Chapter 2
Summary

WHAT IS THE DEFENSE TECHNOLOGY BASE?

The defense technology base is that combination of people, institutions, information, and skills that provides the technology used to develop and manufacture weapons and other defense systems. It rests on a dynamic, interactive network of laboratory facilities, commercial and defense industries, sub-tier component suppliers, venture capitalists, science and engineering professionals, communications systems, universities, data resources, and design and manufacturing know-how. It includes laboratories run by the Department of Defense (DoD), other government departments and agencies, universities, and industrial concerns. It draws on the work of scientists and engineers in other nations. Information circulates both through formal routes dictated by chains of command, research contracts and other agreements, and through informal contacts within specialized technical communities, interdepartmental projects, seminars, etc.

Department of Defense technology base programs-and the accumulated results of these programs-are an important part of the defense technology base, but are far from all of it. Although DoD officials tend to speak of the defense technology base and the Department of Defense technology base programs interchangeably, they are not the same. The defense technology base is an accumulation of knowledge, skills, capabilities, and facilities, while the Defense Department's technology base programs are a collection of thousands of individual research projects funded through the DoD budget, the results of which contribute to the defense technology base.

Almost all research and technology development can be drawn upon in producing defense systems, so that with the exception of classified research available only for defense applications, the defense technology base is largely the same as the national technology base as a whole. Of course, not all technology is of interest for defense applications, and not all is equally accessible to defense. Any research published in open sources (e.g., scientific journals) is available for use by engineers and scientists for defense applications. This includes foreign research and development, even work done in the Soviet Union. Proprietary work that is conducted by private companies, and remains unpublished in order to preserve competitive advantages, may also find its way into defense systems as those companies build the systems, subsystems, or components.

There are some practical limitations-amplified by recent government policy–on the transfer of technology between the defense and civilian sectors.[1] First, much defense technology is classified. Hence it is only available to those working on defense projects. Second, researchers and engineers working on defense projects tend to forma community that interacts through mechanisms such as defense-related professional society meetings. Communication with those in similar fields doing nondefense work exists, but is often more limited. Indeed, in companies that do both defense and commercial work, engineers in either "side of the house" tend to be isolated from those in the other.

There are also mechanisms that reduce technology transfer and communication from nondefense areas to researchers and engineers doing defense work. Companies that develop commercial products seek to protect their investments by concealing their best technology as long as possible. Thus, cutting edge technology may remain inaccessible to DoD until after it has been introduced into the commercial

[1]For example: Department of Defense Directive 5230.25, Nov. *6, 1984;* and Executive Order 12356. For more detail see Science *Policy Study Background Report No. 8. Science Support By The Department of Defense,* prepared by the Congressional Research Service for the Task Force on Science Policy of the House Committee on Science and Technology, December 1986.

marketplace. Additionally, some scientists and engineers prefer not to do defense-related work. Finally, regulations on doing business with the government tend to enforce a separation between companies that work for the government and those that do not—including separations between divisions of the same company. Knowing how to do business with the government creates a competitive advantage for some, while government regulations and contracting procedures present barriers against others. Indeed some observers argue that the problems of doing government business—close scrutiny, regulation of profits, and excessive military specification of product characteristics-tend to discourage innovative small- and medium-size companies and steer them away from government work.

Thus, while in principle the defense sector can draw from a very wide technology base, there is some degree of isolation. Not all of that more general technology base flows into defense applications with equal ease.

DoD organizes its technology base programs into three categories which provide a working definition of the kinds of work and information that are considered part of the technology base. DoD's technology base programs consist of research into basic and applied sciences (funded under budget category 6.1), the exploratory development of practical applications of that research (budget category 6.2), and the building of prototypes to demonstrate the principle of an application (budget category 6.3A). Work funded under the remainder of the Defense Department's budget for research, development, test, and evaluation (most of DoD's RDT&E budget) is not part of the technology base.' In DoD jargon, "the tech base is 6.1, 6.2, and 6.3 A," but the defense technology base is actually the accumulated results of those 6.1, 6.2, and 6.3A programs and much more.

'Strictly speaking, by the Office of the Secretary of Defense definition, the technology base programs are 6.1 and 6.2. Technology base plus 6.3A are the science and technology programs. However, these definitions are often used interchangeably, and in recent years common useage has been to refer to 6.1, 6.2, and 6.3A as technology base programs while 6.3B and 6.4 are specific system developments linked closely to procurement.

Basic research, by definition, is almost entirely non-specific in its potential applications. Most could lead just as easily to defense applications, commercial applications, or no practical applications whatsoever. There are, however, a few areas in which the Department of Defense has a specific interest in basic research because the connection to defense systems is clear. Examples are underwater acoustics (important for submarine detection and hiding) and the physics of explosive nuclear reactions (of obvious application to the nuclear weapons programs run by the Department of Energy (DOE)).

As science leads to technology, potential applications become clearer, and a sharper delineation of technologies with defense applications becomes possible. Some technologies are almost entirely military while others have little, if any, defense application. This separation is heightened as military programs become classified. Nevertheless, many technology areas are pursued for both military and commercial applications.

As technologies lead to the development of defense systems, developments that had been pursued primarily for commercial reasons can, and do, work their way into the defense systems. Prime contractors call on subcontractors for subsystems, and subcontractors call on lower tier suppliers for the components of their subsystems. Many of these lower tier suppliers sell to both military and commercial buyers, and use their commercial technology to develop products that are used in defense systems. Commercial components are sometimes designed directly into defense subsystems.

A diverse group of organizations contributes to the defense technology base. A large portion of basic research is performed at universities, which also train the next generation of scientists and engineers. University research is funded by the Department of Defense, other parts of the federal government (e.g., the National Science Foundation and the Department of Energy), industry, and various private funds and endowments. DoD's university research program is growing and appears to have generated significant interest in the academic community. There appears to be more interest and capability than available funding permits DoD to support.

The Army, Navy, and Air Force maintain systems of research laboratories. Of the more than 140 individual laboratories, research and engineering centers, activities, and test facilities run by the Armed Services (Army, Navy and Air Force), about half contribute significantly to the technology base. The rest concentrate on activities such as testing production aircraft. In addition to conducting research, some of these laboratories fund and monitor research by other organizations.

Other government laboratories–primarily the Department of Energy national laboratories, the National Bureau of Standards, and NASA's research centers–contribute both directly and indirectly to the defense technology base. DoD contracts with the national laboratories and engages in cooperative research projects with NASA in areas of mutual interest. The results of research conducted at these institutions is generally available to organizations engaged in defense work.

