Chapter 3

Structure of the Current Base

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Chapter 3

Structure of the Current Base

INTRODUCTION

The defense technology and industrial base (DTIB) has two broad functions. The first is to conceive of, develop, produce, maintain, and upgrade both modern weapon systems and supporting equipment in peacetime; the second is to respond to crisis or war with increased production of current materiel and the development of new systems.[1] These objectives are to some extent in competition for limited resources, and one of the primary challenges of DTIB planning and management is finding the proper balance between the two.

In considering the transition to the future DTIB, it is important to understand the overall structure and condition of the current base, including both its strengths and its weaknesses, and the policies that have led to the current situation. This chapter draws together the findings of numerous assessments over the past decade, as well as information from surveys and discussions conducted by OTA. The chapter provides insights into the current structure of the base, explains the differing requirements of elements of the DTIB, and outlines its current management structure.

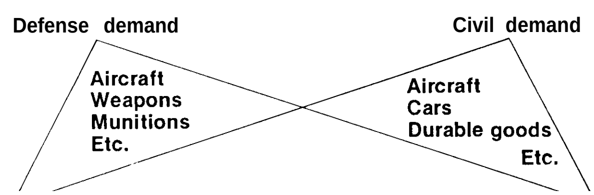
STRUCTURE OF THE CURRENT BASE

The DTIB can be broadly defined as the combination of people, facilities, institutions, and skills required to design, develop, manufacture, test, and maintain the weapons and supporting equipment for the U.S. armed forces. It is composed of three functional elements: research, development, and engineering; production; and maintenance and repair. The base comprises the U.S. and Canadian defense industries, as well as offshore foreign firms that supply goods and services to North American manufacturers.[2]

The broad 'guns v. butter" tradeoffs that must be made at the national level are suggested by the dual-pyramid demand model in figure 3-1. As military threats increase, goods and services are shifted from civilian to defense use; as threats recede, demand shifts back to the civil sector. For example, defense demand increased dramatically relative to civil demand during World War II, when defense spending went from 1.7 percent of GNP in 1940 **to over** 39 percent in 1944.[3]

Under the wartime conditions existing from 1942 through 1945, this massive shift in allocation was tightly controlled by the Federal Government. During periods of reduced external threat, market

Figure 3-l—Dual-Pyramid Demand Model



End product	**Aerospace, electronics (e.g., computers, telecommunications, software), shipbuilding, automotive, construction equipment, farm machinery, etc.**
Subtier	**Forgings, castings, ball bearings, machine tools, robotics, semiconductors, semiconductor equipment, etc.**
Basic	**Steel, petrochemicals, metals (e.g., aluminum, titanium, copper mining), ceramics, composite fibers, fiber optics, etc.**
Inputs	**Raw materials, energy, capital, technology, scientific/skilled manpower, management**

SOURCE: Roderick L. Vawter, *Foreign Dependency and Foreign Vulnerability: Part 1, A Survey of the Literature* (Washington, DC: Mobilization Concepts Development Center, National Defense University, Ft. McNair, September 19S6).

[1] U.S. Congress, Office of Technology Assessment, *Adjusting to a New Security Environment: The Defense Technology and Industrial Base Challenge,* OTA-BP-ISC-79 (Washington, DC: U.S. Government Printing Office, February 1991), pp. 4-6.

[2] The integrated U.S.-Canadian defense industrial base has evolved over a period of four decades because of its benefits to the security and economic interests of both countries. Guidelines for this collaboration laid down in numerous letters of agreement and memoranda of understanding known collectively as the Defense Development and Defense Production Sharing Arrangements (DD/DPSA), have led to the emergence of a North American Defense Industrial Base. For further discussion see App. I.

[3] Office of Management and Budget, *Historical Tables Budget of the United States Government, 1990* (Washington, DC: Government Printing Office, 1989), table 6.2 "Composition of Outlays in Percentage Terms: 19401994," p. 132.

incentives are more often used to reallocate resources. Industrial production is not a zero-sum game, and a shift of resources to defense does not necessarily entail an absolute loss to the civil sector. In periods of increased security threats and improving economic conditions, both the defense and civil bases can increase in size, as occurred during the Korean and Vietnam wars and the peacetime military mobilization for the cold war.

The complexity of the DTIB means that no single view or model is adequate for policy development. Figure 3-2 indicates some of the relationships between the defense elements and the broader base, as well as among the components. The DTIB has its source in the global science and technology base and is fed by the national industrial base. Because of legislation, however, the national base has evolved separate elements that perform defense functions.

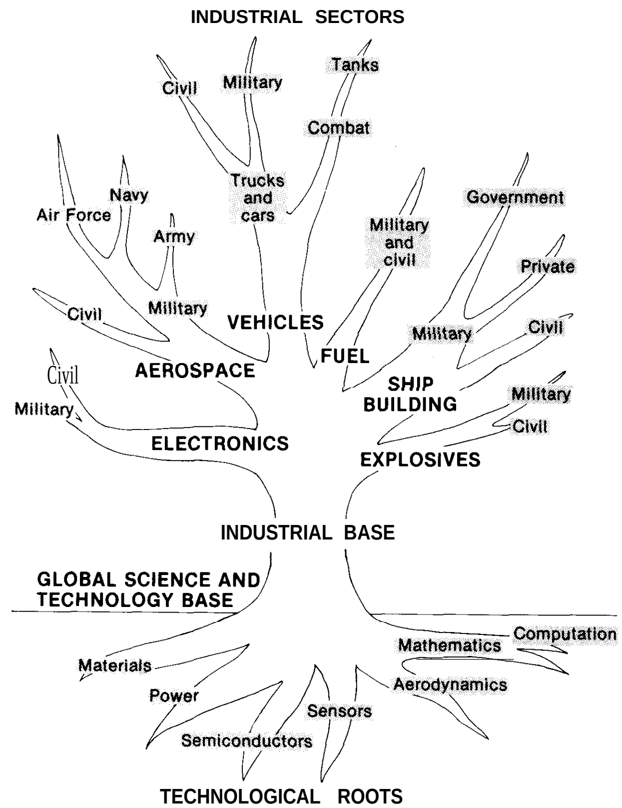
Combining views from several perspectives yields a more comprehensive picture of the DTIB and its relation to the larger national industrial base that is useful for considering policy choices and the implications of those choices. The following sections describe the DTIB from four perspectives:

1. *the tiers* associated with the weapon development and assembly process (primes, subcontractors, and suppliers);
2. *ownership* (private and public);
3. different *industrial sectors (e.g.,* shipbuilding and electronics); and
4. *functional areas* that correspond generally to the steps of the procurement cycle (R&D, production, and maintenance).

Tiers of the Base

The DTIB is part of the larger national industrial base and increasingly a part of a global industrial base. Figure 3-3 illustrates the structure of the defense base from the standpoint of the weapon development and assembly process. The larger truncated pyramid represents the overall North American industrial base (both civilian and defense elements), while the smaller embedded pyramid contains defense-specific elements. A 1988 report by the Under Secretary of Defense for Acquisition noted that the DTIB "generally comprises the same manufacturers that produce goods for the general public. . . . [The Defense] Department depends on virtually every sector of the manufacturing base for materiel.'[4] While figure 3-3 highlights the interrelationship between the DTIB and the overall industrial base, it fails to capture adequately the suppliers and producers located outside of North America.

Figure 3-2—Relationships Among Defense Sectors and the Broader National Industrial Base

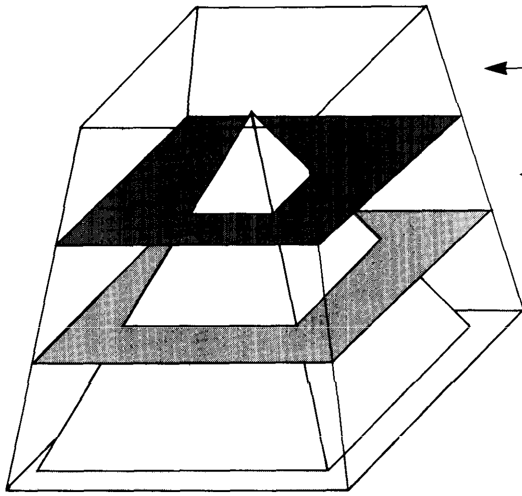


SOURCE: Office of Technology Assessment, 1991.

Both the larger national technology and industrial base and the embedded DTIB are fed by inputs that include raw materials, manpower, and capital. At the lowest level are basic industries such as steel and aluminum; at the middle level are industrial producers of items such as forgings, castings, and semiconductor chips; and at the top level are final assemblers of end-products such as military or civilian aircraft. Elements of a single firm might operate at all three levels.

[4] Report to the Secretary of Defense by the Under Secretary of Defense (Acquisition), *Bolstering Defense Industrial Competitiveness,* July 1988, p. v.

Figure 3-3-Tiers of the Defense Technology and Industrial Base



SOURCE: Office of Technology Assessment, 1991.

One of the chief concerns expressed in interviews conducted by OTA and numerous recent studies is that the national base, viewed from the standpoint of the weapon development and assembly process, increasingly lacks key supporting firms. While this concern appears to have merit in some sectors, in aggregate the national base can still be thought of as a truncated pyramid of supporting firms and capabilities that potentially can be used for weapons development and production. How firms might be moved from being potential to actual producers is a key policy question.

Firms within the DTIB are often divided into three tiers according to size and function: 1) large prime contractors acting as systems integrators and assemblers; 2) subcontractors and component manufacturers; and 3) parts, capital equipment, and material suppliers. This division is particularly useful in considering alternative DTIB policies, since many policies appropriate to large prime contractors are not suitable for supporting subtier firms and material suppliers.

Prime Contractors

The top tier of the defense industrial pyramid consists of large prime contractors such as General Dynamics, McDonnell Douglas, and Lockheed, which perform the overall assembly and integration of weapon systems, as well as some parts fabrication (table 3-l). Studies indicate that 40 to 60 percent of defense procurement funds for any particular weapon system stays with the prime contractors, while the remainder is passed on to supporting subcontractors.[5] Prime contractors generally retain large design and engineering staffs, which conduct applied research and development and also perform some of the more basic R&D.

While some prime contractors are highly dependent on defense work, others are more diversified. In 1989, for example, Department of Defense (DoD) contracts comprised 73 percent of total revenue for General Dynamics, 62 percent for McDonnell Douglas, 57 percent for Martin Marietta, and 64 percent for Grumman. For more diversified fins, DoD contracts comprised a smaller share of total revenue, including 18 percent for United Technologies, 16 percent for Rockwell International, 15 percent for Boeing, 13 percent for Westinghouse, and 11 percent for General Electric.[6] As a group, prime contractors are more international in outlook than smaller, more specialized firms in that they are willing to source goods and services from abroad, and also seek to export.

