing so is not a simple matter; it would require a variety of congressional actions, the consequences of which would extend far beyond their impact on foreign dependence for defense technology. Therefore, Congress will want to take many economic security considerations into account in considering whether or how to act.

The basic strategy for minimizing military dependence on foreign technology would be to extend a variety of incentives to U.S. companies to carry out R&D and manufacturing in the United States. A second, and perhaps complementary, course would be to establish incentives and sanctions to encourage foreign (and U. S.) companies to locate their R&D and manufacturing facilities in the continental United States (case 2). In high-technology industries where these two approaches might be unavailable, a realistic policy would rank technologies (according to military necessity) and countries (according to geopolitical factors). It would then be necessary to proceed on an industry-by-industry basis, weighing the risks of foreign dependence against the cost and feasibility of maintaining a particular capability in the United States. A policy framework for each of the four cases is shown in figure 10.

Case 1: If the goal is to promote military security, then it makes sense to establish policies to enhance the dual-use portion of the defense technology base that is U.S.-owned and located in the United States. The question of foreign dependence arises when a critical industry is failing in the United States or when U.S. companies fail to enter the competition in a particular technology at all. The policy problem is how to stimulate and otherwise assist corporations that produce technologies and products that are (or could be) important to the U.S. military. Policies that are intended to improve the defense capacity of these largely civilian companies may simultaneously affect their economic competitiveness. What is good for the military may or may not contribute to the health of any particular dual-use industry. It may be necessary to set up one group of institutional mechanisms to assist U.S. dual-use corporations and another to enhance military access to, and procurement of, technology and products developed in the civilian sector of the economy. These mechanisms are discussed at the end of this chapter.

Figure 10-Military Dependence on Foreign industry Ownership v. Location

LOCATION OF MANUFACTURING/R&D CAPACITY	OWNERSHIP: U.S.	OWNERSHIP: Foreign
U.S.	1. Promotes military security	2. Acceptable, subject to U.S. priorities in a crisis
Foreign	3. Risk depends on specific technologies and nations	4. Least acceptable in terms of military security (#3 also applies)

SOURCE: Office of Technology Assessment, 1989.

Case **2:** There will be some dual-use industries of military significance that are located in the United States, but which are partly or largely foreign-owned. The advanced composites industry is a good example. Roughly half of these companies are foreign-owned, but their R&D and production facilities are mainly based in the United States. This critically important technology is enabling for many defense aerospace applications. DoD has tended not to discriminate among such companies on the basis of national ownership, and has not promoted a stronger U.S. presence in this industry. In most cases, it makes little difference to the military whether or not a corporation or industry is dominated by foreign interests—so long as the critical R&D capacity and production facilities are maintained at state-of-the-art in the United States. Yet, distinctions would be necessary. For example, would it be acceptable for a company to manufacture products in the United States if all the machinery used in the plant were foreign-built? Similarly, in complex weapons systems, how far down the parts-supplier chain should a requirement to manufacture in the U.S. reach'?