A substantial part of the defense technology base is embedded in the defense industrial base, and in the broader national industrial base. Much of the technology that finds its way into defense systems is developed by defense contractors and subcontractors, and by commercial high technology companies. In addition, some companies—e.g., AT&T, IBM, and UTC–run research laboratories that do a great deal of basic and applied research, most of which is available for defense applications.

The large defense contractors—e.g., Lockheed, Martin-Marietta, General Dynamics, McDonnell-Douglas, Rockwell–primarily design, develop, and produce weapons and other defense systems. They develop technology inhouse and draw on technology developed elsewhere. They are both users of, and contributors to, the defense technology base. Because the defense industry sells only to the government, it operates under a special set of regulations.[3] And because there is only one customer (albeit one with many branches) and a limited type of competition, the defense market has evolved a unique set of business characteristics. There is controversy over whether this is the most efficient way to produce defense systems, and how to maintain sufficient capacity to meet surge requirements in the event of a conflict. These production issues are not a focus of this study, but the business structure of these companies strongly influences how they invest in technology. A more relevant issue is identifying the best methods for stimulating these companies to develop cutting edge technology for defense applications, draw on developments elsewhere, and incorporate the latest technology into products and production.

The industrial sector includes not just the defense industries that produce major defense systems, but also civilian industries. The so-called "dual use" industries, which produce primarily for the civilian market, provide components for defense systems, and stimulate technological advances that find their way into defense systems. Perhaps the best-known example of a dual-use industry is the semiconductor industry, the subject of a recent Defense Science Board study. In addition, laboratories run by companies that do very little defense work provide important basic technology that is eventually engineered into defense systems.

In some areas, civilian industries merely keep pace with or lag behind technologies that are being developed in the defense sector. But in other areas it is the commercial firms that drive the pace of technological development. In general, the Department of Defense exerts strong influence on industries that are primarily devoted to defense and on newly emerging technologies. But DoD has far less influence with industries that have large commercial markets. For those industries it is very much a minor customer: the civilian market shapes the industry and dictates the large investment in and consequent rapid progress of technical

'Those divisions of defense companies that sell in the civilian marketplace operate differently.

development. Defense production is a consumer of technology from these industries; defense interests are far less able to stimulate technology development in these industries than they are in the defense industries. If technologies that are dominated by the commercial market could not be transferred into defense applications, the defense sector would have to rely solely on technology developed in isolation, and would likely end up buying less advanced technology than is available in the commercial marketplace.

A major focus of this OTA study is identification and evaluation of the factors behind the erosion of important dual-use U.S. industries at the leading edge of technology, and the implications of this erosion for national defense. The concern here is much less shaping technology development—defense is often a minority customer with only limited leverage on the industries–than it is ensuring that the technology and technical capacity will be available when needed. If these industries deteriorate substantially, the source of the technology will be in question, and if they leave the United States, DoD may find that the technology is no longer available and secure. Thus DoD has a vital interest in the future of these industries. The government as a whole has an interest both from a national security perspective and a national economic perspective, although these two perspectives may not always coincide.

ISSUES

Maintaining this diverse defense technology base raises a large number of individual issues, which fall generally into the following seven categories:

1. DoD's mechanisms for making technology policy and determining investment strategy to implement that policy;
2. funding for DoD technology base programs;
3. the management of DoD laboratories and other government research institutions;
4. foreign dependence;
5. dual-use civilian high-technology industries;
6. the defense industries; and
7. the supply of scientists and engineers.

This section discusses these individual issues and the concerns from which they arise. These issues and concerns raise analytical questions that are not generally amenable to definitive answers, but provide a basis for analysis and informed debate. This section also presents—but does not analyze-some solutions that have been proposed. OTA reports these suggestions because they appear to merit exploration as Congress considers the issues, but OTA does not endorse them. OTA will explore some of these proposed solutions in further work on this project.

Department of Defense Mechanisms for Making Technology Policy and Technology Investment Strategy

The DoD science and technology program is a complex and sometimes bewildering array of 160 program elements encompassing thousands of individual projects, whose success is often difficult to judge. Consequently, there is widespread uneasiness that DoD may not be making the most effective use of its technology budget, and that its program may not be efficiently run. Some critics charge that technology base programs do not receive attention at a sufficiently high level, that Pentagon bureaucracies have no equivalent of a corporate vice president for research and development. Recognizing this problem, DoD has recently taken steps to address the situation. Other observers believe that the management system has developed the wrong focus: that performance is emphasized too highly over cost and quality, and product technology is emphasized to the virtual exclusion of process (manufacturing) technology.

There is also concern that "requirements pull" and "technology push" may be out of balance. Some argue that overly strict application of relevance tests in determining projects to be funded maybe stifling creativity, while others point out that excessive loosening of the ties between research projects and military needs could lead to a technology base program that produces little practical benefit. There is an overriding concern that communications between developers of technology and military operators and planners are not sufficiently well developed. Developers could be more aware of military needs and planners could be more attuned to technological opportunities.

Research is by nature disorderly and risky, Its twin goals of seeking breakthroughs–including serendipitous, unanticipated discoveries—and evolving previous discoveries into useful applications are somewhat contradictory. Overconcentration on either is a prescription for disaster sooner or later. It maybe that the apparent chaos of defense R&D programs is a reflection of these contradictions, and that it cannot and should not be managed in any more orderly fashion than it now is. Or it may be that valuable gains can be made through more effective management. Clearly, orderly evolution can benefit from orderly programs, but overly focused and controlled programs will inhibit the wide-ranging exploration that produces breakthroughs.

An area of growing concern is that of highly classified or "black" programs.[4] Congressional and bureaucratic oversight of these programs is very limited. Critics charge that black programs retard the diffusion and exploitation of important technology, while providing cover for poorly managed programs. Others claim that freedom from excessive oversight allows much more rapid progress and more efficient management. Some observers claim that technology transfers out of black programs slowly, if at all, but others claim that much of the technology in black programs came from “white” programs and only became highly classified when potential applications were identified.[5]

Some observers suggest that large-scale demonstration programs ought to be pursued as engines of technological innovation. They point out that projects such as Polaris and Apollo have served to focus the efforts of creative people and have produced much important technology. Like Apollo, such projects need not be confined to military goals. Some cite SD I and the National Aerospace Plane as current examples of such large-scale technology drivers. Others fear that such programs consume too much funding, driving less dramatic efforts out of existence, and that while providing a dramatic stimulus to technical and scientific development they are an indirect and inefficient path to developing the technology that is desired. These critics argue that such programs take on lives of their own, and that as funding levels decrease the secondary goal of spinning off technology is sacrificed to the primary goal of completing the program.