[5] Jacques S. Gansler, *Affording Defense* (Cambridge, MA: Massachusetts Institute of Technology Press, 1989), p. 247.
[6] Tom Shoop, "The Top 25 Government Contractors," Government Executive, vol. 22, No. 8, August 1990, pp. 32-44, and 123-132.

Table 3-l—Top 25 Department of Defense Contractors, Fiscal Year 1989

Rank	Parent company	Total DoD ($ billion)
1	McDonnell Douglas	$8.99
2	General Dynamics	7.28
3	General Electric	5.87
4	United Technologies	3.54
5	General Motors	3.38
6	Martin Marietta	3.35
7	Raytheon	3.29
8	Boeing	3.11
9	Lockheed	2.56
10	GTE	2.35
11	Grumman	2.35
12	Rockwell International	2.02
13	Litton Industries	1.99
14	Westinghouse Electric	1.66
15	Honeywell (since 1990, Alliant Techsystems)	1.54
16	Textron	1.41
17	TRW	1.30
18	IBM	1.26
19	III-	1.25
20	Unisys	1.02
21	Gibbons, Green & Van Amerongen	0.95
22	Allied-Signal	0.90
23	Tenneco	0.89
24	Avondale Industries	0.88
25	FMC	0.79

NOTE: Rankings are based on prime contracts of $25,000 or more for the Department of Defense.

SOURCE: James Kitfield, "Stepping Back From Reform," *Government Executive*, vol. *22, No. 8*, August 1990, pp. 24-25.

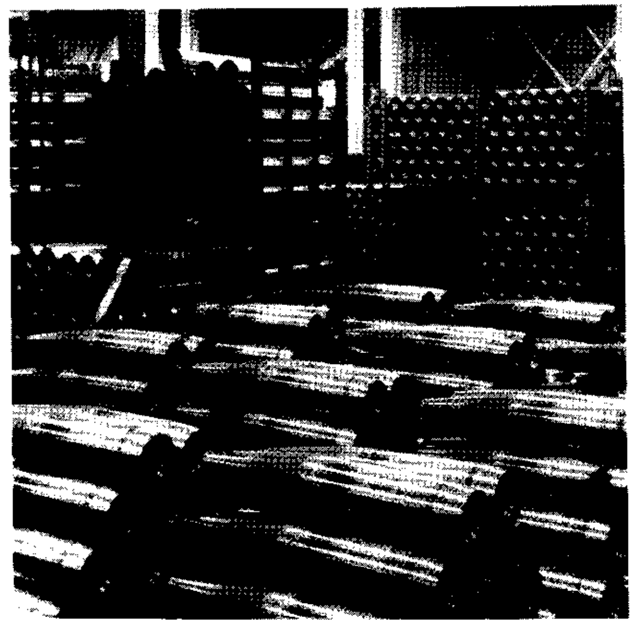


Photo credit: Royal Ordnance plc

Artillery shells for 155mm howitzers are manufactured by Royal Ordnance of Great Britain, one example of the international defense technology and industrial base.

Subcontractors

The middle tier of the defense industrial pyramid is composed of subcontractors that manufacture major subsystems and components of weapon systems, such as radars, computers, engines, and electronics. These firms, including Loral and Alliant Techsystems (formerly Honeywell), vary greatly in size. A subcontractor might be a large firm (e.g., Avco), a subsidiary of a major defense contractor such as General Electric Aerospace, or a government organization such as an Army arsenal that supplies gun tubes to a prime contractor as government-furnished equipment.

A survey of prime defense contractors by the Air Force Association indicated that their respondents each purchased subcomponents from an average of more than 1,300 subcontractors and vendors, both domestic and foreign. The DDG-51 Aegis destroyer program depended on more than 500 equipment vendors, and one of these vendors, GE, relied in turn on more than 1,200 suppliers.[7] Subcontractors conduct extensive R&D related to components. Over time, they have developed considerable expertise in critical technologies and survive by that expertise. They are, therefore, more concerned than the prime contractors about technical data rights and any attempt by the government to gain access to commercially developed technology that might be embedded in their defense products. They are less international in outlook and argue that they have been hurt by the growing trend of prime contractors to transfer technology offshore and to source abroad (see box 3-A).

Suppliers

The bottom tier of the pyramid is composed of suppliers of parts and materials, including electronics packages, integrated circuits, batteries, and bearings. Many of these firms produce "dual-use" equipment and supplies, such as fasteners and materials, that are essential to both military and civilian applications. As a group, supplier firms are

[7] Air Force Association and USNI Military Data Base, *Lifeline in Danger: An Assessment of the United States Defense Industrial Base* (Arlington, VA: The Aerospace Education Foundation, 1988), p. 65; and Naval Sea Systems Command, *United States Shipbuilding Industry*, briefing papers, July 1990.

OTA DEFENSE INDUSTRY SURVEY

Box 3-A—Differences Between Primes and Subtiers

The survey revealed a number of differences in approach to dealing with reduced defense budgets between large prime contractors and smaller subtier fins.

International

- **primes** tend to support international sales, talk about the global nature of the defense technology and industrial base, and report that they source widely abroad. They are generally skeptical about tracking foreign dependency and sources of items.
- Subtiers are more supportive of Buy-American provisions, argue that even R&D should be oriented toward U.S. firms rather than abroad, complain about the negative effects of offset requirements, and express greater concern about loss of technology to foreign competitors.

Diversification

- **Primes** hope to diversify in defense work as well as non-defense. They generally see defense business expansion (possibly through diversification) as a requirement to maintain stock value in the face of a reduced defense budget. Diversification into civilian areas is generally approached through acquisition.
- Subtiers note a threat from primes moving into technical areas previously left to smaller, more specialized firms. Subtiers often have few resources to diversify into civilian work and stress the difficulty of making the transition, especially in a recession. In order to diversify, they tend to pursue teaming arrangements with other fires rather than acquisitions.

Commitment to Defense

- **Primes** generally express a continued commitment to defense. However, firms with a solid base of non-defense business note the difficulty of doing business with DoD and appear to be somewhat less committed to defense work.
- Subtiers' responses are mixed. Several hope to leave the defense sector, and some already have done so. They contend that the cost of doing business with DoD is far too high in light of potential returns.

Government Action

- **Primes** generally oppose government intervention and advocate letting the market decide which firms will survive the downsizing of the base.
- Subtiers see more need for intervention to protect them from international competition and from U.S. primes moving into their business sector during downsizing.

more diversified and are linked directly to the broader national industrial base.

Foreign Sources

The DTIB extends beyond the borders of the United States to include subcontractors and suppliers from Canada and other countries. Most of the foreign contracts listed in table 3-2 are for services and fuel to support U.S. forces overseas, but many key components and some weapon systems are sou.reed abroad. In addition, international exchanges of technology take place through commercial licensing agreements and through government-sponsored or private industrial collaboration. Although a few cooperative programs such as the codevelopment of the FSX fighter with Japan have attracted much attention and criticism, the military services manage a host of other intergovernmental exchanges of technology relating to propellants, explosives, airframe design, and other areas-almost all without controversy. Company-to-company collaborations are also increasing. Firms collaborate across borders to gain access to foreign markets and technology, or to meet foreign governments' insistence on offset arrange-

Table 3-2—Department of Defense Foreign Contractors

Rank[a]	Parent company	Parent location	Fiscal 1989 awards ($ 000s)	Market share (percent)
1	Federal Republic of Germany[b]	Bonn, Germany	$350,498	0.2%
2	Royal Dutch Petroleum	The Hague, Netherlands	304,543	0.2
3	SNECMA[c]	Paris, France	258,650	0.2
4	Canadian Commercial Corp.[d]	Ottawa, Canada	253,478	0.2
5	European Utilities Cos.[e]	—	173,258	0.1
6	MIP Instandsetzungsbetrieb	Germany	166,329	0.1
7	Philips Gloeilampenfabrieken	Eindhoven, Netherlands	135,064	0.1
8	CAE Industries	Toronto, Canada	125,287	0.1
9	Nisshin Service	Japan	109,619	0.1
10	Bahrain National Oil	Bahrain	101,043	0.1
11	British Aerospace	Bristol, United Kingdom	100,113	0.1
12	Kuwait National Petroleum	Safat, Kuwait	96,720	0.1
13	N.J. Vardinoyannis Group	Athens, Greece	88,880	0.1
14	Selm Servizi Elettrici Montedi	Milan, Italy	85,005	0.1
15	Imperial Chemical Industries	London, United Kingdom	83,061	0.1
16	Daimler-Benz	Stuttgart, Germany	71,822	0.1
17	FN Fabrique Nationale De Herst	Herstal, Belgium	58,379	0.1
18	Okinawa Electric Power	Okinawa, Japan	53,477	0.1
19	Greenland Contractors	Greenland	46,964	0.1
20	General Electric OLC	London, United Kingdom	42,671	0.1
21	Bell Canada Enterprises	Montreal, Canada	42,619	0.1
22	Aral AG	—	40,180	0.1
23	Compania Espaniola De Petroleos	—	34,545	0.1
24	Netherland Ministry of Defense	Netherlands	32,604	0.1
25	Rafael Armanents Development	Haifa, Israel	32,570	0.1

a Rankings are based on R&D, service, and production prime contracts of $25,000 or more received by foreign entities. Market shares are of all Department of Defense contracts.
b The Federal German Government acts as a middleman for contracts involving U.S. bases in Germany.
c SNECMA'S contract awards are from CFM International, a joint venture with General Electric of Fairfield, Conn.
d canadian Commercial Corp. is a Canadian government agency that processes DoD contracts for Canadian companies.
e European Utilities Companies represents the aggregate of utilities contracts for U.S. bases in Europe.
SNECMA = National Company for the Design and Construction of Aircraft Engines

SOURCE: James Kitfield, "Stepping Back From Reform," Government Executive, vol. 22, No. 8, August 1990, p. 26.

ments, which may involve coproduction and technology transfer.[8]

Ownership Perspective

A second policy perspective is provided by categorizing according to ownership the various companies and organizations that make up the DTIB. The majority of the base is privately owned and operated, although the government may own some of the equipment at particular facilities. A matter of some concern is the increasing foreign ownership of defense firms. While still very small, it could grow as a result of the need for additional capital.

There is also considerable public ownership in the defense industry. Currently, about one-third of the aircraft industry's facilities are government-owned, as are almost all of the fina1 assembly operations for artillery and tank munitions.[9] While DoD relies primarily on private industry to support defense production, it is U.S. Government policy, based on the Defense Industrial Reserve Act (50 U.S.C. 451), to maintain "a minimum essential nucleus (industrial reserve) of government-owned plants and equipment to be used in an emergency."[10] This government-owned portion of the base has shrunk in recent years but may become relatively more important in the wake of significant reductions in defense budgets and the resulting loss of commercial capacity.