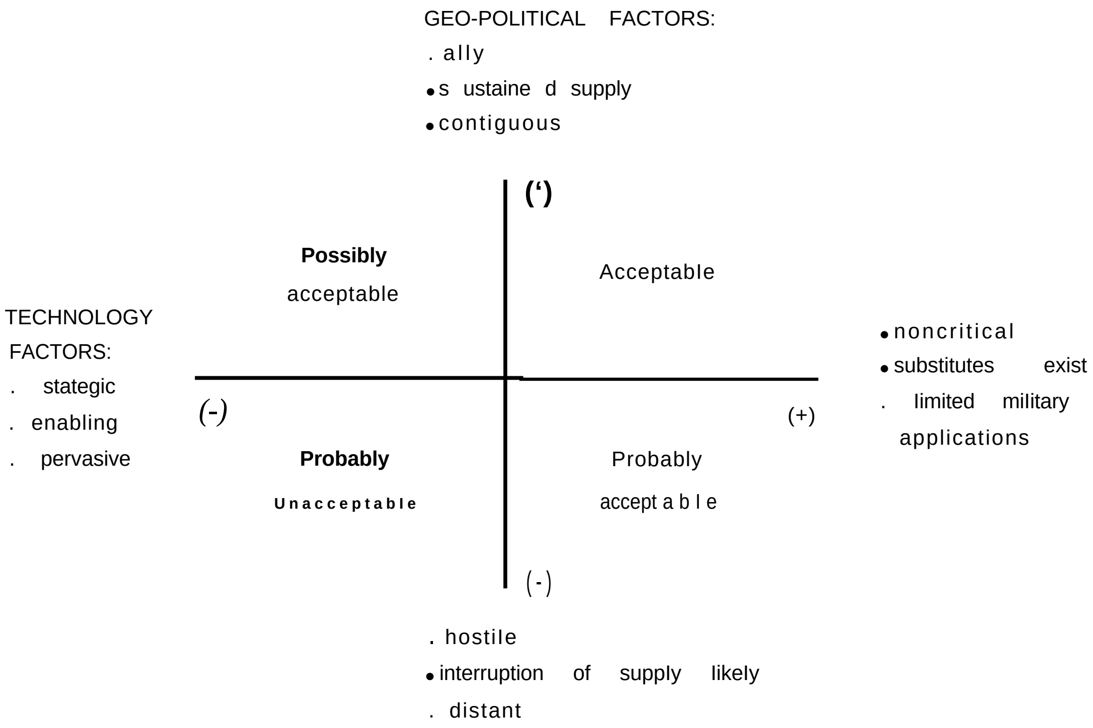
Case **3: Cases 3** and 4 can be combined, with the caveat that case 3 companies (those that are U. S.-owned and foreign-located) would presumably be more receptive to making concessions in the national interest, although still subject to host country controls on their operations. In general, these companies do not contribute significantly to the domestic defense technology base (although profits, if repatriated, may produce economic benefits for the United States). However, some U.S. companies conduct R&D in the United States, but have manufacturing and assembly operations overseas. Policy should be sensitive to this situation, acknowledging that these companies do make a contribution to the U.S. technology base beyond that of case 4 and some case 2 companies. Policy may seek to remove barriers that impede competitive domestic manufacturing.

Case 4: The defense implications of dependence on industries that are foreign-based and foreign-owned are more complex. Policy will have to be sensitive both to the geopolitical relationship between the United States and the particular foreign nation and to the specific technologies under consideration. Although it is an oversimplification, figure 11 displays some of the factors that would have to be evaluated on a case by case basis. The United States might, for example, tolerate foreign dependence for some key technologies and products if they were made in Canada, which shares technology base and free trade agreements with the United States. Contrast this with an extreme case, in which the U.S. military depends on a Warsaw Pact nation for a technology that is enabling for a major weapons system. While it is easy to discriminate between friendly neighboring countries and some Eastern European states, it is a matter of extreme delicacy to assess the security risk associated with technological dependence on a variety of nations, ranging from the EC to the Persian Gulf and the Pacific Rim. There is the further consideration that, for some technologies, the United States might be forced to accept a foreign supplier or do without. One alternative is to create the capacity domestically, using grants, tax incentives, guaranteed low-interest loans, R&D contracts with the government, and other schemes—possibly, but not necessarily, at expense to the taxpayer. There are also models from other nations, including Japan, where a portion of some domestic markets, both civilian and defense, is reserved for domestic firms.

Congressional Action and Institutional Mechanisms

Some analysts believe that new institutions will be needed to address these problems. They think it unlikely that Congress can effect such policies by delegating the task of implementation to existing agencies; no agency presently has the necessary capacities or powers. From this perspective, if Congress is interested in pursuing a policy on dual-use technology and foreign dependence, it could invest extraordinary powers and independence of action in a high-level council or agency created for that purpose. Such an agency would take steps to: 1) gather data on such essential items as foreign content in defense systems and foreign investment in high-technology companies, 2) assist U.S. dual-use industries that are essential to U.S. military security,

Figure n-Military Dependence on Foreign Technology Located in Foreign Countries



SOURCE: Office of Technology Assessment, 1989.

3) induce foreign-owned companies that are located in the United States to conduct R&D and manufacturing operations here as well, and 4) develop or attract an indigenous capacity for dual-use technologies in industries where foreign dependence is unacceptable, and the domestic private sector is unwilling or unable to withstand or enter the competition.