Each Service runs its own R&D program, and the Office of the Secretary of Defense (OSD) coordinates these along with the efforts of the Defense agencies, the Strategic Defense Initiative Organization, and a few special projects. The Armed Services have different systems for setting R&D policy and for implementing that policy. These systems, and OSD's, have recently been reorganized. (Current organizations for making R&D policy are described briefly in a later section of this summary and in more detail in the main body of this report.) It is reasonable to ask whether each Service's management system is optimized for its unique needs, or whether organizing them all along the same lines would be preferable, *taking* the best features of the three existing systems. Some observers believe that it would be useful to adopt management techniques used by other organizations that plan and manage R&D activities, such as private corporations and foreign governments. They claim that some of these organizations are better than DoD at setting and realizing technological

‘See, for example, Alice C. Maroni, “*SpecialAccess Program and the Defense Budget: Understanding the “Black Budget,* “ Congressional Research Service, Issue Brief IB87201, Dec. 2, 1987,

⁵Of course, these contentions can only be verified by those with access to the black programs. However, both are logical. If few people know about a project, there will be few opportunities to envision other applications for the technology. Very little technology is born highly classified; it only becomes worthwhile to limit access to information when its potential applications have been identified.

goals and moving technology forward into products. Some in industry believe that DoD's systems suffer from the lack of a chief technical officer at a very high level, and from an emphasis on managing programs rather than setting policy.

Some observers argue that DoD's ability to attract and keep skilled management personnel is declining. They point out that skilled people can work effectively within a flawed system, but that even a perfect system cannot function well without top-quality people. They see these problems flowing at least in part from legislated restrictions on career paths, particularly those aimed at closing the "revolving door" between industry and government. People may be willing to sacrifice salary to serve their country, but are much less willing to sacrifice their careers.

Congress faces some fundamental issues regarding technology base program management, including that of whether the DoD organization needs yet another shakeup, or a radical new management approach. Even if the system is less than ideal, it may not make sense to reorganize it frequently rather than allow it to settle down and do its job. Congress will be making implicit or explicit decisions regarding the extent to which it should be involved in detailed problems like organizing the DoD staff or selecting R&D programs and specifying their funding levels. Congress may wish to involve itself in the complex process of selecting technologies to be pursued and determining funding levels for each program. Alternatively, it may choose to limit its role to ensuring that the technology base programs have proper goals, adequate funding, and capable management.

DoD Technology Base Funding

Intimately tied to the issue of how DoD manages its technology base programs is that of the funding levels for those programs. This is a more immediate issue, since Congress wrestles with the budget each year. There are concerns that current levels may be inappropriate, and that within the overall totals funding may be misallocated. Imbedded in this latter concern is a worry that tech base program funding may not be adequately protected from "raiding" to support specific systems developments that are well beyond the tech base. Similarly, there is concern that large development programs like SD I or the Advanced Tactical Fighter tend to drain funds from technology base programs, and that the increasing emphasis on prototyping will be funded not with new dollars, but out of the existing technology base program. If the diversion of technology base budgets to support other programs turns out to be a significant problem, Congress may wish to consider taking measures to protect technology base program funding.

Gauging a proper level of technology base funding is difficult, as is the allocation of funding within that overall level. Since the output of a technology base program cannot be measured with any precision, the effect of adding or subtracting any particular sum of money cannot be calculated as it could be for programs such as procurement or maintenance. Some observers believe that it is most important to maintain a level of funding that is predictable and avoids dramatic fluctuations: constant changes in funding make it difficult to attract and keep staff.

The Strategic Defense Initiative (SDI) accounts for more than 40 percent of the technology base funding, and almost all of the increase in technology base funding since 1981. But SDI is outside the system that controls the remainder of the technology base programs. Major changes in SDI could have implications for technology base funding as a whole, particularly since many programs that have more general utility are funded through SDI.

If Congress sets, or endorses, guidelines on basic R&D policy issues–such as the proper balance within the program between the orderly exploration and exploitation of known phenomena and the search for new breakthroughs in areas that are not yet recognized–is there a straightforward methodology that can be employed to determine the allocation of funding to implement those guidelines?

The Management of Government Laboratories

There is concern that the large array of government research institutions that contribute to the defense technology base does not form a coherent system to support technology needs. At issue is whether it could, and whether coherence is, on balance, desirable. There is also concern that some reorganization or consolidation may be in order, particularly among the DoD laboratories, and that they could function more productively if the organizations that operate them—or their relationships to those organizations—were changed.

Many of the Service laboratories are attached to systems commands with charters to develop specific classes of military hardware (e.g., airplanes, communications equipment, missiles). These laboratories are more like product centers run for their 'customer' than they are technology centers. Others, like the Naval Research Laboratory, which the Navy views as a corporate lab and not a product lab, have greater latitude in their technical programs. There is concern that important areas of technology may be overlooked because of the narrow focus of parent organizations, and that innovative technologies that might ultimately benefit the overall mission of the command will be overlooked because they do not support the current major products of that command. Furthermore, unlike the contractor-operated Department of Energy laboratories, DoD's laboratories appear to have a relatively difficult time shifting as the focus of technology shifts, or otherwise adapting to change. Others believe that a product focus is necessary and proper if the labs are to produce anything useful, pointing out that ultimately the task is to put systems into the field. They claim that many labs are not responsive enough.

The actions that Congress may wish to take will depend on understanding whether there are laboratories with unnecessarily redundant programs, substandard programs, unnecessary functions, or functions that could be performed more effectively elsewhere. Depending on the answers to these questions, Congress may wish to take measures to ensure more efficient use of government laboratories—e.g., closing, merging, or consolidating facilities; altering the command of Service laboratories; making greater use of non-DoD laboratories; or setting up systems to enhance technology transfer.

Service R&D managers claim that it is becoming more difficult for the Service laboratories to attract and keep top technical talent, and that the United States may be risking deterioration of these important assets that have been built up over many years. Civil Service salary scales, never competitive with industry, are now in many instances not competitive with academia either. Aging physical plants are becoming increasingly less attractive relative to industry and academia. Finally, government service is becoming less prestigious. If these trends continue, are there measures that Congress could take to make defense laboratories more attractive to top scientists and engineers? Changing the management structure of these laboratories to allow compensation beyond that permitted under Civil Service rules has been suggested. This is being tried on a limited basis at the Naval Weapons Center (China Lake).

