Department of Defense Laboratories | 6

The U.S. Department of Defense (DoD) spent approximately $9,9 billion on research and development (R&D) in its laboratories and test and evaluation (T&E) facilities in 1992.[1] While more than half of these funds went to industry and university contractors, DoD facilities still spent approximately $4.7 billion in-house. The end of the Cold War will undoubtedly cause some consolidation and downsizing of defense labs and closure of individual facilities, but unlike the Department of Energy's nuclear weapons labs, which may be facing some fundamental changes in character and mission, basic changes in mission seem unlikely for DoD labs as a whole. Their budgets have declined only slightly in real terms since 1989, and current plans to consolidate and shrink the laboratory system do little to alter their fundamental defense mission.

Nevertheless, some opportunities exist for DoD labs to contribute to U.S. industrial competitiveness. Congress, the Bush Administration, and the Clinton Administration have all encouraged the defense labs to take a more active role in working with commercial industry through cooperative research and development programs. Industry can gain from these programs through cost-shared R&D, access to lab facilities, and the expertise of lab personnel. DoD can benefit from the contribution of commercial partners to R&D programs and from the possibility that partners may become cost-effective sources of dual-use technology.

Despite a slow start in the mid-1980s, DoD's cooperative R&D programs have grown considerably in recent years. Many

[1] This figure represents 26 percent of the $38.8 billion DoD spent on RDT&E in 1992. Of the funding for labs and T8zE centers, 3 percent was for basic research 10 percent was for applied research, and 86 percent was for development (primarily early stages of development).

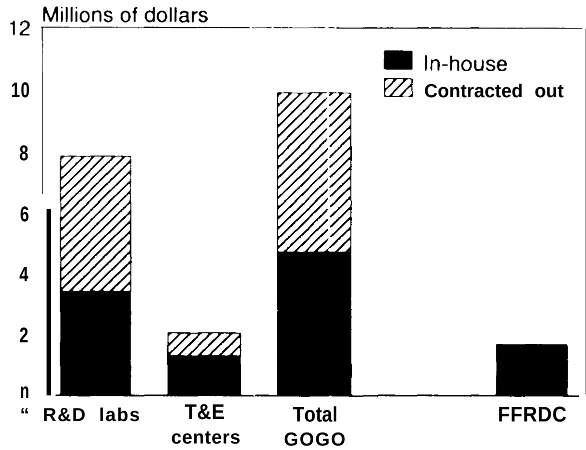
cooperative research projects are conducted with traditional defense contractors who may not be the best conduit for transferring technology to commercial markets, but the services have stated their intention to engage more commercial participants.

RDT&E IN DOD FACILITIES

By some measures, DoD operates the largest lab program in the Federal Government. In addition to the $9.9 billion that DoD budgeted for its own government-owned, government-operated (GOGO) research, development, test, and evaluation (RDT&E) facilities in 1992, another $1.7 billion went to Federally Funded Research and Development Centers (FFRDCs).[2] Though privately owned and operated, these FFRDCs perform most of their work for DoD. DoD's combined expenditures on GOGO R&D labs and T&E centers and on FFRDCs exceed those of all other agencies in the Federal Government; however, much of the money budgeted to DoD's government-owned labs is contracted out to industry and universities. R&D labs spend only about 43 percent of their funds in-house; T&E facilities spend about 65 percent in-house (figure 6-1).[3] As a result, less than half of DoD's lab RDT&E budget, or $4.7 billion, was used to support work within government-owned facilities in 1992. About $3.4 billion of this total was spent in R&D labs; $1.3 billion was spent in T&E centers.