[8] U.S. Congress, Office of Technology Assessment, *Arming Our Allies: Cooperation and Competition in Defense Technology*, OTA-ISC-449 (Washington, DC: U.S. Government printing Office, May 1990), pp. 9-18.
[9] Gansler, op. cit., footnote 5, p. 240.
[10] Office of the Secretary of Defense, "GOCO Policy Statement" Aug. 22, 1989, p. 1.

Private Sector

Before World War II, private business was not extensively involved in defense manufacturing, with the exception of the aviation industry. Business was brought into defense work because of the need for rapid expansion of weapons production and the belief that the private sector is more innovative and efficient than the government sector. The involvement of private enterprise moved to the forefront issues of fairness, access, and profits. Because defense contracting is public work for the common national good, large profits are politically unacceptable, and business has always been justifiably cautious about taking large risks under such conditions. During World War II, the U.S. Government minimized business risk by building defense plants, paying for equipment and tooling, and asking the private sector to run them. The same was true during the initial cold war mobilization, when the U.S. Government paid for almost all the equipment and facilities needed by the private sector, obviating the need for much capital.

That situation has changed over time. Costs of equipment and facilities were increasingly fma.need by business, while changes in tax laws reduced fins' working capital. Congressional concern over instances of fraud, waste, and abuse in contracting in the 1980's resulted in numerous new laws and regulations that often reduced productivity as much as they prevented crime. Thus, despite the rhetoric, the private sector of the defense industry does not conduct business in a free enterprise system. Instead, as the Defense Science Board noted, the defense industry

> . . . is characterized at the prime contractor level by a single buyer (the government) and relatively few suppliers. Exercising its monopsony power, the government has created a regulated industry, similar to a public utility.[11]

The implications for the defense industry of both private ownership and government monopsony (single-buyer) power-creating business risk while limiting potential profits--continue to be insufficiently appreciated in policy development.

Government-Owned/Government-Operated

During and immediately after World War II, there was a large and diverse array of government-owned/ government-operated (GOGO) defense-industrial facilities, ranging from naval shipyards to coffee roasting plants. Beginning in the Eisenhower Administration, most of these facilities were closed or sold off. The remaining GOGOs are oriented toward the production of specialized military systems that have no counterpart in the civilian sector, or the repair and maintenance of existing systems. For example, the Army arsenal at Watervliet, New York, manufactures gun tubes for U.S. artillery. The Army tank rebuild and overhaul facility in Anniston, Alabama, serves chiefly as a repair facility, but like virtually all DoD depot-level repair facilities it has a substantial manufacturing capability that includes unique machinery and welding facilities.

In the R&D area, the government also has some unique government-owned/government-operated laboratories and test facilities. Some of these installations (e.g., China Lake Naval Surface Weapons Laboratory, the Air Force's Wright Laboratories, and the Army's Harry Diamond Laboratories) provide a Service capability for evaluating private R&D development as well as conducting research of their own; others, such as the Department of Energy's Nuclear Test Site and NASA's Langley Wind Tunnel, provide a unique national capability.

The size of the government-owned base is currently under review, including studies on the consolidation of both R&D and industrial facilities.[12] The Services argue that the government facilities are already being reduced to a bare minimum and that further reductions should be undertaken with great caution. Since major cuts in defense spending are likely to affect the various GOGOs in different ways, it is important how the cuts are made. For example, reduction in overall procurement and stretch-out of programs might result in the Services' doing more in-house manufacturing in addition to repair. In a

[11] Office of the Under Secretary of Defense for Acquisition, *The Defense Industrial and Technology Base,* vo1. I (Washington DC: December 1988), p. 12.

[12] The Army's Vision 2000 Report addressed the consolidation of both laboratories and logistics support. The Navy is consolidating its laboratory system, while the Air Force is consolidating its logistics and system commands. The Air Force and Navy appear to be ahead of the Army in many of these efforts. A joint DoD effort is considering a consolidation of functions between Services (aircraft engines to a single Service, for example) and changes in defense laboratories. See also Michael E. Davey, *Defense Laboratories: Proposals for Closure and Consolidation (Washington DC: Congressional* Research Services, 1991).

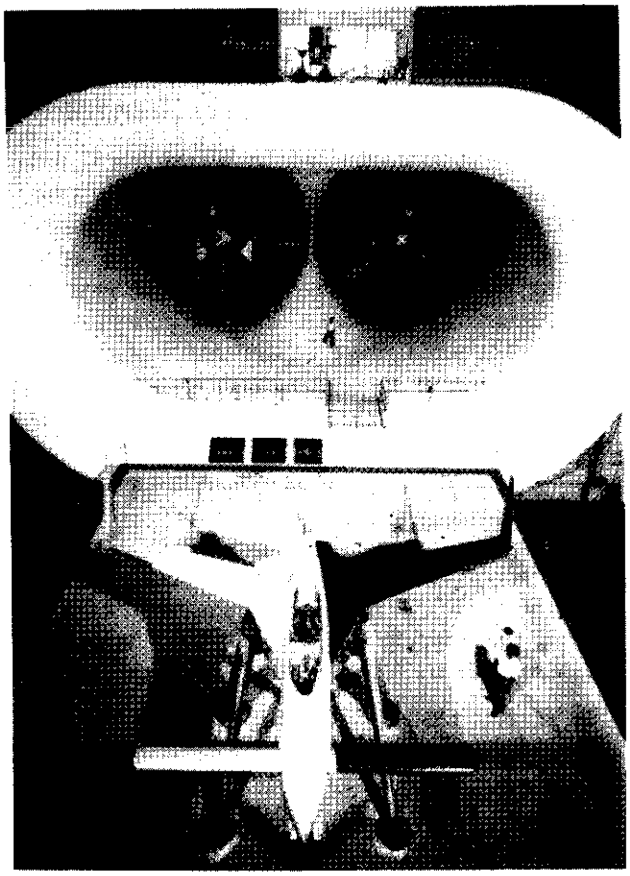


Photo credit: NASA

NASA Langley Wind Tunnel in Langley, VA, is a government-owned, government-operated (GOGO) test facility that provides a unique national capability.

period of reduced procurement, however, maintenance and repair work can help maintain the viability of private firms that will be needed to develop and manufacture the next generation of weapon systems. Allocation of maintenance contracts should therefore take into account the tradeoff between the need to preserve capabilities in the private sector and the need for a secure and responsive Service maintenance base. This tradeoff is discussed in greater detail in chapter 5.

Government-Owned/Contractor-Operated

In addition to the GOGOs, there are government-owned/contractor-operated (GOCO) facilities active in the R&D, production, and maintenance components of the defense technology and industrial base. While DoD has reduced the number of GOCO facilities, three major groups remain: Army-owned ammunition plants, Service-owned manufacturing facilities, and the nuclear weapons R&D and production complex run by the Department of Energy (DOE). In 1989 the Services owned 63 GOCOs with an initial acquisition cost of more than $64 billion.

Contractors run the Army ammunition plants or maintain them in an inactive status. Future force reductions will result in more of these plants being placed in reserve or closed altogether, although demand for ammunition will be affected by policy decisions on troop strength, readiness, and sustainability, and assumptions about the length of warning time preceding a major conflict. Given sufficient warning (24 to 36 months), new munitions plants could be built from the ground up to support a conflict against a major opponent. Thus, the ammunition production complex might be sized solely to deal with lesser regional conflicts.

Some major weapons systems are produced by private companies in government-owned facilities. For example, the F-16 is produced at Air Force Plant No. 4 in Fort Worth, Texas, while the M1A1 tank is manufactured at the Army Tank Plant in Lima, Ohio, and the Army Detroit Arsenal Tank Plant in Warren, Michigan. While the Army considers many of its facilities essential and wants to maintain ownership, the Air Force is prepared to sell its GOCOs. Interest among potential buyers for these government facilities has been depressed, however, by the adverse fiscal environment for defense programs and the liability associated with cleaning up hazardous wastes.

The U.S. nuclear weapons complex consists of National Laboratories (Los Alamos, Livermore, and Sandia) operated by the University of California and Sandia Corp. (a subsidiary of AT&T), and production facilities operated by commercial contractors, who work under close government supervision and control. The National Laboratories are involved not only in the design of nuclear weapons, but also in production and maintenance activities associated with ensuring weapon reliability. Since technical know-how critical to the manufacture of nuclear weapons belongs to the government, the nuclear weapons complex functions like an arsenal system, and many of the critical technologies for the production of nuclear warheads are maintained at a single site. The current nuclear weapons complex still includes some facilities opened during World War II and many of 1950s vintage, and it would make sense to consolidate the complex in response

Photo credit: General Dynamics

Air Force Plant No. 4 in Fort Worth, TX, is a government-owned, contractor-operated (GOCO) manufacturing facility.

to both reduced East-West tensions and the need for the modernization of facilities. Because of severe environmental contamination,[13] however, the costs of essential site cleanup and consolidation will be considerable, requiring large upfront expenditures before any savings could be derived.[14]

Defense Industrial Sector Perspective

The DTIB can also be divided according to industrial sectors, such as aerospace, shipbuilding, communications, electronics, munitions, and armament. Sectoral analysis is important because the sectors differ markedly in the way they do business and may be affected differently by government policies. The mass production of ammunition is unlike the single-item production of warships, and the problem of maintainingg adequate surge ammunition production between wars differs from the problem of keeping a shipyard open between submarine orders. The sectors also vary greatly in the engineering content of their work, the relative state of U.S. and comparable foreign technology, and integration within the broader civil industrial base. All of these factors should be taken into account in developing policies for the overall DTIB and for each industrial sector in particular.

A 1987 study by the Logistics Management Institute identified 215 industries responsible for 95 percent of defense production, including many industries not normally considered in analyses of the DTIB.[15] According to the study, defense production accounted for 10 percent or more of total U.S. output in 61 industries, and 25 percent or more in 21 industries (see table 3-3). The 40 industries in which defense production accounted for 10 to 25 percent of total output were mainly "supplier" industries: fasteners, ball and roller bearings, and industrial controls. It is in these subtier-level industries that the dependence of defense production on the larger civilian industrial base is most evident, indicating

[13] The environmental problems associated with the nuclear weapons complex are discussed in detail in: Office of Technology Assessment, *Complex Cleanup: The Environmental Legacy of Nuclear Weapons Production, OTA-O-484 (Washington DC:* U.S. Government Printing Office, January 1991).

[14] Department of Energy, *Nuclear Weapons Complex Reconfiguration Study*, Washington, DC, January 1991.