As an alternative, Congress may wish to consider mandating coordination between existing agencies and offices such as the Department of Commerce, DoD, and the United States Trade Representative. There can be no assurance that such an approach would work. Each agency has its own established areas of business and expertise, and debilitating battles over leadership, functions, and turf could be expected. Congress might, of course, opt to require further studies of this problem and various approaches to it.

If Congress decides that an institutional approach to this policy area is inadequate, an array of strategies, used by other nations with varying degrees of success, is available. These include incentives and sanctions, both positive and negative. For example, Congress could require foreign-owned companies to locate manufacturing and R&D capacities in the United States if they intend to sell dual-use, high-technology products in this country. In addition, Congress could substantially strengthen the U.S. defense technology base through increased funding of graduate education for scientists and engineers, and by targeting the funds for American citizens, who are more likely to make their careers in the United States. Congress might require a policy of reciprocal dependence—for example, the United States might depend on Japan for DRAMs[16] and in return, Japan would agree to depend on the United States for jet engines, with the intent of establishing a regime of equivalent dependencies. Or Congress could change the structure of the tax system to encourage U.S. companies to make longer term investments, and change the tax code so that it no longer favors speculative investment by increasing taxes on short-term capital gains.

These options require painstaking analysis that is beyond the scope of this particular assessment. They are raised here because they illustrate the point that the solutions to the problems of eroding high-technology capacity and increasing military dependence, while critical to the national defense, fall outside the usual jurisdictions of the requesting committees of Congress. If the Armed Services committees believe that there is a national security interest in conserving the health of the defense technology base in the United States, it may be necessary to reorient the way in which the business of the committees is conducted—i.e., to focus less on the internal structure of DoD and more on taking steps to build a consensus within the Congress that can place these problems centrally on the national agenda.

Institutional and Administrative Barriers

Unlike the problems discussed above, the issue of military access to domestic technology falls squarely within the purview of DoD and the jurisdictions of the Armed Services committees of Congress. DoD and the military-industrial sector have become insulated from the rest of the economy in ways that tend to weaken military access to leading-edge civilian technology. This is largely the result of a gradual accretion of regulations, auditing requirements, paperwork, detailed specifications, and inefficient business practices that constitute substantial barriers between the military and civilian sectors of the U.S. economy. Most of these rules were instituted for good reasons and in response to real problems. But the cumulative effect has been to make defense procurement cumbersome and to concentrate military buying in a relatively small group of companies that have learned to conduct business according to government rules and norms.

If Congress wishes to improve military access to civilian technology, it will have to make some extremely difficult choices. Congress has played an integral role in establishing the structure of the military-industrial sector, as well as the rules and regulations under which it is run. To a large extent, Congress already approves or disapproves many important decisions that affect the defense technology base in the United States, The problem is that many isolated decisions and actions—taken not only by Congress, but also by DoD and the executive

[16]Dynamic random-access memory chips.

branch—have built up over time, and the resulting system is a patchwork of conflicting requirements and goals. To remove barriers that impede military access to the civilian sector, Congress will have to balance competing interests—many of which are supported by basic notions of fairness and other values that have shaped the present system. The most important barriers are outlined below, together with discussion of the relevant policy choices and problems.

Procurement Reform

In recent months, interest in the defense procurement process has focused on allegations of criminal activities by officials in the Pentagon and among some of the large defense prime contractors. While it is important to discourage such misconduct, an exclusive focus by the 101st Congress on issues of malfeasance will do little to address underlying structural problems that inhibit DoD's access to advanced civilian technology. Indeed, if Congress mandates several new layers of regulation and auditing in response, it may inadvertently create additional barriers.

Many civil-sector companies are already reluctant to bid on contracts with DoD because they are not organized and staffed to comply with the FAR, and because they do not need government business. Generally speaking, DoD has structured its procurement process to deal with corporations that are primarily or exclusively engaged in work for the military. These regulations inhibit access to companies whose technology and business is largely resident in the civilian sector of the economy. One result is that DoD is often forced to pay a premium for the development of a range of technologies and products that already exist in the civilian sector.

If Congress acts to increase regulation and auditing requirements, it may be able to reduce the amount of fraud and misconduct within the procurement system. But in so doing, it will almost certain] y also reduce the efficiency of existing defense companies, because they will have to increase their paperwork load and internal audits to meet the new requirements. At the same time, tightening up the system to eliminate malfeasance would result in an even more complex regulatory environment for civilian firms, increasing the probability that such firms would not choose to work with the government in the future. One alternative is to do nothing, which is a possibility when combined with rigorous enforcement of criminal statutes already on the books.