The DoD laboratory system is managed and operated largely by the individual services (Army, Navy, and Air Force). The Navy operates the largest lab program with a total budget of $3.3 billion in 1990, $1.8 billion of which was spent in-house (table 6-l). R&D labs received $2.8 billion of the total. The Navy system includes one corporate lab, four warfare centers (that contain their own R&D labs, T&E centers, and support facilities), and six small medical labs. The Navy's corporate lab, the Naval Research Lab, or NRL, conducts basic and applied research on a broad range of technologies that support service goals and missions.[4] The four Naval Warfare Centers—Air, Surface, Undersea, and Command, Control, and Ocean Surveillance--each focus on a set of applied technologies relevant to their particular mission. Each maintains in-house expertise in all

Figure 6-1—DoD's Intramural RDT&E Program for 1992 (estimated)



NOTES: Funding levels for R&D labs and T&E centers were estimated by taking the National Science Foundation's figure for DoD's 1992 "intramural R&D" and distributing it according to DoD's reported funding levels for 1990. In-house percentages are also based on 1990 data

SOURCE: Office of Technology Assessment, 1993; based on U.S. Department of Defense, Office of the Secretary of Defense, Deputy Director of Defense Research and Engineering/Science and Technology, *Department of Defense In-House RDT&E Activities: Management Analysis Report for Fiscal Year 1990* (Washington, DC: 1992), pp. vi-xiv; National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 1990, 1991, and 7992,* NSF 92-322 (Washington, DC: July 1992), p. 51.

[2] National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 1990, 1991,* and *1992,* Detailed Statistical Tables, NSF 92-322 (Washington, DC: July 1992), p. 51.

[3] These percentages are approximations based on reported funding levels for fiscal year 1990, the most recent year for which such figures are available. Some of the funds spent outside the labs are used to hire contractors who work in DoD facilities.

[4] These areas include information sciences, artificial intelligence, environmental sciences, micro- and nanoelectronics, electronic warfare, advanced materials, sensor technologies, and space technologies.

Table 6-1—Service Budgets for R&D Labs and T&E Centers, 1990

Service	RDT&E funding (millions)					
	R&D labs		T&E centers		Total, GOGO facilities	
	Total	In-house	Total	In-house	Total	In-house
Army	$2,150	$ 923	$ 470	$ 322	$2,620	$1,245
Navy ., ... , ...	2,815	1,521	477	317	3,292	1,838
Air Force . . . . . . , , ...	1,798	439	805	507	2,603	946
Total ., ...	*$6,763*	*$2,883*	$1,752	$1,146	$8,515	$4,029

SOURCE: U.S. Department of Defense, Office of the Secretary of Defense, Deputy Director of Defense Research and Engineering/Science and Technology, *Department of Defense In-House RDT&E Activities: Management Analysis Report for fiscal Year 7990* (Washington, DC: 1992), pp. vi-xiv.

stages of R&D, from research to development and support of fielded systems. But whereas NRL focuses on the early "science and technology" stages of RDT&E, warfare centers tend to focus on subsequent advanced development, engineering development, and system support stages.[5] The warfare centers are also responsible for T&E activities and operate several large test ranges (formerly the Air Test Center, Ordnance Missile Test Center, Pacific Missile Test Center, and Weapons Evaluation Facility) that are used for flight tests of aircraft and missiles as well as for operational testing of electronic warfare and radar devices.

The Army system is similar to the Navy's in that it contains a corporate lab (the Army Research Lab, or ARL), eight Research, Development, and Engineering Centers (RDECs), several small medical laboratories, and nine T&E centers. It also contains four laboratories run by the Army Corps of Engineers and the Research Institute for Behavioral and Social Sciences. These facilities had a total RDT&E budget of $2.6 billion in 1990-80 percent of which went to R&D facilities-and spent $1.2 billion in-house (table 6-l). ARL conducts the Army's technology base activities in areas such as electronics, materials, ballistics, and human engineering. Army RDECs, like the Navy's warfare centers, perform a full spectrum of R&D activities in specific technical areas: aviation, chemicals, communications, missiles, tank and automotive technology, and troop support. Its T&E centers, including such facilities as White Sands Missile Range and the Yuma Proving Ground, measure and test the operational performance of Army aircraft, missiles, artillery, and electronics. They had a total budget of $470 million in 1990.