Foreign Dependence

This issue is intimately bound up with the next two—erosion of important civilian high-technology industries and problems in the defense industries. The United States is part of a global economy, particularly in high-technology industries. Foreign components are engineered into important defense systems, and other nations lead us in some areas of technology that are key to building defense systems. This is, at least in part, a result of the success of post-war U.S. policy to build up the economies of friendly states. Many economists argue that the United States has no choice but to buy what it wants on a dynamic global market, and that to do otherwise will have major adverse effects on our own economy.

But we are caught on the horns of a dilemma. The least-risk approach from a national security perspective is to satisfy all our needs from domestic suppliers, so that our ability to get what we need is under U.S. control alone. This is, however, almost certainly not the least-cost approach. And it may ultimately risk losing access to important technology that either is not developed here or can only be developed here at a prohibitive cost or with a significant delay. Saving money through foreign sourcing, while generally appealing as a principle, can become much less attractive on a case-by-case basis when the specific economic impacts of funding a foreign project rather than its American alternative are examined.

Thus, some argue that the United States is becoming (or is in danger of becoming) too dependent on others for our defense technology. Others take the opposite position, that we are missing out by failing to take full advantage of the technological capabilities of our friends and allies.

Foreign dependence can be helpful and desirable, harmful and avoidable, or just unavoidable. In general, it is a mixture of all of these, complicating policy formulation. In a perfectly competitive world market, exploiting the technology of our allies would permit a more efficient division of labor, with each nation concentrating its technological efforts on what it does best, rather than duplicating effort and spreading national resources too thin. It would allow us to exploit superior foreign technology where it exists, by contracting for foreign technology development, licensing foreign technology, or buying foreign products. In the real world of today's marketplace, realizing these benefits may require taking measures to ensure that the U.S. share of this pie is maintained. Some observers have suggested that the United States make a serious effort to exploit foreign technology by establishing organizations to target, transfer, and exploit leading edge foreign technology. This might include reverse engineering of foreign products (i.e., analyzing them to understand how they are designed).

But this dependence risks cut-off of supplies for either economic or political reasons. Foreign high-technology companies may be reluctant to commit resources to design specific items required by DoD when they find it more profitable to turn their energies in other directions. If the United States lacks a base of technical knowhow in a particular technological discipline in which foreign sources cannot be induced to make developments in militarily significant directions, the Nation would be faced with a choice between stimulating domestic development or doing without the desired technology.

If other nations dominate industries based on technologies that are important to U.S. defense efforts, the United States will have to decide either to buy what it needs from foreign sources, or to invest whatever is necessary to develop and keep a viable domestic technology and production base. This latter approach might involve inefficient measures to ensure domestic markets for domestic suppliers.

Ultimately, interdependence among nations may prove more advantageous to the United States than dependence on others. As the United States gets more deeply involved in reciprocal buy/sell relationships with its allies (particularly those with whom we have formal alliance ties), the risk inherent in relying on foreign suppliers is mitigated by mutual and interlocking military and economic dependence. Ties and interdependence are the political basis of alliance cohesion. This is qualitatively different from a situation in which the United States buys high-technology products in the international marketplace, and is at the mercy of the policies (or whims) of other nations.

Interdependence appears to be increasing in both the defense and commercial sectors. Within NATO, the United States participates in a number of groups working on cooperative development programs, and is involved in several major international development programs. The international nature of high-technology industry has led to interdependence among companies in various countries for components and finished products.

Congress is faced with the complex issues of whether the United States should: 1) exploit foreign technology to a greater degree; 2) look for ways to reduce foreign dependence; or 3) encourage development of strategic U.S. high-technology capabilities, insulating them from foreign competition, or at least preventing damage from unfair competition. A basic policy issue is how much the United States should become involved in cooperative defense programs, thereby increasing its dependence on allies and third parties for military technology. The United States will also have to decide how to respond to the movement offshore of high-technology industries that ultimately supply key technologies to defense systems, and to foreign ownership of U.S. high-technology companies.

Resolving these issues will involve understanding whether, on balance, it is in the national interest to rely on friends and allies for selected military technologies and to allow those capabilities to diminish in the United States. This will, in turn, depend on how confident we are that our friends will remain our friends and technology will remain available. Fostering economic, political, and defense interdependence may help. It will also depend on developing criteria to identify those areas in which increased foreign dependence would be desirable or undesirable, and on determining the risks to national security of certain technologies moving offshore. Ultimately, the United States will have to identify those technologies for which it is most important to maintain a domestic technology base. It maybe that some technologies are so important to national security that the United States cannot accept foreign dependence under any circumstances. This may be particularly so in the case of technologies that are important to many systems. Some believe that dependence for any important military technology is unacceptable. Realistically, what are the options to stop this movement and/or to take compensatory measures that will preserve a domestic technology base despite market forces?

"Dual-Use" Civilian High-Tech Industries

The foreign dependence problem is most pronounced in those industries—e.g., semiconductors, computers, machine tools, structural materials, and optics— that are vital lower tier suppliers for defense projects, but do most of their business in the commercial marketplace. These industries are the sources of much of the innovation in their fields. But the Department of Defense has relatively little influence over them.

The degree of foreign dependence varies from industry to industry. In some, such as semiconductors and machine tools, foreign companies hold a majority of the market and control a major share of the technology. In industries like computers and materials, the United States still holds a decisive lead in the technology, but foreign companies are taking an increasing share of the market. As the market shares move to foreign companies, the technology is likely to follow. In the past, many major technologies began in the defense sector and expanded into commercial markets, reducing DoD's share and leverage. This pattern is still strong, although perhaps not as prevalent as it once was.

These industries are strongly influenced by the global market. If political or market forces move them toward foreign manufacture, foreign management, or foreign ownership, or away from developments of interest to defense, that is where they are likely to go. There is a twofold danger in this. First, defense contractors may find it increasingly difficult to obtain the latest high-technology products. Some U.S. manufacturers believe that foreign suppliers of machine tools and computer parts sell U.S. companies products employing technology that is 2 to 3 years behind that of the products they sell their domestic customers. Second, DoD may find it increasingly difficult to induce those foreign companies that dominate a technology to use their R&D talents to develop specialized devices for military applications that are remote from most of their business. Ultimately, if the technical expertise moves entirely out of the United States, the Services would have little idea what new technical developments they should request of the foreign suppliers. This latter stage would mean an obvious decline in U.S. technological leadership over the Soviets, and to some degree a leveling of U.S. and Soviet access to the same advanced technology.

The government faces two problems with regard to these industries. First, from both defense and national economic perspectives, it faces the problem of keeping these industries viable here in the United States. Second, it has the problem of keeping the companies interested in doing business with the Department of Defense.