The opposite course is also a viable policy option. Congress could take steps to reduce paperwork, regulation, and auditing, with the intention of increasing overall efficiency and DoD's access to high-technology companies and products in the civilian sector of the economy. Such action might or might not result in an increase of fraud and mismanagement in the defense sector. But it might expand the interaction with civil-sector firms that are now reluctant to do business with DoD. Some argue that the complexity of the defense regulatory environment encourages defense contractors to find ways to skirt the rules, simply because the proliferation of such regulations over time has made it extremely difficult to conduct business in an efficient and rational manner. Congress will have to sort out these issues as it seeks a policy that discourages misconduct without increasing the barriers of inefficiency and complexity that afflict the present system.

If Congress is reluctant to act, it may wish to study these problems in greater depth. To do so it could **establish an independent commission to explore the effects of: 1) reducing or expanding procurement regulations, and 2) exempting high-technology civil-sector firms from some procurement regulations.** This commission would examine the difficulties that civilian companies face in doing business with DoD. It would evaluate the ways in which the procurement system itself mitigates against military access to civil-sector technology. And it would weigh the costs and benefits of expanding or reducing procurement regulation. A central purpose would be to recommend changes in the procurement system that would induce civil-sector companies to sell their products to DoD or to modify them to meet DoD's needs.

A complementary and probably subsequent approach would be to create a market for civilian products in DoD by **mandating a preference for commercial items that are not developed under contract with DoD, using simplified and expedited contracting and acquisition procedures.** In DoD, commercial products are referred to as nondevelopmental items (NDI) and commercial off-the-shelf. The purpose of this preference would be to ensure that program managers give careful consideration to existing NDI/COTS technology before beginning new development. Despite repeated cabinet-level memoranda and executive direction to the contrary, DoD rarely substitutes commercial products for milspec developmental items. This is due partly to a historical bias in favor of contracting for development, partly to a reluctance of program managers to risk using items not designed to military specification, and partly to the regulatory structure that governs the procurement process. If Congress decides to increase government access to civilian-based technology and products, it will have to use the blunt instrument of a direct and unambiguous legislative mandate to overcome a large measure of resistance within DoD and the military sector of the economy.

It is likely that any reform of the procurement process that encourages the use of civil-sector technology and products will also require fundamental changes in the relationship between DoD and some of the firms with which it does business. Civilian sector executives who do not need DoD business are unlikely to tolerate the heavy hand of government regulators and auditors changing the administrative policies and practices of their companies. Regulated profits, detailed military specifications, set-asides for small and minority firms, affirmative action, specialized auditing procedures, and competitive bids from sub-tier suppliers may satisfy government notions of fairness and social responsibility. But when they are imposed on commercial operations, they tend to weaken the efficiency and competitiveness of companies that depend on sales in consumer markets for survival. These companies are in business to make a profit. Their managements are responsible to stockholders, who expect shorter-term results than are typically envisioned by government programs or international competitors. Congress will have to make allowances for the fundamental differences in the way business is conducted in the defense and civilian sectors of the economy, if it wants to increase military access to advanced, commercially based technologies and products.

Specifications Overhaul

In general, the DoD specifications process is too cumbersome and too rigid to establish reasonable and realistic standards for technologies that are changing rapidly. Too often, prescriptive standards are mandated where performance specifications would be more appropriate. Although they are necessary if DoD is to conduct procurement at all, specifications can lock the military into a developmental mode and block access to existing civil-sector technologies, products, and systems. The OTA case studies found instances where the military could not use existing superior civilian technology because DoD regulations mandated compliance with outmoded specifications. Civil-sector companies, military prime contractors, and milspec specialists in the Services all agree that there are too many specifications, referencing too many additional documents, and that there is no effective process for eliminating outdated and unnecessary documentation. Military specifications can exert the largely unintended effect of creating divergence between military and civilian applications of the same technologies.