The Air Force operates the smallest of the service lab systems with $2.6 billion in funding in 1990. It also uses the smallest percentage of its RDT&E funds in-house (table 6-l). Air Force R&D facilities are organized into four large ''super-labs: Wright Lab for aviation and weaponry; Phillips for space technologies; Armstrong for medicine and human factors; and Rome for command, control, and communications (C^3). Each is considered a' 'full spectrum' lab capable of research, development, and support activities, but each focuses primarily on applied research and advanced technology development. Basic research activities are managed by the Air Force Office of Scientific Research; operation and support activities are managed by the four major

[5] DoD divides its budget into 10 accounting categories. Category 6 contains all RDT&E activities. RDT&E is further subdivided into six components: 6.1, basic research; 6.2, exploratory development or applied research; 6,3, advanced development; 6.4, engineering development 6.5, management and support; and 6.6, operational systems development. Budget item 6.3 is further subdivided into 6.3a, advanced technology development which includes activities to demonstrate the feasibility of a given type of military system, and 6.3b, in which technology is applied to a specific military program. Categories 6.1 and 6.2 are considered the technology base; categories 6.1 through 6.3a comprise ' 'science and technology" (S&T).

Table 6-2—Employment in Service RDT&E Facilities, 1990

	Personnel						
Service	Total	R&D	T&E	Military	Civilian	Professional	Ph.D.
Army	31,198	21,280	9,918	6,235	24,963	15,593	1,825
Navy	42,186	32,133	10,053	4,730	37,456	20,234	2,138
Air Force	27,245	7,390	19,855	17,228	10,017	9,696	775
Total	100,629	60,803	39,826	28,193	72,436	45,523	4,738

SOURCE: U.S. Department of Defense, Office of the Secretary of Defense, Deputy Director of Defense Research and Engineering/Science and Technology, *Department of Defense In-House RDT&E Activities: Management Analysis Report for Fiscal Year 1990* (Washington, DC: 1992), pp. vi-xiv.

commands to which these labs report. The Air Force also operates five T&E centers, which together comprise the largest testing program of the three services with over $800 million in RDT&E funding. These facilities include the Arnold Engineering Development Center, the Air Force Development Center, the Flight Test Center, and two test wings. They house test ranges for aircraft, parachute drop zones, impact ranges for testing bombing and gunnery systems, wind tunnels, engine test cells, and instrumented labs and ranges for testing avionics and radar systems.

Service R&D labs and T&E facilities employed over 100,000 people in 1990 (table 6-2), a figure that has declined only marginally in the last 3 years. About 60 percent of these employees work in the R&D labs. Over 70 percent of all employees are civilian, the Air Force being the only service to employ more military than civilian personnel[6] Almost half of all the employees in these DoD facilities are professional scientists and engineers; 4,700 hold Ph.D. degrees.

FFRDCs funded by the DoD include 11 organizations that employ over 8,000 professionals and conduct a variety of services for the military, not all of which are strictly R&D. Only one FFRDC, MIT's Lincoln Laboratory, conducts actual R&D for military hardware. Lincoln Lab receives some $400 million a year for defense RDT&E and conducts programs ranging from basic research to design, development, and demonstration of prototype systems. Four FFRDCs, including MITRE Corporation, perform systems engineering and systems integration work for DoD, much of which is associated with the management of large systems development programs.[7] Six other FFRDCs, such as the Institute for Defense Analysis, are study and analysis centers that help solve organizational and operational problems, but perform little or no hardware-related research or development. While their funding comes from the RDT&E budget, most of their work is quite remote from the R&D done in DoD labs and test facilities.

DOD LABS AND THE "PEACE DIVIDEND"

Through fiscal year (FY) 1993, defense RDT&E had been relatively unaffected by the end of the Cold War. While overall defense spending had declined 20 percent in real terms since 1989, RDT&E dropped only 12 percent, from $41.6 billion in 1989 to $36.7 billion in 1993 (table 6-3). Budget cuts took their greatest toll on procurement, which dropped almost 30 percent, from $91.7 billion to $65.1 billion between 1989 and 1993. Defense RDT&E has been insulated from defense budget cuts by DoD's new acquisition strategy, formally announced in early 1992, which attempts to maintain the technological superiority of U.S. military forces through contin-

[6] Much of this difference is attributable to the fact that two of the Air Force's largest T&E facilities are predominantly military.

[7] This work includes formulation of requirements for new systems, development of design specifications, and certification of system performance upon completion of development.