[15] Donna J.S. Peterson, Nicholas R. Chacht, and Paul R. McLenon, *Identifying Industrial Base Deficiencies* (Bethesda, MD: Logistics Management Institute, December 1987).

Table 3-3-Defense Share of Selected U.S. Industries

Standard Industrial Category (SIC) code	Industry name	DoD purchases ($ millions)	DoD purchases as percent of industry sales
3483	Ammunition, except small arms	$3,733	84.5%
3731	Shipbuilding & repair	8,111	79.0
3489	Ordnance & accessories	2,298	72.2
3761	Guided missiles, space vehicles	8,678	71.9
3721	Aircraft	17,104	55.3
3728	Aircraft equipment	11,542	54.3
3795	Tanks & tank components	2,445	52.1
3662	Radio &TV communication equipment	32,610	50.9
3724	Aircraft engines & engine parts	7,174	50.7
3339	Primary nonferrous metals	786	49.3
3825	Electronic measuring instruments	6,517	48.8
3676	Electronic resistors	605	42.1
3482	Small arms ammunition	399	40.4
2892	Explosives	416	39.7
3463	Nonferrous forgings	504	36.7
3675	Electronic capacitors	480	35.7
3811	Engineering & scientific instruments	1,618	34.6
3677	Electronic coils & transistors	431	30.9
3537	Industrial trucks & tractors	1,086	29.5
3674	Semiconductors & related items	4,065	27.6
3678	Electronic connectors	901	25.1

SOURCE: Donna J.S. Peterson, Nicholas R. Chacht, and Paul R. McLenon, */identifying Industrial Base Deficiencies* (Bethesda, MD: Logistics Management Institute, 1987).

the importance to national security of a healthy, competitive, and technologically advanced manufacturing sector.

The integration with the civil sector at these lower subtier levels is complex. For example, there is considerable integration in areas such as bearings and fasteners, in which DoD accounted for 12.1 and 15.4 percent of production respectively in 1986. Yet defense production is also specialized in ways that make it difficult for DoD to retain selected industrial capabilities between procurement cycles. Superprecision bearings are only 6 to 7 percent of the domestic bearing production, but the military consumes 60 to 70 percent of that total.[16]

Functional Area Perspective

A final useful perspective on the DTIB is provided by dividing it according to functional areas:

- research, development, and engineering;
- production; and
- maintenance and repair.

These functional areas generally follow the weapon system life cycle from concept and design, through development and deployment, into operation, and ending with retirement. ‘

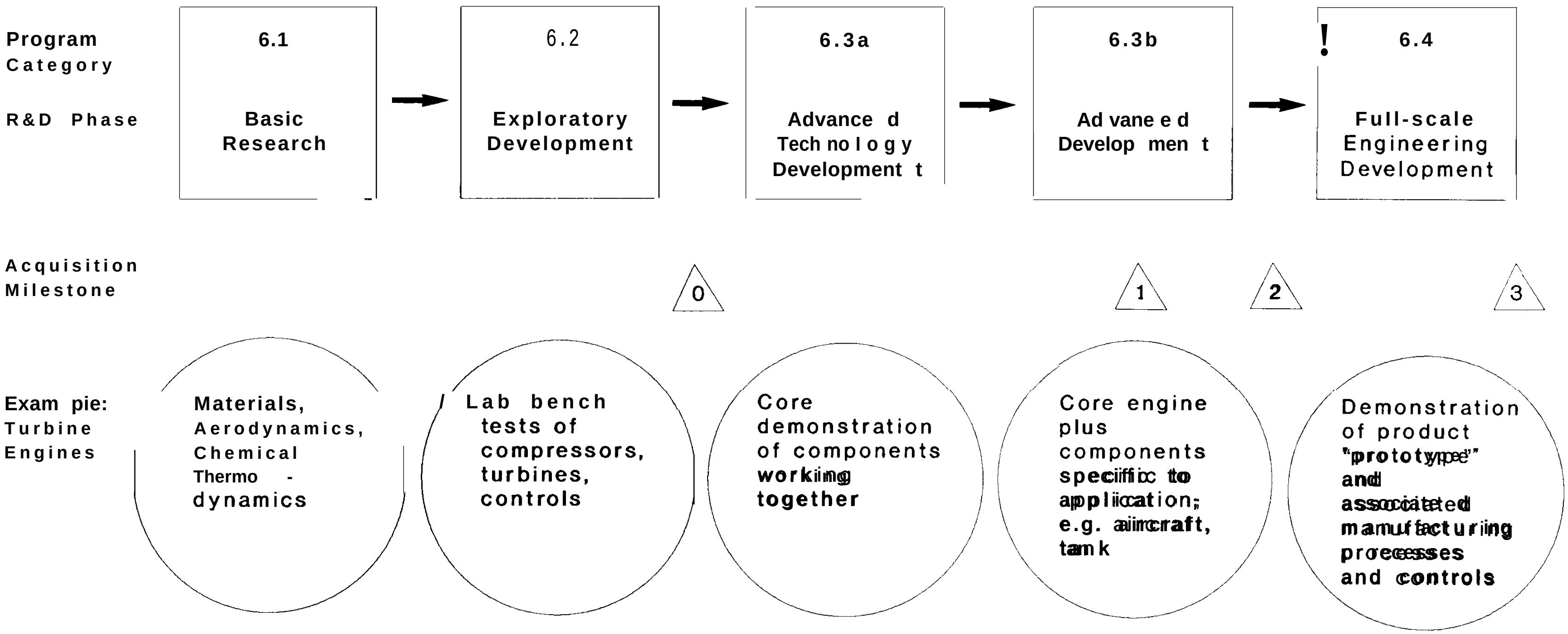
Research, Development & Engineering (RD&E)

The RD&E component of the defense technology and industrial base is located primarily in private industry but, as previously noted, also includes government laboratories and test facilities run by the Departments of Defense, Energy, Commerce, and NASA, and university laboratories conducting research relevant to defense. DoD research and development is composed of several budget categories in order of increasing technological maturity (see figure 3-4): 6.1 (basic research), 6.2 (exploratory development), 6.3A (advanced technology development), 6.3B (advanced development), and 6.4 (full-scale engineering development).[17] Figure 3-5 shows the funding breakdown. As a very rough rule, universities tend to concentrate on basic research, Service laboratories on applied research, and industry on development and engineering. For example, in fiscal year 1990, DoD's total obligation for basic

[16] Joint Bearing Working Group of the Joint Group on the Industrial Base, *Joint Logistics Commanders Bearing Study*, June 18, 1986, p. 5.

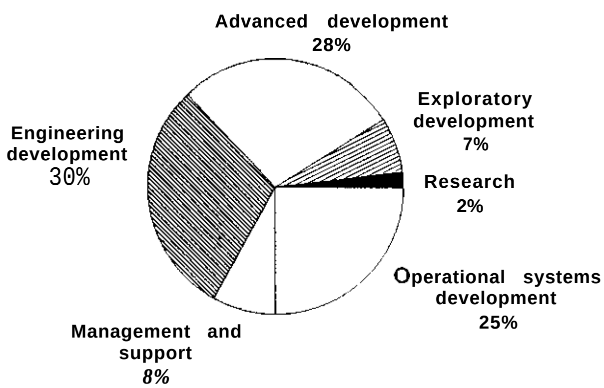
[17] U.S. Congress, Office of Technology Assessment, The *Defense Technology Base: Introduction and Overview*, OTA-ISC-374 (Washington, DC: U.S. Government Printing Office, March 1988), pp. 34-35.

Figure 3-4-Department of Defense Research and Development Process



SOURCE: James Moldenhauer, *Identification and prioritization of 6.2 Technologies Demonstration* (Pasadena, CA: Jet Propulsion Laboratory, 1986), pp. 1-2; and Office of Technology Assessment.

Figure 3-5—Allocation of Research and Development Funding by Function, Fiscal Year 1990



SOURCE: U.S. Department of Defense, Office of the Comptroller, *RDT&E Programs (R-1), Fiscal Yearn1992 and 7993* (Washington, DC: Department of Defense, Feb. 4, 1991), p. II.

research (category 6.1) was $964 million, of which $551 million was spent in universities, $286 million in DoD-operated laboratories, and only $87 million in industry laboratories.[18] In contrast, of the funds spent on advanced development (categories 6.3A and higher), universities received only $264 million, government laboratories $9 billion, and industry $25 billion. Figure 3-6 shows funding and work breakout.

The research phase involves investigating new technologies that have a variety of applications; when a specific application is in sight, much development and engineering work is still required to incorporate the technology into a product. The purpose of the exploratory and advanced development stages is to obtain information about the design and engineering of a new system so that a decision can be made to enter production with adequate confidence about schedule, performance, and cost. Almost all of engineering and development is performed by private-sector contractors, who have the greatest experience in the practical application of knowledge to the production of weapons and components and expect to manufacture a particular weapon system directly related to the R&D. While this private component of the base is critical to the U.S. Government's defense responsibilities, it is

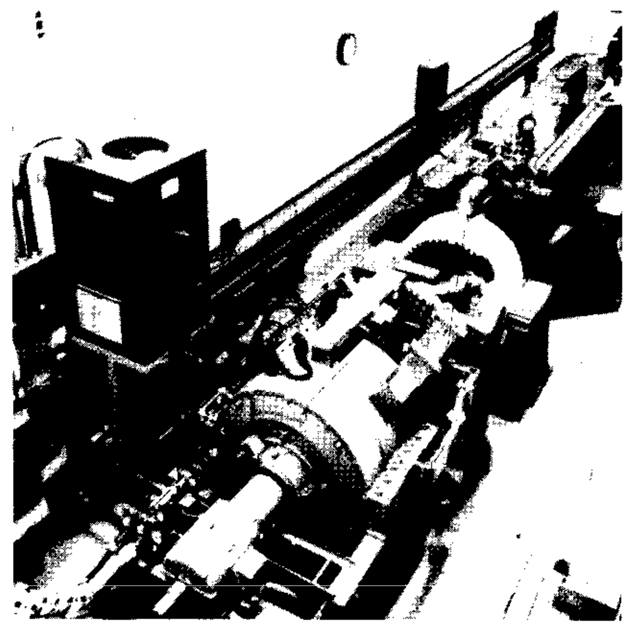


Photo credit: U.S. Department of Defense

Prototype of an electromagnetic cannon undergoes testing at the Picatinny Arsenal in New Jersey, an R&D facility run by the U.S. Army.