If Congress wishes to address this problem, there are a number of steps it could consider. In high-technology fields where civilian products and technologies are clearly at the leading edge, Congress **could require the harmonization of military specifications with best practice in the civilian, high-technology sector.** Such a requirement would apply to dual-use technologies where meeting adverse training and battlefield conditions is not at issue. In its study of fiber optics and software, for instance, OTA found numerous examples where the military could benefit from adopting best practice in fast-moving civilian technologies. Such action might encounter resistance from quarters within DoD where there is a strong belief in the necessity of designing systems specifically to meet user requirements and battlefield conditions. Nevertheless, where the underlying technologies are similar in the defense and civilian sectors, great cost savings might be realized by tailoring military specifications to take advantage of existing civilian products and applications —as opposed to designing divergence into the specification and codifying it.

In addition, Congress may wish to mandate the use of performance-type specifications in fast-moving, high-technology fields. The alternative is to nail down prescriptive standards that tend to freeze military systems at or below present-day levels of technological development, Performance specifications have the advantage of introducing a measure of flexibility into the system itself, and into the procurement process, that could substantially enhance military access to advanced technologies in the civilian sector. They could be written broad] y to encourage substitution of NDI or COTS products where possible,

It is unlikely that specific policy options can be implemented until the system of writing military specifications and the culture that sustains it are changed. With this caveat in mind, Congress might require the review and consider the revision or nullification of existing prescriptive specifica**tions at some specified interval.** The purpose of such a review would be to make the process of writing specifications more responsive to technological advances in the civilian sector, and to do away with the proliferation of unnecessary or outdated requirements and documentation. By the time they are written, many military specifications no longer reflect the state of the art in dual-use technology industries. This is partly because the product cycle is so much shorter in the civilian sector. In order to reduce the multiyear process of specification writing, it may be necessary to introduce greater flexibility by reducing inter-Service coordination and permitting the different Services to use different specifications to meet their specific needs.

Restructuring Data Rights

It is extremely difficult to strike an equitable and appropriate balance in allocating data rights in contracts between the government and the private sector. Government agents tend to demand as many data rights as they can get in any given contract because they are under a fiduciary obligation to protect the interests of the government. In many cases, the contractors lose most, if not all, of their intellectual property rights to the technology and products they develop. DoD negotiators typically demand the right to duplicate, use, and disseminate such data without restriction. The claim to unlimited data rights is based on three important considerations. The first is that by securing complete data rights, DoD is in a position to foster competition by sharing the data among potential contractors. Second, unlimited rights protect the government from future costs and claims of infringement, and help to ensure dissemination of publicly sponsored research efforts. And third. full data rights to software ensure that DoD will be able to modify and maintain software in the field.

This orientation contrasts sharply with practice in the civilian sector, where R&D and process data are carefully guarded and no company could expect any rights to another's proprietary information. Many executives of civil-sector firms believe that government procurement officers and regulations do not recognize the extent to which high-technology industries are driven by R&D activity. These firms are typically unwilling to share data, because they believe it can be used to reveal a core of proprietary information. In some cases, software and fiber optics companies invest tens of millions of dollars to develop a process or series of products. Consequently, these civil-sector companies are unwilling to contract with DoD, because it insists on extensive data rights and may even set a competitor up in business.

In the case of software, the most recent directives and regulations enable DoD to accept limited rights to intellectual property. For software developed wholly with private funds, the contractor can negotiate restricted data rights giving the government the ability to modify software and make backup copies, but allowing the developer to incorporate a typical licensing agreement. The government hopes to retain the ability to maintain its software systems and to ensure that future maintenance and reprocurements will be competitive. Despite these acknowledgments and the flexibility granted government contracting officers to negotiate less-than-exclusive rights to data, DoD still insists on full transfer of data rights in most cases.

If Congress wants to increase government access to civilian high-technology firms, it will have to reevaluate the principle of exclusive and unlimited data rights. In part, this may require that DoD distinguish companies that have developed a product or process with private funds from those that have done so under contract with the government or with funds that are reimbursed by DoD. In addition, Congress might require DoD to create different categories of data rights—ranging from the unlimited to the narrowly specified-when it is buying from firms that do most of their business in the private sector. Congress may wish to review existing data rights policies and procedures mandated internally by DoD directives, and to assess the level of training that would be necessary to enable contracting officers to negotiate data rights and still protect the legitimate interests of the government.