Table 6-3—Defense Outlays Since 1989

Budget category	Outlays (billions of 1992 dollars) 1989	1990	1991	1992	1993
RDT&E	$41.6	$40.4	$35.7	$36.1	$36.7
Procurement	91.7	87.2	84.5	74.0	65.1
Operations and maintenance	97.7	95.1	105.0	97.8	84.8
Personnel	90.6	81.4	86.0	79.3	74.5
Other[a]	9.7	8.0	-40.6	-7.4	8.2
Total	*$331.2*	*$312.0*	*$270.5*	*$294,6*	*$269.4*

a Includes outlays for military construction, family housing and revolving/management funds. A minus sign denotes income from these funds in excess of outlays.

SOURCE: *Budget of the United States* Government, *Fiscal Year 7993* (Washington, DC: U.S. Government Printing Office, February 1992), pp. Part Five-46-47.

Table 6-4-Proposed Defense Outlays, 1993-97

Budget category	Proposed outlays (billions of 1992 dollars) 1993	1994	1995	1996	1997
RDT&E	$36.7	$36.4	$34.8	$32.8	$31.0
Procurement	62.5	58.5	55.8	54.0	52.2
Operations and maintenance	84.8	78.5	76.6	76.4	75.8
Personnel	74.5	67.8	65.1	64,4	64.1
Other[a]	6.2	10.3	11.6	11.3	10.6
Total	*$264.7*	*$251,5*	*$243.9*	*$238.8*	*$233.7*

a Includes outlays for military construction, family housing and revolving/management funds. A minus sign denotes income from these funds in excess of outlays.

SOURCE: *Budget* of the *United States Government, Fiscal* Year *7993* (Washington, DC: U.S. Government Printing Office, February 1992), p. Part Two-5.

ued investment in the technology base (i.e., basic and applied research). Under this policy, DoD stated its intention to upgrade existing weapons systems rather than develop new ones, but continue to fund development of new technologies, through prototype, from which future systems can later be constructed.[8]

The effect of acquisition strategy on future RDT&E funding was unclear in Spring 1993. The Bush Administration, in its final budget request, projected only a modest decline in RDT&E spending, from $36.7 billion in 1993 to $31 billion in 1997, again in constant 1992 dollars (table 6-4). The services planned to take most of the reduction in the systems development and operational field support portions of their RDT&E budgets so as to leave the science and technology portion (from which the labs are funded) relatively intact. With a new Administration in office, changes in appropriations are almost certain. President Clinton has signaled that defense spending will be cut at a somewhat faster rate than was previously projected, perhaps to $200 billion in FY 1997, but it is not yet clear how much of this reduction will be taken from RDT&E. The budget released by the Clinton Administration in April 1993 proposed a 1 percent real decline in outlays for defense RDT&E in FY 1994;[9] assuming RDT&E remains about 15 percent of the defense budget, it could still total $30 billion in FY 1997.

[8] U.S. Department of Defense, ''Defense Acquisition' white paper, May 1992.

[9] *Budget of the United States Government, Fiscal Year 1994 (Washington* DC: U.S. Government Printing Office, 1993), p. Appendix-72.

However, the services may argue that they have already trimmed their operations and procurement budgets to the maximum extent practicable and may therefore take a larger portion of future defense cuts from RDT&E. Similarly, the new Administration may opt to cut defense RDT&E further and redirect R&D funding from defense to nondefense programs after 1993 to boost commercial competitiveness.[10]

Even less certain is the way in which reductions in RDT&E will affect the size of the labs' budgets. In order to reduce the cost of developing military systems, DoD is considering additional changes in its acquisition process that would allow greater reliance on commercial technology. If successful, these changes might, in turn, allow the Defense Department to reduce its expenditures on in-house R&D and shift the greater proportion of RDT&E funding to the private sector. However, it is also possible that with the shrinking defense industrial base, DoD may opt to rely more on its own institutions for developing military technology if it concludes that commercial industry will not satisfy all defense needs.