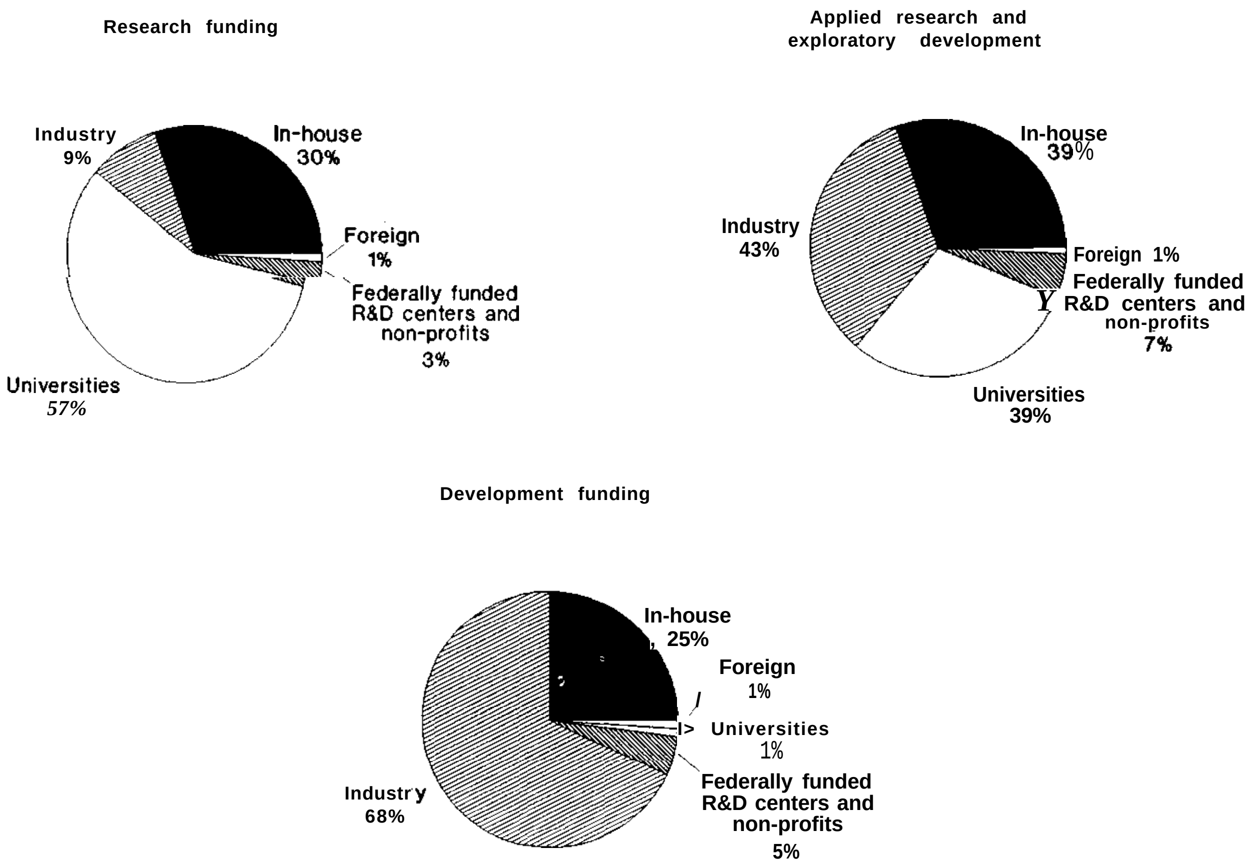
also the most difficult to maintain during a period of declining defense spending.

Corporate research and development is funded either from direct DoD contracts or from company profits generated through sales of goods and services. Many R&D efforts are supported from both sources of funds. For example, while the government may provide a company a contract for the development of a system, the company may also contribute substantial amounts of its own money, which can be justified if the development leads to a profitable production contract.

Defense contractors currently defray some negotiated fraction of R&D expenses through "independent research and development' (IR&D) charges against ongoing contracts; that is, companies can charge some of their R&D as an allowable expense, similar to overhead. In fiscal year 1989, government-allowed IR&D charges totaled $2.2 billion. IR&D is conducted under the supervision of DoD, which must approve the general research areas and amounts but exerts little detailed control beyond review and audit once approval has been given. The companies

[18] National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 1988,1989, and 1990*, vol. 38, NSF 90-306 (Washington, DC: National Science Foundation 1990), p. 35 and 57. Breakouts do not add up to the total because some categories, e.g., nonprofit institutions, are not listed.

Figure 3-6-Allocation of Research and Development Funding by Performer, Fiscal Year 1990



SOURCE: National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 1988, 7989. and 7990,* vol. *38,* NSF 90-308. Detailed Statistical Tables (Washington, DC, 1990), tables 14, 21, and 28.

propose the areas in which to work and keep the commercial rights to developments. Significant design work associated with a specific request for proposal can also be included in a company's bid and proposal (B&P) efforts for future contracts and also recovered as an overhead expense. In 1989, industry recovered $1.3 billion in B&P overhead charges.[19]

There has been some controversy about the IR&D program over the years. Critics argue that IR&D funds are used for research that the companies would probably undertake in any case, and that IR&D creates an added hurdle to market entry for firms that do not have DoD production contracts and hence are not eligible for the funds. Proponents of IR&D counter that since government procurement procedures limit profit, companies need a mechanism to fired R&D. The proponents also contend that the current IR&D approach benefits DoD by allowing companies to stay current in critical areas of defense technology, encouraging technical innovations, and giving government scientists and engineers valuable insights into ongoing industrial research. Other programs, such as the Small Business Innovative Research Grants, are meant to compensate for initial lack of access to IR&D funds by firms entering the defense market.

Of course, if research and development costs are not recoverable as IR&D, nothing prevents companies from paying for some R&D out of their gross profits. Indeed, under freed-price contracts, the actual accounting category does not affect a com-

[19] Information provided by the office of the Secretary of Defense (Research and Advanced Technology), April 1991.

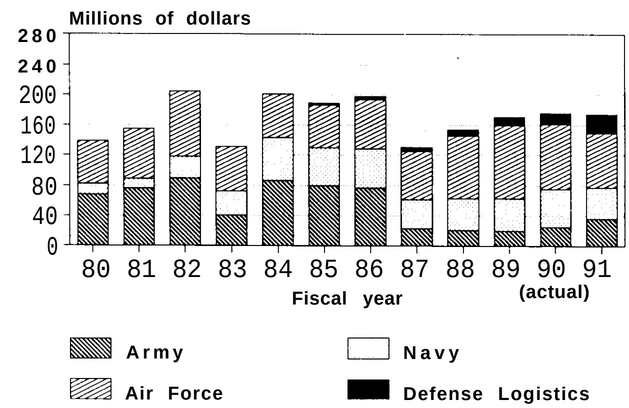
pany's profit because the charges either come out of profit or go into overhead, reducing profit by the same amount. Some firms, especially specialized subtier companies that depend for their livelihood on one technology, are wary of government-sponsored R&D because of potential conflicts over government rights to technical data. These firms prefer, therefore, to support their own R&D out of profits.

Private industry's decisions about research investment are strongly influenced by financial considerations. Since profits come largely from produced weapons, there is a general preference for R&D with a fairly predictable near-term return on investment and hence for product development rather than more basic research. Most firms concentrate on improving existing products and components, or developing new products most certain of gaining acceptance.

In addition to DoD-funded R&D contracted out to the private sector, in fiscal year 1990 over $11 billion was spent in-house by the research, development, and test facilities operated by the individual military Services. The size and missions of Service laboratories vary greatly. Some Service laboratories do basic research, but most focus on application-specific work and may also carry out prototype development. Each Service has a different style and emphasis: Navy laboratories do considerable in-house R&D, including basic research at the 6.1 level; Army laboratories generally focus on research at the 6.2 and 6.3 levels; and Air Force laboratories are organized by technology and emphasize the development of expertise to contract effectively with industry rather than performing extensive in-house research. The Services are currently responding to cutbacks by consolidating their laboratories to preserve in the surviving facilities the minimum number of personnel needed for good research. Test facilities such as those at China Lake and Nellis Air Force Base are particularly crucial because they involve a large capital investment and hence are unlikely to be replicated by the private sector.

The Office of the Secretary of Defense (OSD) does not operate any research laboratories, but it does have the Defense Advanced Research Projects Agency (DARPA), whose mission is to support "high-risk, high-payoff' research. DARPA establishes priorities and funds research carried out either in government or industry laboratories and managed in collaboration with the Services. Although DARPA's charter has caused it to concentrate on the early stages of research, it has also begun to support selected projects to more advanced stages of development to demonstrate proof-of-concept. Such demonstrations are intended to make the Services more likely to apply the results of DARPA-funded research. While DARPA projects cut across Service boundaries, the agency does not have the resources to support a comprehensive technology program alone, nor does it have the explicit role of filling the gaps between Service research programs.

Figure 3-7-Funding of Manufacturing Technology (MANTECH) Program, 1980-91



SOURCE: Office of Technology Assessment, 1991, based on information supplied by the U.S. Department of Defense.

DoD also has access to 10 Federally Funded Research and Development Centers (FFRDCs). These nonprofit institutions include: the Institute for Defense Analyses, the Rand Defense Research Institute, the Logistics Management Institute, the Massachusetts Institute of Technology's Lincoln Laboratory, Mitre Corp., and Aerospace Corp. They provide research and analytical support to OSD and the Services and in fiscal year 1990 had finding in excess of $1.5 billion.

Most military R&D is product rather than process related. Nevertheless, a considerable amount of manufacturing process R&D occurs as firms learn how to manufacture a system. Since this cost is part of overall procurement, however, it is not funded as R&D. This loophole may be particularly important for subtier producers of critical subsystems, who may receive a fixed-price contract from a prime to deliver a particular product.

Box 3-B—Department of Defense Manufacturing Technology Program

U.S. military support for improvements in manufacturing technology can be traced back at least as far as the 19th century, when the Army supported manufacture of interchangeable parts for muskets. Since the Second World War, the military has become increasingly active in manufacturing technology, a prominent example being the Air Force's support of numerically controlled machining. Manufacturing Technology, or MANTECH, has been a formal DoD program to advance defense manufacturing since 1977.

The purpose of MANTECH programs is to improve productivity and responsiveness, with the expectation that these efforts will ultimately reduce defense procurement costs. MANTECH programs support a broad range of manufacturing technologies. For example, the Defense Logistics Agency funds programs to automate the manufacture of uniforms, the Navy to improve shipbuilding technology, the Air Force to lower costs of engine repair, and the Army to speed the inspection of ammunition.

MANTECH and similar programs are needed because defense manufacturers have few incentives to improve productivity under cost-based procurement. In normal commercial manufacturing a company has incentives to improve productivity because profits can be increased by reducing manufacturing costs. In contrast, the price of government contracts are typically based on cost, so that any reduction in cost results in a lower price for the government. Companies benefit indirectly from lower costs by improving their chances of getting the next contract, but not directly by obtaining higher profits. Since the government is the main beneficiary of productivity improvements, it ends up having to pay explicitly for at least some of them.