A number of rules and regulations pertaining to doing business with the Department of Defense inhibit companies from seeking government business and limit the flow of commercial products into defense systems. Innovative small- and medium-sized companies are particularly discouraged by conditions such as close scrutiny of their business, “red tape, ” and regulation of profits. Military specifications (MILSPECs) can have much the same effect, keeping out high-technology products that might be able to do the job but have not been designed to meet a complex list of specifications. These regulations by and large serve useful functions, but their utility should be weighed against the roles they play in keeping companies and products out of defense.[6] They have served to create a situation where experience in doing business with the government is an important company asset in competing for more government business, and lack of such experience is a major obstacle to companies trying to enter the market. Indeed, within some companies separations exist between divisions that sell to the government and those that do commercial business, stifling the transfer of technology within the company.

[6]Some in industry see many of these regulations as unfair.

Most modern industrial nations have industrial policies and specific bureaucratic organizations responsible for industry. The movement of high-technology industries offshore can be attributed, at least in part, to other governments following policies that nurture these industries more effectively than do U.S. policies. Partnerships with industry, and the availability of ‘patient capital, which encourages long-term results rather than short-term returns, are examples of the ways in which other governments encourage their industries. Developing and marketing high-technology products tends to be capital-intensive. The cost and availability of capital affect both the ability of companies to undertake long-term developments (which pay off handsomely but not soon) and their ability to rush a product to market once it is ready. The schedule for bringing a product to market can have a major effect on its share of the market. Some observers believe that the United States should be building the structure for a government-industry partnerhip to replace the current adversarial relationship. As Congress grapples with these problems, it will be important to understand the relationship between government policies and the deterioration of domestic high-technology industries that are important for defense. Are there realistic policy options that could reverse these trends?

This problem will raise before Congress the issue of whether the United States should have a more active national industrial strategy, and if so, what it should be, and what government agency should be responsible for it. It will be necessary to determine how defense needs would be taken into account and balanced against other needs in the formulation and implementation of that policy. Should the United States seek to maintain a viable domestic base for all industrial technologies that are of value for defense? Or would it make more sense to stimulate the international competitiveness of some U.S. industries and rely on the world market to meet the needs U.S. companies cannot provide? If the former is chosen, should the United States attempt to maintain, through government-funded projects, technical capabilities that are being lost in the commercial sector?

Defense Industries

For most technical developments of military significance, the road from laboratory to field runs through the large defense contractors. Each of these companies can perform a variety of important tasks, but their major roles are as prime system integrators, the companies that assemble the products of subcontractors and component developers into finished missiles, airplanes, submarines, etc. These companies, which both consume and develop new technology, have a unique niche in the economy, which results in unique business conditions.

There is longstanding concern that these conditions can inhibit technical development and efficient application of new technology. Like many corporations selling in the commercial market, defense contractors in the last few years have tended to plan for the short term rather than the long term. This de-emphasizes the value of investing in new technology which may only pay off 5, 10, or more years downstream.

Government procurement habits tend to reinforce this mode of planning. The method of government contracting has also tended to discourage both plant modernization and product innovation: the higher costs of operating inefficient plants can be charged to the customer, but the risk of failure due to trying new technology cannot. Much of the benefits from plant improvements–particularly large-scale improvements that pay back over relatively long terms—accrue to the government, further decreasing incentives for companies to fund such improvements. Of course, a company that can bid lower costs, because it will employ modern manufacturing technology or can produce a more capable product due to better technology, has an advantage in the competition for a contract. But it risks losses if it loses the competition despite investing in better technology. Congress may wish to consider whether government policies are inhibiting investment in modern manufacturing technology and what, if anything, should be done to stimulate these companies to develop and invest in better manufacturing technology. Related issues are whether (and how) government policies inhibit the transfer of technology to defense companies, discourage the entry of innovative companies into defense work, or encourage short-term planning rather than long-term planning. What options are available to correct these problems?

The IR&D (independent research and development) program has been controversial, especially within Congress, for many years. IR&D allows companies to recover some part of the cost of research programs initiated and funded by the company by treating it as a cost of doing business with, and developing products for, the Department of Defense. The cost is recovered as an allowable expense, similar to overhead, in contracts with DoD.[7] The companies decide what areas to work in and keep the commercial rights to their work. DoD judges the relevance of the work to defense needs and decides how much of the cost can be recovered, within an overall ceiling set by Congress. The remainder of the company's R&D costs are funded out of corporate profits.

In the view of the participating companies and other experts, IR&D benefits DoD because it allows the companies to stay current in areas of technology that are important to defense, and it encourages the generation of research ideas by company scientists and engineers. IR&D is treated very seriously by most companies and receives high-level corporate scrutiny. Industry spokesmen point to long lists of specific systems that have originated in work funded through IR&D. The companies contrast this to contract research-which they also do—in which, for the most part, government officials decide what areas to pursue, and exercise greater control over research projects. The companies are concerned that what they see as overcontrol by DoD will strangle IR&D.

'The results of IR&D recovery (reimbursement) improve a company's competitive position by improving its technology base, but the addition to the company's cost basis reduces its competitiveness on future contracts.

DoD, on the other hand, is concerned about keeping IR&D relevant to defense needs. The program tends to create friction between OSD —which supports the latitude for innovation that IR&D is supposed to provide–and the Services, who want greater control over how their money is spent. Both DoD and industry agree that one benefit of the IR&D program is the communication it forces between government and industry researchers.

Congressional and other critics see IR&D as little more than a government giveaway, letting the companies bill the government for expenses they would incur anyway. They assert that the program is being abused. There is also concern that the incentives of the IR&D program are oriented toward short-term applications in which relevance can be demonstrated and cost recovered quickly, rather than to long-term advanced technology. One significant problem of IR&D is its complexity: even if all parties could agree that its goals are worthwhile, understanding the mechanisms of the program is very difficult. Some have suggested that the IR&D program be abolished in favor of simpler means to support company-initiated R&D.

Supply of Scientists and Engineers

Ultimately, a vibrant domestic defense technology base depends on a steady supply of highly capable scientists and engineers. Yet in recent years the rate at which U.S. citizens become scientists and engineers has fallen behind that of our allies and the Soviet Union. Furthermore, a large percentage of graduate students studying technical disciplines in the United States are foreign nationals, often supported by State and Federal grants and subsidies. Although about two-thirds remain in the United States at least 5 years after completing their degrees, many go home once their education is complete (or a few years thereafter), and contribute their talents to foreign companies competing with U.S. high-technology companies. As long as these foreign nationals remain in the United States, they contribute to the technology base. The fact that so many choose to study in the United States is an indication of the quality of U.S. technological training.