In general, support for the MANTECH program is stronger from Congress than it is from the Department of Defense (DoD). For example, for the 1991 budget, Congress added $150 million to DoD's $265 million request. Nor has Congress been completely satisfied with DoD's management of the MANTECH program. One result has been Congress' mandate in the 1991 defense appropriation act for a DoD Manufacturing Technology Plan, which is still being developed.

MANTECH is tiny compared to defense procurement programs and is only apart of DoD's efforts to improve manufacturing technology. Much learning is involved whenever a new item is manufactured; for example, a great deal of the technology involved in using composite materials is associated with manufacturing them and incorporating them into products. DoD also supports other manufacturing technology programs. The Defense Advanced Research Projects Agency's SEMATECH program, designed to improve micro-chip manufacturing, is probably the best known. The Strategic Defense Initiative Office also funds research efforts such as improved manufacturing of precision optics. Other sources of funds, such as Independent Research and Development (IR&D), are not earmarked specifically for manufacturing technology but may be used for this purpose.

Measuring the results and effectiveness of MANTECH is difficult because of the program's broad goals. Return on investment can be calculated for a particular project, but MANTECH projects are supposed to have wide applicability. Despite DoD newsletters, technical publications, conferences, and databases, however, there are frequent complaints that the benefits of MANTECH are not adequately diffused throughout industry.

The Services and OSD explicitly fund research on manufacturing process technologies through the Manufacturing Technology (MANTECH) program (see figure 3-7 and box 3-B). Since 1986, the Air Force has most heavily funded MANTECH and the Navy somewhat less so. Prior to that year the Army placed heavy emphasis on MANTECH, but it moved to terminate the program on the grounds that it was too small to accomplish its stated objectives. Although the Army subsequently reinstated its MANTECH program, Army officials favor devoting more resources to manufacturing technology development by providing funds for this purpose in weapon-system production contracts. The 1991 Defense Authorization Act increased MANTECH funding and directed OSD to develop a more coordinated program.

DARPA has also supported manufacturing process R&D through its former Defense Manufacturing Office (DMO), which was established to improve manufacturing know-how, reduce the cost of end-items, and create a production capacity for critical items where one did not exist. Like all DANA programs, DMO-funded R&D was contracted out to industry, government, and university laboratories, and collaboration was encouraged. The office was eliminated in April 1991 and some of its functions transferred to other offices. DMO's best known effort, SEMATECH, a consortium of U.S. electronics firms with the goal of improving semiconductor manufacturing technologies, is now managed by DARPA's Electronic Systems Technology Office.

Defense contractors have few financial incentives to improve manufacturing efficiency. Since the Federal Government is the sole buyer and limits a fro's profits, a defense firm (unlike its commercial counterpart) cannot easily increase its profit margin by reducing manufacturing costs and selling at the old market price. Using its audit authority, the government has available actual costs as the basis for next year's contract negotiations. Because profit is calculated as a percentage of cost, the more efficient the contractor becomes, the less profit it makes.

Congress may want to investigate in more detail how to encourage the manufacturing R&D that is naturally embedded in weapon system production, as well as corporate investments in improved productivity. There are indications that perverse incentives created by the current acquisition process impose more important constraints on manufacturing productivity than any lack of know-how. These constraints are examined in greater detail in the discussion of trends in the base in chapter 4 and in the discussion of policy options in chapter 5.

Other government agencies play important roles in defense R&D. Three DOE laboratories, Lawrence Livermore, Los Alamos, and Sandia, conduct both defense and non-defense research and have primary responsibility for the scientific understanding, design, development, testing, and "surveillance" of nuclear warheads. (The latter term refers to continued testing and quality assurance, which are necessary because of the unstable nature of nuclear materials.) Currently, nuclear weapons responsibilities account for about 40 percent of the work of the three laboratories.

DOE Laboratories also have a secondary but important role in research on advanced conventional weapons and military support tasks, such as communications, intelligence, and arms control verification. These missions accounted for 16 percent of total weapons laboratory funding in 1990, and represented the lion's share of DOE's "work-for-others.

Some of the DOE laboratories are currently involved in consortia seeking to develop innovative manufacturing capabilities for the Strategic Defense

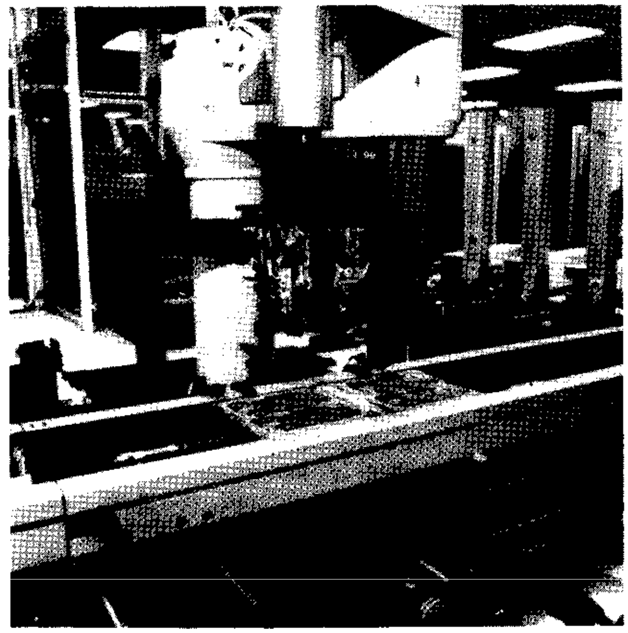


Photo credit: General Dynamics

Robot assembles electronic circuit boards for the Army's SINCGARS radio system at the automated General Dynamics plant in Tallahassee, FL.

Initiative. A Manufacturing Operations Development and Integration Laboratory (MODIL) specializing in survivable optics is located at Oak Ridge National Laboratory, while a second MODIL at Sandia National Laboratory is devoted to advanced infrared sensors and signal processing. These MODILs draw together government, industry, and university participants to develop and demonstrate new production and automation processes for specific technologies.

Other research by the national laboratories in non-defense fields (energy, environment, etc.) helps to maintain a pool of scientific and engineering talent and knowledge that could be helpful for meeting future military needs. Indeed, one expected benefit of mixing defense and nondefense work at the same laboratories is that mutually beneficial cross-fertilization will occur.

The Department of Commerce's National Institute of Standards and Technology (NIST) specializes in measurement technology (metrology) and performs some research and testing for DoD, including long-ten-n basic research. In fiscal year 1991, DoD-funded work performed by NIST amounted to just under $60 million. Of particular importance to industrial base issues is that NIST sets standards for

Table 3-4-Defense Procurement Funding (Budgetary Authority) for Fiscal Years 1990-93

	Procurement funding ($ millions)				Total percent change 1990-93
	FY1990 (actual)	FY1991 (estimate)	FY1992 (estimate)	FY1993 (estimate)	
Army					
Aircraft	3,703	1,080	1,667	1,247	-66
Missiles	2,463	2,044	1,106	1,342	-46
Weapons/tracked vehicles	2,495	1,903	839	574	-77
Ammunition	1,861	1,248	1,250	1,195	-36
Other procurement	3,532	2,457	3,164	3,254	-8
Navy					
Aircraft	9,158	6,150	7,217	6,953	-24
Weapons	5,278	5,623	4,531	4,755	-lo
Shipbuilding and conversion	11,210	9,789	8,759	8,298	-26
Other procurement	7,599	5,520	6,459	6,521	-14
Marines					
Total procurement	1,162	650	1,010	651	-44
Air Force					
Aircraft	15,414	9,322	10,916	13,457	-13
Missile	6,371	5,498	5,842	6,777	+6
Other	8,491	7,582	8,058	8,869	+4
Defense agencies					
Total procurement	1,351	2,433	2,112	2,201	+63
National Guard & Reserves	988	2,464	NA	NA	NA
Defense Production Act	50	50	NA	NA	NA
Chemical agents and munitions	88	101	—	—	—
	81,214	63,914	60,818	66,094	-19

NA-Not available.

SOURCE: U.S. Budget for fiscal year 1992.

both civil and military producers, for example in automated manufacturing.[20]

Production

The production component of the DTIB,1ike the R&D component, is made up primarily of private firms but also includes both government-owned/government-operated and government-owned/contractor-operated facilities. Defense procurement funds authorized for fiscal year 1990 were $81.2 billion[21] directed toward a wide range of production programs (see table 3-4), and roughly another $23 billion in procurement through the central supply and maintenance spending in the operations and maintenance accounts. Procurement budget authority has been falling in constant dollars since fiscal year 1986. Despite several years of continued high outlays of funds as previously ordered systems are built, defense firms and the financial markets have already begun adjusting to planned reductions in defense spending in the 1990s.

The production component of the DTIB has been important during the cold war not only for the weapon systems it has produced, but because it has been key to maintaining the overall health of the base. The expectation of profitable production runs has kept companies in the defense business, and production has helped pay for corporate R&D. As noted earlier, IR&D funding is tied directly to procurement. Further, contractors may spend their own money on research for decades in anticipation of a future production run that will result in improved profits for the firm. Production, then, has long been the "engine" of the DTIB. For this reason, the expected reduction in production contracts is viewed with much concern.

The actual number of firms in the defense production base is difficult to determine precisely. In March 1989, the Pentagon reported that somewhat over 9,000 production facilities had been identified as planned emergency producers for surge or mobili-

[20] Data provided by the National Institute of Standards and Technology, January 1991.

[21] This figure does not include the tens of billions of dollars in the operation and maintenance accounts for supplies and materials and equipment.

zation.[22] Yet such "planned producers" represent only a small fraction of the overall defense production base. Much of this base is, as noted earlier, composed of manufacturing firms that supply components and parts to firms having direct contracts with the Department of Defense. These subcontractors in turn purchase parts from lower tier suppliers.

Production planning requires a tradeoff between efficient peacetime production of weapons and wartime responsiveness. The production component has also been most heavily affected by many of the defense acquisition rules. Critics contend that these rules, mandating methods of manufacturing, auditing, special testing, and so forth, have increasingly isolated producers of defense goods from the broader industrial base.

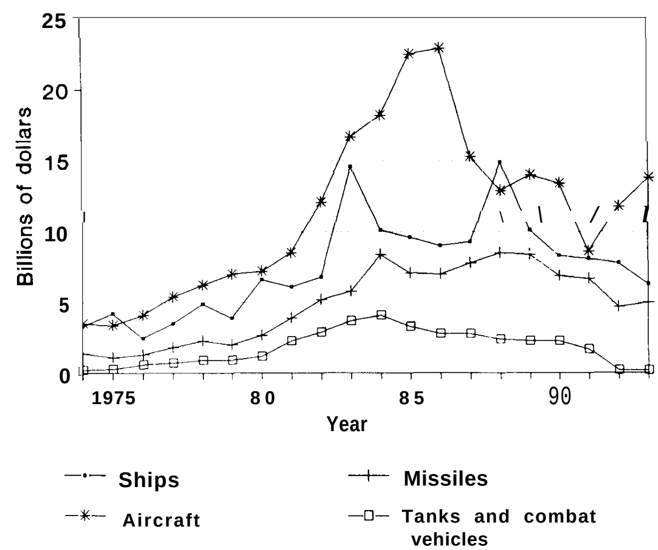
The procurement reductions since 1986 have had a negative effect on almost all programs (see figure 3-8). Aviation has been particularly hard hit and a number of other programs are scheduled to be terminated or greatly reduced. As a result, production rates will continue to show a strong downward trend. Few new major programs are expected over the next 5 years other than the Army's Light Helicopter and the Air Force's Advanced Tactical Fighter. The effects on firms will be significant, since the defense industry currently possesses enormous overcapacity at the prime contractor level.

Studies over the last decade have also indicated a decline in the number of subtier defense suppliers. These findings have given rise to two sets of concerns:

- that the remaining defense suppliers will have inadequate capacity to respond to a surge or mobilization requirement; and
- that the declining number of suppliers will result ultimately in a total loss of domestic capacity and critical skills in key sectors.

The degree to which either of these concerns is valid in the c-merit situation is a matter of debate. A major unknown is the Nation's future requirement for surge or mobilization. Another unknown is the number of firms that are capable of supporting U.S. defense needs but choose not to do business with the government.

Figure 3-8--Procurement of Major Weapon Systems, Fiscal Years 1974-93 (currant $)



SOURCE: Raymond J. Hall, "Total Quantities and Costs of Major Weapon Systems Procured, FY 1974-93" (Washington, DC: Congressional Budget Off"me, 1991), pp. 1-2.

Maintenance and Repair

The maintenance and repair component of the DTIB consists of government facilities such as Naval Shipyards, Naval Aviation Depots, Air Logistics Centers, and Army Arsenals and Depots (see table 3-5), as well as private firms that maintain and repair equipment either at their own facilities or in the field. Maintenance and repair, always a critical factor in supporting military forces, will be increasingly important in a period in which equipment is retained for extended periods.[23]

DoD's in-house maintenance and repair facilities contain unique rebuild, overhaul, and manufacturing capabilities. While organic maintenance capabilities attached to operating forces can be expected to decline in rough proportion to reductions in force levels, the potential effect on depot-level facilities is less predictable. Over the short term (5 to 10 years), retirement of older systems associated with force reductions may greatly diminish maintenance requirements. After that point, however, equipment will probably be retained longer and upgraded rather than replaced. Thus, in the long run (10 years or

[22] U.S. Department of Defense, Office of Industrial Base Assessment, *A Guide for Industrial Mobilization,* March 1989, PP. 1-2.

[23] Studies indicate that 50 percent of the total cost of a weapon system are attributed to the operations and maintenance costs over tie life of the deployed systems. Not only does this make maintenance and repair capabilities important, but it should also increase the importance of maintainability and reliability as design factors in weapons systems.

Table 3-5-Principal Maintenance and Repair Facilities

Army
Anniston Army Depot
Corpus Christi Army Depot
Letterkenny Army Depot
Lexington Bluegrass Army Depot
Red River Army Depot
Sacramento Army Depot
Tobyhanna Army Depot
Tooele Army Depot
Air Force
Oklahoma City Air Logistics Center, Tinker AFB
Ogden Air Logistics Center, Hill AFB
San Antonio Air Logistics Center, Kelly AFB
Sacramento Air Logistics Center, McClellan AFB
Warner-Robins Air Logistics Center, Robins AFB
Aerospace Guidance and Metrology Center, Newark AFB
Wright-Patterson AFB
Navy
Norfolk Naval Aviation Depot
Cherry Point Naval Aviation Depot
Jacksonville Naval Aviation Depot
Pensacola Naval Aviation Depot
North Island Naval Aviation Depot
Alameda Naval Aviation Depot
Navy Ordnance Station, Indianhead
Norfolk Naval Shipyard
Philadelphia Naval Shipyard
Portsmouth Naval Shipyard
Charleston Naval Shipyard
Long Beach Naval Shipyard
Puget Sound Naval Shipyard
Mare Island Naval Shipyard
Pearl Harbor Naval Shipyard

SOURCE: Office of Technology Assessment, 1991.

more) DoD maintenance facilities may receive more work despite lower force levels. The ongoing consolidation and streamlining of government facilities must therefore maintain critical skills for the future even while reducing the current workforce.

In addition to GOGO maintenance facilities, private contractors do substantial repair and overhaul work for all of the military services. Private fins, facing the downturn in new procurement, see repair, overhaul, and upgrades as a means to maintain their manufacturing capabilities and stay in business. Although the Services reserve a critical minimum amount of work for in-house facilities to ensure that core capabilities are retained and can be made available in a responsive manner, DoD plans to contract work above this minimum on a competitive basis between Service facilities and private fins.

MANAGEMENT OF THE BASE

After World War II, several key pieces of legislation were passed to retain an armaments production and mobilization base for future crises. The Strategic and Critical Stockpiling Act of 1946 established the national strategic stockpile of raw materials. The National Security Act of 1947 contained provisions for the creation of a National Security Resources Board to advise the President on military, industrial, and civilian mobilization and on programs for the effective wartime use of U.S. natural and industrial resources,[24] and the retention of the Munitions Board to coordinate industrial base activities within DoD.[25] The Armed Forces Procurement Act of 1947 provided a means for the Defense Department to build an industrial mobilization base by taking national security interests into account when awarding defense contracts. The Industrial Mobilization Plan of 1947 formed the basis for industrial preparedness planning and created the physical plant program for the DTIB.[26] This plan envisioned the mobilization of the Nation's resources as a fundamental aspect of national security and considered peacetime investment in mobilization capacity. Finally, the National Industrial Reserve Act of 1948 enabled the Secretary of Defense to husband certain industrial capabilities for emergency defense uses.[27]

Responsiveness

The flurry of legislation enacted at the close of the 1940s under the rubric of mobilization planning established the legal basis for the DTIB that exists today. In response to the outbreak of war in Korea and concern over the possibility of escalation,

[24]*The National Security Act of 1947*, Title I, sec. 103.

'Ibid., sec. 213.

[26]Ibid., pp. 9- I 1. Annex 47 of the 1947 plan detailed the objectives of the plant survey and allocation program: 1) to determi e where essential military items can be obtained; 2) to eliminate competition among procurement agencies for output of a single plant; 3) to acquaint industry with its task in wartime and to encourage industrial planning for rapid expansion; 4) to promote orderly distribution of the initial production load of war requirements; 5) to maintain a current record of competent producers and their capacities; 6) to determine what required items cannot be provided by conversion of private industry in order to establish requirements for construction of new facilities; and 7) to minimize requirements for new construction by proper utilization of existing facilities.

[27]Roderick L. Vawter, *Industrial Mobilization: The Relevant History (Industrial College* of the Armed Forces Study in Mobilization and Defense Management Washington, DC: National Defense University Press, 1983), pp. 8-9.

President Truman declared a national emergency and ordered a mobilization effort far in excess of the immediate requirements of the Korean conflict. The Defense Production Act of 1950 provided the authority to expand overall national industrial production capacity and to manage the base during the conflict. Various portions of the Act remained in effect until its expiration in October 1990; a reauthorization of the Act is currently being debated.

Emergency preparedness functions are controlled by Title 50 of the U.S. Code, Presidential directives, and Executive orders. Under Title 10, U.S. Code, Chapter 148, "Defense Industrial Base," the major responsibility for defense-industrial responsiveness planning belongs to the Department of Defense. DoD manages the industrial base program through a series of production base analyses (PBAs), which support industrial preparedness planning for force regeneration over a wide range of crises and emergency situations. This process complements the strategic planning system employed by the U.S. Joint Chiefs of Staff, who develop mobilization requirements on the basis of critical items lists prepared by U.S. military commanders throughout the world.

A key to meeting the Nation's potential wartime requirements in the 1990s and beyond will be to determine the role of the DTIB in deterrence and response to warning. The national security community has sought a range of options to deal with crisis-options that could signal determination, provide flexibility, and, ultimately, deter conflict.[28] Starting in the mid- 1980s, defense analysts proposed the notion of incremental response to crisis or war based on the formal military Defense Alert Condition (DEFCON) scheme. This approach later evolved into the concept of Graduated Mobilization Response (GMR), which "provides a system for developing and implementing mobilization actions . . . responsive to a wide range of national security threats and ambiguous and specific warning indicators."[29] GMR actions are designed to enhance deterrence, mitigate the risk of a crisis, and reduce significantly the lead time associated with mobilization should the crisis intensity.

Within the Department of Defense, GMR is viewed as both a near-term mobilization planning tool and as a hedge against the long-term reconstitution of Soviet military power. Testifying before the Senate Committee on Foreign Relations, Under Secretary of Defense for Policy Paul Wolfowitz commented:[30]

> We must also be prepared to respond over a much longer period of warning to any future Soviet attempt to reconstitute its strategic theater capability. With this in view, crisis management capabilities and graduated mobilization responses to assure continuing deterrence will become relatively more important than in the past.

Peacetime Acquisition

General government procurement policy is contained in Titles 40 and 41 of the U.S. Code, while defense procurement policy is contained in Title 10 (Armed Forces). These statues have been translated into regulations known as the Federal Acquisition Regulations (FAR), which govern contracting procedures, and supporting DoD and Service directives.