This raises the issue of whether there is a need for additional scientific and engineering manpower-either across the board or in selected disciplines–to satisfy both national security and commercial needs, and if so, what steps Congress could take to increase the supply. These might include measures to increase the attractiveness of science and engineering careers to U.S. citizens, and measures to increase the general quality of education. Congress may wish to consider the role of foreign nationals in the defense technology base, and whether steps are necessary to influence the number of foreign graduate students in U.S. universities.

EXPLOITING THE DEFENSE TECHNOLOGY BASE

An important element of getting new technology quickly into the field is how well the technology base can be exploited. Indeed, some observers believe that the major problems lie not in developing or maintaining the technology base, but in exploiting it, and that the major source of delay in getting technology from the laboratory to the field is not producing and developing the technology, but successfully designing it into military systems once it has been developed. Dr. Robert Costello, the Undersecretary of Defense for Acquisition, has cited the VHSIC program as an example of DoD's failure to get new technology rapidly into the field:

> While over 60 systems have VHSIC products in their plans, VHSIC parts are only in one current, deployed system . . , The technology is available and proven; and the Japanese are already using equivalent technology in commercial applications . . .[8]

[8]Quoted in *Defense Daily,* Dec. 3, 1987, p.203.

Exploiting the technology base is not, strictly speaking, part of maintaining it. But in practice, the two are inseparable. No clear line separates developing technology from developing technology for applications. Part of creating a technology is developing the means to build something based on that technology. It is precisely in this area of manufacturing technology that many observers believe the United States has sustained the greatest losses in technological capability. They believe that the United States is not so much slipping in applied science and the development of product technology, as it is in the craft and know-how of manufacturing devices: process technology must develop along with product technology if the product technology is to appear in actual devices. Moreover, designing a new technological advance into a useful device is itself a technology and may draw on several disciplines. For example, now that materials having superconducting properties at relatively high temperatures can be produced, the search is on both to find applications for these materials, and to fabricate them into useful forms.

A related problem is that many program managers are reluctant to design new technology into their systems. Over the several years it takes a system to go through full-scale development and into production, the technology in some of its subsystems and components is likely to fall behind the state of the art, especially in areas that are evolving rapidly. Ignoring new technology results in a system that is behind the leading edge, but changing the system to include new technology will introduce delays. Adding, new technology carries a risk that unforeseen factors will lead to additional delays. Thus, Service program managers have incentives to stay with the technology they know in order to minimize risks of schedule slippage.

One proposed solution is to insert new technology in retrofits to existing systems. Retrofitting takes less time than new developments and, therefore, gets the technology into the field faster. It also has the advantage of upgrading fielded capabilities without waiting for a new generation of major equipment.

A related approach is to include new technology in scheduled block upgrades of systems in production. Introducing new technology subsystems would not have to wait for the design and introduction of an entire new generation of the major system. A company that is now building a particular fighter airplane might also be working on an upgraded design that it would switch over to in a year or two. Both of these approaches are now used to some extent. Both require some degree of prior planning to ensure that new technology can be inserted with minimum disruption.

Yet another approach is through the organizational links between technology and systems development. For example, the Air Force has reorganized its technology base programs to be closely linked to the systems commands which are responsible for developing and buying equipment. This is an approach with attractive features, because it is supposed to make program managers more aware of new technology and make technology development more responsive to the needs of program development, thereby speeding the introduction of technology into systems. But linking technology too closely to development also risks stifling creativity-especially in areas that program managers do not currently recognize as being relevant to their missions.

HOW THE DEFENSE DEPARTMENT MAKES AND IMPLEMENTS TECHNOLOGY POLICY

The Defense Department's ability to manage its technology base programs is central to maintaining the defense technology base. In fiscal year 1988 DoD invested $8.6 billion in technology base activities. (See table 1.) One-third of the work was conducted "in-house;"

Table 1.—Department of Defense Fiscal Year 1988 Funding of Technology Base Programs (in millions of dollars)

	Army	Navy	Air Force	DARPA	Total
Research (6,1)	$169	$342	$198	$83	$ 902'
Exploratory development (6.2)	$556	$408	$557	$512	$2,033
Advanced exploratory development	$319	$227	$754	$202	$1,502
Total services and DARPA					$4,437
Strategic Defense Initiative					$3,604
Other defense agencies					$ 564
Total DoD technology base programs					$8,605

[a]This sum includes $110 million for the URI which OSD has not yet allocated among the three Services and DARPA.

SOURCE Office of Technology Assessment, 1988, from data supplied by the Office of the Secretary of Defense

more than half was contracted to industry,and universities performed the rest. Efficient management of the program-deciding what technology base policy is, allocating resources to implement that policy, avoiding unnecessary duplication of effort, and ensuring that important areas donot"fallbetween the cracks"that separate the elements of the program--will become all the more important if budgets become increasingly constrained.

Generally speaking, each Service department assembles a technology base program to suit its particular needs. OSD exercises oversight, and attempts to ensure that these programs are balanced and coordinated into a coherent whole with those of the defense agencies and the Strategic Defense Initiative Organization (which accounts for over 40 percent of DoD's technology base program funding). How all this works in detail is rooted in the structures of the various organizations within OSD and the Services that make R&D policy, but is not entirely determined by them. These structures are still undergoing reorganization in the wake of the Goldwater-Nichols Reorganization Act (Public Law 99-433). Consequently, what follows may well change in the months ahead. Once the structures are settled, it may take even more time for the process to adjust to the structure.

The three Services and the defense agencies (particularly the Defense Advanced Research Projects Agency (DARPA)) formulate their technology base programs with overall guidance from OSD. The Under Secretary of Defense for Acquisition has principal responsibility for all RDT&E activities except those of the Strategic Defense Initiative Organization (SDIO), which reports directly to the Secretary. For the Services, the principal focus for this guidance and the principal point of contact is the Deputy Under Secretary of Defense for Research and Advanced Technology (DUSD(R&AT)), a deputy to the Under Secretary of Defense for Acquisition. After the Services have formulated their programs, the role of the DUSD(R&AT) is to structure the overall program across service lines in order to eliminate gaps and overlaps, and enhance the return on investment. DUSD(R&AT) works continually with the services to help them achieve mutual interests and balance in their science and technology programs. DUSD (R&AT) coordinates activities with other government agencies and the scientific community.