As a result of the Military Reform Act of 1986 (the Goldwater-Nichols Act), the Department of Defense established the position of Under Secretary of Defense for Acquisition (USD(A)), responsible for all DoD industrial and technology base programs except the Strategic Defense Initiative Organization. The Defense Management Review conducted by Secretary of Defense Cheney noted that the USD(A)'S authority on acquisition extends to "directing the Secretaries of the Military Departments on the manner in which acquisition responsibilities are executed by their Departments."[31]

The Goldwater-Nichols Act further required the individual Armed Services to appoint Service Acquisition Executives, who manage the weapon procurement activities of subordinate Program Executive Officers (PEOs). The PEOs, in turn, oversee Program Managers for each major system. The Service Acquisition Executives also participate in the Defense Acquisition Board, which reviews procurement milestones for major weapon system programs and makes recommendations to the Secretary of Defense regarding continuation and required

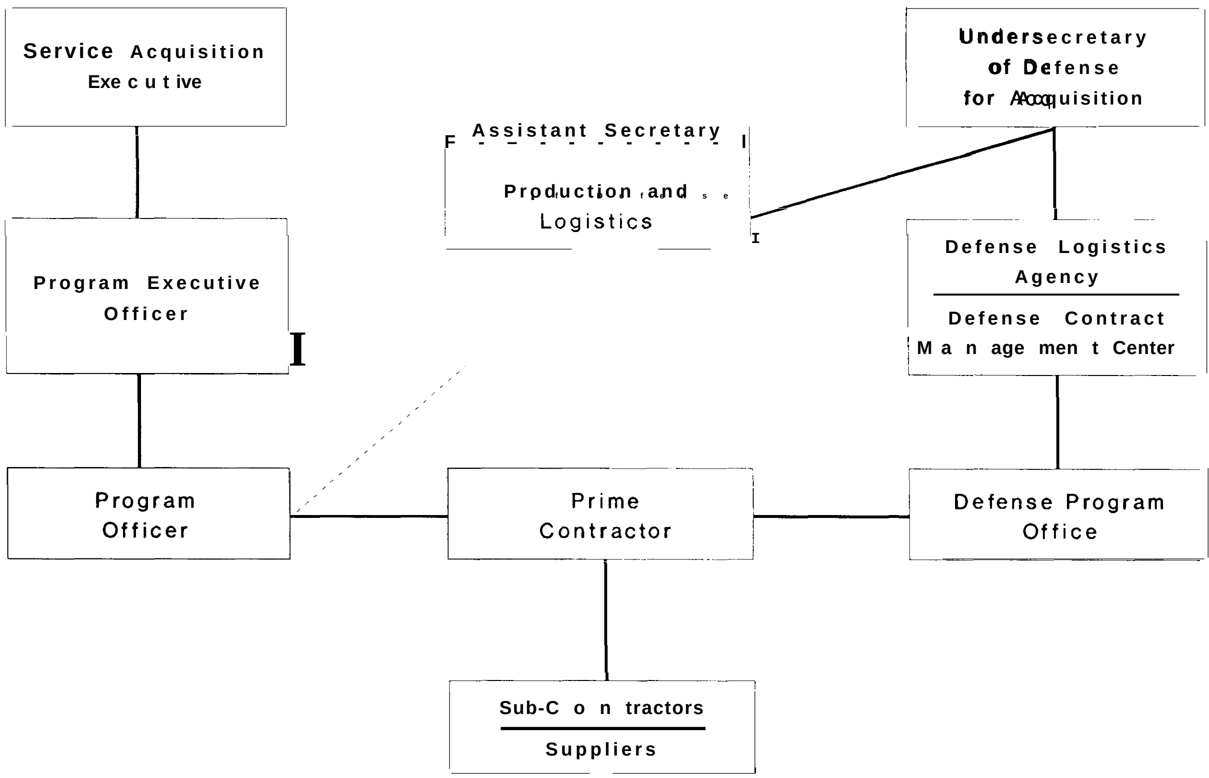
[28] Frank Carlucci, National Security Council Memo 1063/1, "National Security Emergency Preparedness priorities," Sept. 15, 1987.

[29] 44 CFR Part 334, "&adwted Mobilization Response," Jan. 19, 1990.

[30] Paul Wolfowitz, "Statement Before the Senate Committee on Foreign Relations," April 1990.

[31] Secretary of Defense Richard Cheney, *Defense Management Report to the President*, July 1989, p. 3.

Figure 3-9-Management Structure of a Typical Weapon Acquisition Program



SOURCE: U.S. Department of Defense briefing, April 1991,

levels of funding. The management structure of a typical weapon acquisition program is illustrated in figure 3-9. This structure is said to allow oversight over program cost and progress by both the Services and OSD.

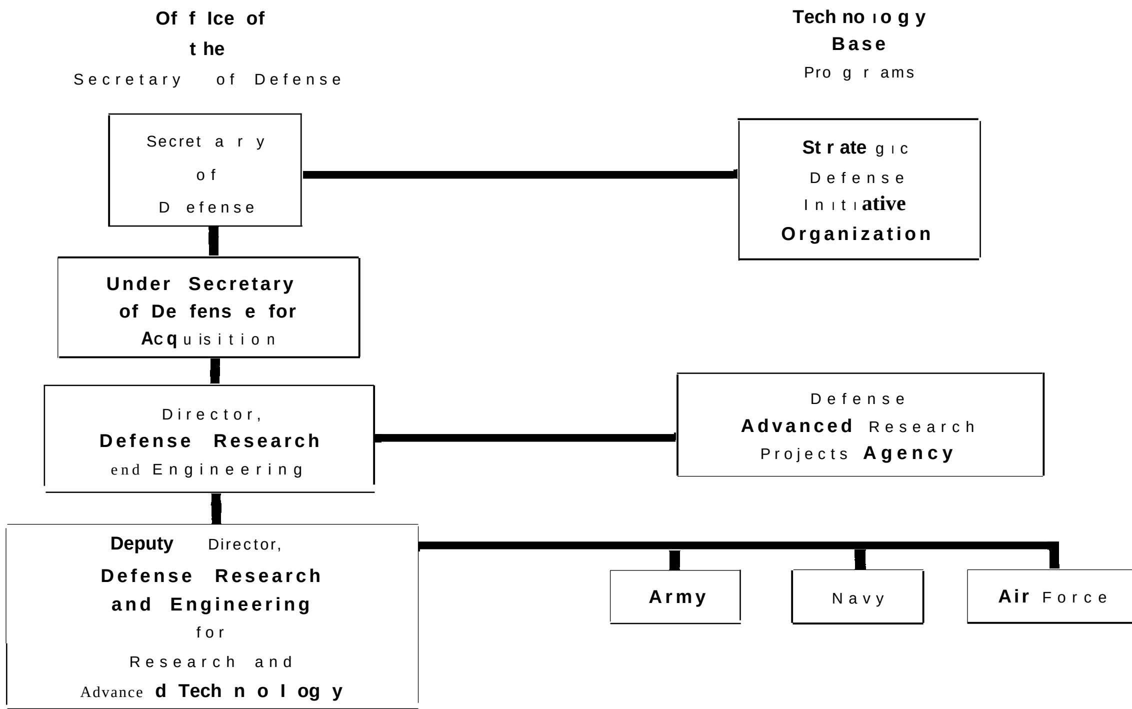
At present, management of defense R&D is dominated by the individual Services. Each Service not only runs its own laboratories but sets its own research priorities and goals, on the grounds that it is best placed to determine its technology strategy and funding levels.[32] The drawback of this approach is that the Services' technology base strategies are geared to maximize their respective military missions, with little coordination among them in the interest of overall national security needs. As the defense laboratory system shrinks, coordination at a high level may be required to avoid both redundancy and gaps in coverage.

In particular, some critics contend that the Nation's overall security interests would be better served by stronger guidance and control of technology programs from a central OSD source.[33] While OSD's Defense Guidance document does provide some technology planning guidance, it has been criticized as superficial and has had little impact on the direction of Service technology efforts. Furthermore, the Services, DARPA, and the Strategic Defense Initiative Organization (SDIO) report to different levels of the OSD bureaucracy, making an overall R&D strategy virtually impossible to develop or implement (see figure 3-10). Although the Service Chiefs of Research have recently begun to coordinate their basic research programs, a reorganiza-

[32] See, for example, the Air Force's *FY 1990 Technology Area Plans*, the Army's *Technology Base Master Plan*, and the Navy's *Exploratory Development (6.2) Investment Strategy.*

[33] Frederick Riddell et al. (eds.), *Report of the Task Force for Improved Coordination of the DoD Science and Technology program* (Alexandria, VA: Institute for Defense Analyses, Report R-345, August 1988), p. 3.

Figure 3-10-Department of Defense Management Structure for Research and Development



SOURCE: U.S. Congress, Office of Technology Assessment, *Holding the Edge: Maintaining the Defense Technology Base,* OTA-ISC-420 (Washington, DC: U.S. Government Printing Office, April 1989), p. 21.

tion of DoD's research management structure may be necessary to achieve greater efficiency.

Logistics, maintenance, and repair are essentially handled as Service functions. As previously noted, however, the consolidation of some of these functions across Services is being undertaken as a cost-saving measure.

In recent years, the legislative branch has exerted influence over the management of the DTIB, both directly (e.g., the Goldwater-Nichols Act) and indirectly through appropriations and hearings. The massive increase in defense spending in the 1980s, and the perception of pervasive "fraud, waste, and abuse" that accompanied some spending scandals, caused Congress to increase its oversight.[34] As a result, DoD is currently monitored by 30 committees, 77 subcommittees, and 4 panels in the process of budgeting, authorizing, appropriating, overseeing, and investing defense resources each year.[35] Critics contend that the redundancy and complexity of the congressional oversight process, and the extensive reporting requirements, impose a burden on DoD that constrains its ability to manage. They further argue that the yearly budget cycle that dominates procurement makes it extremely difficult to conduct longer range planning and inhibits industry investment in improved manufacturing productivity.

SUMMARY

A comprehensive view of the DTIB is possible only by combining several different perspectives, the major ones having been outlined in this chapter. Although one can talk of the DTIB as a coherent

[34] J. Ronald Fox with James L. Field, *The Defense Management Challenge: Weapons Acquisition* (Boston, MA: Harvard Business School Press, 1988), pp. 72-84. Fox believes that this resulted in micromanagement as evident in the numbers of hearings held, committees and staffs involved, details of legislation written, and the number of reports required. "The 1985 budget request contained 1,890 separate line entries for procurement and 897 program requests for R&D. A joint Senate-House conference committee eventually authorized 92.5 percent and 94.4 percent of the Budget Authority requested by the Administration for procurement and R&D, respectively. Nevertheless, the HASC and SASC together changed. ..23.3 percent of the procurement line entries, and. . . 35.3 percent of all R&D programs." He also noted that "in 1985, the Pentagon was able to identify 458 congressional reporting requirements stemming from prior years' defense authorization and appropriation bills and their accompanying reports."

[35] *Defense Management Report to the President,* footnote 31, p. 24.

entity, it is clearly a complex mixture of government and private ownership, large and small fins, R&D- and production-oriented organizations, and domestic and foreign sources. Moreover, the structure of the base is in constant flux. The private/public ownership mix is changing, and the importance of particular industrial sectors will shift as new types of weapons are developed. As a result, no single perspective can describe more than one or two aspects of the base. Distinctions based on one perspective, such as between public and private ownership, may be outweighed by other factors such as the size of the firm.

While the complexity of the DTIB makes it difficult to formulate universal policies, good management practice argues against trying to develop individualized measures for each defense-industrial sector and firm. The challenge that the complex structure of the base poses for Congress is to develop policies broad enough to be manageable, yet sufficiently tailored to be effective.