Although DUSD(R&AT) is involved in coordinating Service programs with those of DARPA and the other defense agencies, he does not have oversight for the technology base programs of the defense agencies. However, since DARPA contracts most of its programs through the Services, much of its effort in fact receives DUSD(R&AT) oversight. The DUSD(R&AT) and the directors of all the defense agencies except DARPA report directly to the Director of Defense Research and Engineering (DDR&E), who reports to the Under Secretary for Acquisition. The Director of DARPA is also the Assistant Secretary of Defense for Research and Technology (ASD(R&T)) and reports directly to the Under Secretary for Acquisition.

DUSD(R&AT) runs some programs directly. The Computer and Electronics Technology Directorate of the DUSD(R&AT) manages: the Very High Speed Integrated Circuit (VHSIC) program; the Microwave/Millimeter Wave Monolithic Integrated Circuit (MIMIC) program; and the Software Technology for Adaptable Reliable Systems (STARS) program.

The three Service departments maintain structures for managing their technology base programs that are similar in some ways, but nonetheless have significant differences. Each has been planned to take into account the peculiar needs of the Service, and each is rooted in its own history. Each of the Services conducts an annual "top down, bottom up" planning exercise. From the top, each receives OSD's annual Defense Guidance Manual (as well as specific Service guidance), and from the bottom each research institution contributes a technology base plan. Outside advisory groups and in-house technical directors and staffs also contribute. Planning includes a review and evaluation of the previous year's programs. It culminates with decisions to start new programs, continue or terminate existing programs, or transition programs into a new category (e.g., from 6.1 to 6.2).

Of the three Services, the Navy has removed its technology base management institutions farthest from its procurement institutions. But relevance to Navy needs remains a powerful factor in selecting projects, particularly those beyond 6.1. Although it has the smallest overall technology base program, it has the largest research (6. 1) program, and performs the largest fraction of the work in-house. The 6.1 and 6.2 programs are run, respectively, by the Office of Naval Research and the Office of Naval Technology, both of which report to the Chief of Naval Research, who in turn reports directly to the Chief of Naval Operations (CNO) and the Assistant Secretary of the Navy for Research, Engineering, and Systems. Some Navy laboratories are run by the Office of Naval Research and others are run by the Space and Naval Warfare Systems Command (SPAWAR), which also reports directly to the CNO. Until recently the laboratories now run by SPAWAR were run by the "buying commands" such as the Naval Air Systems Command and the Naval Sea Systems Command. The decisions regarding *6.2* work to be done in SPAWAR laboratories are made by the Office of Naval Technology. Of the three Services, the Navy has the smallest advanced technology demonstration (6.3A) program; it is run directly by the Office of the CNO (OPNAV).

In contrast to the Navy's program, which is structured for finding and developing new technology of use to naval missions, the Air Force structure puts greater emphasis on getting technology into the field. The Air Force 6.3A program, which the Air Force sees as transition money, is five times as large as the Navy 6.3A budget. The technology base programs are run by Systems Command, the individual divisions of which are the Air Force's "buying commands. " These divisions run the laboratories which conduct and manage the 6.2 and 6.3A programs. Roughly two-thirds of the work is contracted out. The 6.1 programs are administered by the Air Force Office of Scientific Research, which is also part of Systems Command. Within Systems Command, the Deputy Chief of Staff for Technology and Plans has oversight responsibility for the science and technology programs, but these programs must be approved by the Director of Science and Technology Programs in the Office of the Assistant Secretary of the Air Force for Acquisition. The Air Force has recently taken a decision to treat its technology base program as a "corporate investment' that deserves a fixed fraction of the total Air Force budget.

The Army's structure is perhaps the most complicated and decentralized of the three Services. The Army has the smallest headquarters staff and relies the most on elements outside headquarters to run the technology base programs. Some aspects of the Army system are analogous to the Air Force system, while others are similar to the Navy 's. About three-fourths of the science and technology programs are run by the Army Materiel Command (AMC); other S&T programs are run by the Surgeon General of the Army, the Corps of Engineers, and the Office of the Deputy Chief of Staff for

Personnel. The offices within these organizations that are responsible for the S&T programs all report for oversight by Army headquarters to the Deputy for Technology and Assessment who, in turn, reports to the combined Office of the Assistant Secretary of the Army for Research, Development, and Acquisition (RD&A) and the Deputy Chief of Staff for RD&A. Within the Office of the Deputy for Technology and Assessment, it is the Director of Research and Technology who has responsibility for planning and coordinating the entire technology base program. The Army Materiel Command is analogous to the Air Force Systems Command.[9] It is organized into mission-specific "buying commands, " which run laboratories and technology base programs, and Laboratory Command (LABCOM) which, like the Office of Naval Research, runs laboratories and conducts generic research. Under LABCOM, the Army Research Office is responsible for AMC's 6.1 programs. Unlike the Office of Naval Research, the Army Research Office has no in-house capabilities and contracts all of its work out.

[9]The Navy equivalent, the Naval Material Command, was eliminated a few years ago in a reorganization. The component commands-e. g., the Naval Air Systems Command-now report directly to the CNO.

ROLES OF THE COMPONENT RESEARCH INSTITUTIONS

Nearly 200 Federal Government laboratories, research and engineering centers, activities, and test facilities contribute to the defense technology base. About 65 of these play a major role. Of these major centers, roughly 50 belong to the Army, Navy, and Air Force Departments, and the rest are run by the Department of Energy, the Department of Commerce, and the National Aeronautics and Space Administration (NASA). Many of the Department of Energy laboratories are Government Owned Contractor Operated (GOCO) facilities, permitting the hiring of personnel outside the Civil Service system. The defense agencies do not operate laboratories; however, DARPA maintains a close liaison with some Service laboratories.

Army

Within the Army Materiel Command, six "mission specific' systems commands run research, development, and engineering centers that conduct exploratory and advanced technology development into areas that are specific to the command's mission, while the Laboratory Command (LABCOM) operates laboratories that are focused on generic research and development, primarily at the 6.2 and 6.3 levels. The Army's research (6.1) program is almost entirely contracted out. Some of the mission-specific centers are more influential than LABCOM, and greatly influence the structure and priorities of the Army S&T program.

LABCOM runs the Electronic Technology and Devices Laboratory, the Materials Technology Laboratory, the Human Engineering Laboratory (the Army's lead lab for man-machine interface and robotics), the Ballistic Research Laboratory, the Atmospheric Science Laboratory, and the Vulnerability Assessments Laboratory. It also runs Harry Diamond Laboratories, which is involved in a variety of areas including ordnance electronics, electromagnetic effects, and advanced electronics devices. These laboratories do most of their work in-house, but contract out a substantial portion.

The facilities belonging to the systems commands conduct some exploratory development, but the main thrust is toward the "mature" end of the S&T program, leading to components, products, and systems. These centers conduct some in-house work, but the bulk is contracted out. For the most part, they bear the names of their parent commands, and their missions are specified by their names: the Armaments, Munitions, and Chemical Command; the Aviation Systems Command; the Missile Command; the Tank Automotive Command; the Communications Electronics Command; and the Troop Support Command.[10] The Missile Command Research and Development and Engineering Center has the capability to carry a concept nearly to production almost without outside help. The Night Vision and Electro-optical Laboratory, run by the Communications Electronics Command, is a recognized leader in infrared and other night vision devices for all three Services.

Navy

The in-house R&D capabilities of many Navy laboratories are substantial, through the tech base and into full-scale engineering development. Some can carry a system through development and almost to production, like the Army's Missile Commmand Research and Development and Enginering Center does. At least one Navy laboratory–the Naval Research Laboratory—does a substantial part of its work as the result of proposals by lab personnel to conduct R&D for the other Services and other parts of the government. The Naval Weapons Center has developed major missile systems to the production stage.

The Office of Naval Research oversees the activities of several laboratories—including the Naval Research Laboratory, the Naval Ocean Research and Development Center, and the Naval Environmental Prediction Research Facility. The Naval Research Laboratory is the Navy's principal research laboratory and, in some areas, DoD's. It conducts a broad-based program that includes such diverse fields as computer science, artificial intelligence, device technology, electronic warfare, radar, materials, directed energy, sensor technology, space technology, and undersea technology.

Aside from ONR's laboratories, all Navy development centers and activities are assigned to the Space and Naval Warfare Command. Although these facilities perform 6.2 and 6.3A work, the emphasis is on development. *The ma*jor centers are the Naval Air Development Center, the Naval Ocean Systems Center, the Naval Weapons Center, the Naval Ship Research and Development Center, the Naval Surface Warfare Center, the Naval Undersea Systems Center, and the Naval Coastal Systems Center. Science and technology programs in these centers include electro-optics, acoustics, microwaves, artificial intelligence and knowledge-based systems, ocean science, bioscience, electronic materials, structural materials, ship magnetics, hydrodynamics, and charged particle beams.

Air Force

All of the Air Force laboratories are run by the systems divisions of Systems Command—Armaments Division, Aeronautical Systems Division, Electronic Systems Division, Space Division, and Human Systems Division—in support of the division's specific mission. Exploratory and advanced development (6.2 and 6.3A) are funded directly by the divisions, while research (6.1) is funded and managed by the Air Force Office of Scientific Research. The centers are the Air Force Armaments Laboratory, the Rome Air Development Center, the Geophysics Laboratory, the Air Force Weapons Laboratory, the Air Force Astronautics Laboratory, the Human Resources Laboratory, the Aeromedical Laboratory, and the Wright Aeronautical Laboratories. The Wright Aeronautical Laboratories is a cluster which includes the Aeropropulsion Laboratory, the Avionics Laboratory, the Flight Dynamics Laboratory, and the Materials Laboratory. Managed outside Systems Command, but coordinated with it, is the Air Force Engineering and Services Laboratory.

[10]For example, the Armaments, Munitions, and Chemical Command runs the Armament Research, Development, and Engineering Center and the Chemical Research, Development, and Engineering Center.

Department of Energy

The Department of Energy's laboratory system, established during World War II to develop nuclear weapons, has grown dramatically in scope and size. About 60 institutions employing 135,000 people and having a replacement cost of about $50 billion conduct research into physics, chemistry, cosmology, biology, the ecosystem, geology, mathematics, computing, and medicine, as well as a broad range of technologies that spring from these disciplines. Nine multiprogram laboratories and 30 specialized laboratories are involved in these fundamental science and technology activities. These laboratories maintain close ties with academic researchers, often subsidizing part of their work at the DOE facilities.

A primary focus of DOE work for national defense is the nuclear weapons programs. Moreover, some of the major multiprogram laboratories–Sandia National Laboratory, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Oak Ridge National Laboratory–do 10 to 15 percent of their work under contract to DoD on defense related research not directly related to nuclear weapons, and most of their work is available for exploitation by DoD or its contractors. Several other laboratories—Argonne, Brookhaven, Lawrence Berkeley, Idaho National Engineering Laboratory, and Pacific Northwest Laboratory–do little or no work for DoD, although they do basic and applied research that is available for exploitation for defense purposes.

The National Aeronautics and Space Administration (NASA)

NASA runs a number of major facilities, many of which are dedicated almost exclusively to the design and testing of space-launch systems and space systems. Several others, while they also support the space program, have a broader mandate. The major NASA field centers are the Ames Research Center, the Lewis Research Center, the Langley Research Center, the Goddard Space Flight Center, the Marshall Space Flight Center, the Johnson Space Center, the Kennedy Space Center, and the Jet Propulsion Laboratory. These centers conduct work in aeronautics, space, communications, propulsion, and computers, among other fields.

Other Federal S&T Activities

By far, the majority of federal science and technology activities with potential defense applications are conducted within DoD, DOE, and NASA. There are pockets of activity within other agencies that can, and do, contribute to the defense technology base.

The National Science Foundation funds three times as much university research as DoD. But NSF conducts no research of its own, and does not contract for research; it funds unsolicited proposals. NSF supports research projects in almost every area of science and technology.

The Commerce Department's National Bureau of Standards conducts a number of applied research projects that contribute to the defense technology base. NBS researchers, in partnership with others from industry, government, or academia, investigate areas such as electronic technology, information processing, biotechnology, chemistry, and manufacturing technology. This partnership arrangement is designed to get the technologies quickly into applications. NBS technical work is carried out in the National Measurement Laboratory, the National Engineering Laboratory, the Institute for Computer Sciences and Technology, and the Institute for Materials Science and Engineering.

The Department of Transportation-particularly the Federal Aviation Administration and the Coast Guard-the Department of Agriculture, the Department of Interior's U.S. Geological Survey, and the National Ocean and Atmospheric Administration all share interests with DoD, and conduct some research and development with potential defense applications.

University Research Programs

University laboratories perform a substantial portion of the basic and applied research conducted in the United States. They work in all areas of basic research and most areas of applied research and exploratory technology. University research is an area of potentially high leverage for DoD, since DoD funds less than 25 percent of it, but has access to almost all of it. DoD has generated great interest in its new programs for university research; many more requests have been received than could be funded. The two most significant are the University Research Instrumentation Program, to upgrade laboratory equipment, and the University Research Initiative, most of which goes to multidisciplinary research programs and programs to promote scientific training. DOD has also put money into creating university "centers of excellence" in selected disciplines.

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Part II

Background and Analysis