In response to declining budgets and congressional pressures, DoD has initiated steps to reduce the size of its lab system through both downsizing and consolidation. The 1991 Defense Authorization Act requires the services to cut back their civilian acquisition workforce--which includes RDT&E employees—by 20 percent between 1991 and 1995.[11] The 1991 legislation also created the Advisory Commission on Consolidation and Conversion of the Defense Research and Development Laboratories, composed of both private and public sector representatives, to recommend ways to improve the operation of the DoD labs through consolidation or closure of some or all of the labs. The Army, Navy, and Air Force submitted their plans to the commission in April 1991 for consideration and review. With only a minor reservation regarding the Army's plan to construct a new microelectronics facility, the commission recommended that the plans be implemented without delay .12

The services may also submit proposals for closure to the Base Closure Commission, which was reinstituted for another 6-year term by the 1991 act. The Base Closure Commission was authorized to recommend closure of all types of military facilities, including RDT&E facilities, to Congress and the President in three phases: 1991, 1993, and 1995. According to the law, Congress may not pick and choose among the Commission's recommendations; all must be voted up or down as a unit-and if Congress fails to vote, they become law automatically}'. The Commission's first and second slates of base closings and realignments (announced in 1989 and 1991) were adopted; the second included the closure of 34 military bases, many of which contain R&D facilities.

The Army's consolidation plan, as proposed, would eliminate 4,000 to 6,000 of the 31,000 positions in its labs and centers and transfer another 3,000 jobs among locations. As part of this plan, the Army has consolidated seven labs along with portions of its RDECs into a single corporate lab, the Army Research Lab, that will have facilities in two primary locations: Aberdeen and Adelphi, Maryland. About 800 civilian positions will be eliminated in the move; another 1,600 will transfer to new locations. By 1993, construction had already begun on new facilities to house transferred personnel. Three Army medical labs are also affected by the plan, with

10 Following an agreement between Congress and President George Bush, the Budget Enforcement Act of 1991 mandated that through FY 1993 reductions in the defense portion of the budget could not be redirected to nondefense programs.

11 U.S. Congress, *National Defense Authorization Act for Fiscal Year 1991*, conference report to Accompany H.R. 4739, Oct. 23, 1990, p. 143. This act was codified as Public Law 101-510.

12 Federal Advisory Commission on Consolidation and Conversion of Defense Research and Development Laboratories, *Report to the Secretary of Defense*, September 1991.

one slated for elimination and two for consolidation with labs in the other services.

The Navy also plans a significant realignment of its RDT&E facilities. Three major facilities, the Naval Air Development Center (NADC) in Warminster, Pennsylvania and two Naval Surface Warfare Centers in White Oak and Annapolis, Maryland, had already begun closing down by 1993.[13] About 670 positions will be eliminated, and another 3,200 will be transferred as a result of these closings; most are associated with NADC. Several smaller RDT&E support activities are also slated for closure, as is the Weapons Evaluation Facility in Albuquerque, New Mexico. The Navy will also eliminate three medical labs in cross-service mergers. According to the Navy's April 1991 submission to the Base Closure Commission, consolidation alone will result in the loss of 2,280 laboratory positions.[14] In its 1993 budget submission, however, the Navy projected the elimination of 11,252 positions from R&D laboratories-roughly one-quarter of its 42,000 member workforce--due to both consolidation and general workforce reductions.[15] Plans to implement most of these changes had not yet been formalized.

The Air Force's consolidation plans have already been implemented and are strictly organizational in nature. The Air Force does not plan to close any facilities; rather it has reorganized its 14 labs into 4 "super-laboratories" that align with and reside in the Air Force Materiel Command's four product divisions: Aeronautical Systems, Electronic Systems, Space Systems, and Human Systems. Of some 27,000 jobs in Air Force labs, approximately 800 positions—58 percent of which are scientists and engineers-are expected to be eliminated by the consolidation.

If accomplished in their entirety, the services' closure and consolidation plans could have a significant effect on the size and structure of the DoD RDT&E system. Initial estimates provided by the services to the base closure and lab consolidation commissions indicate that restructuring plans could lead to the closure of up to one-third of all DoD laboratories and the elimination of 12,000 to 15,000 jobs in the labs alone,[16] but these figures may need to be revised upward in light of the Navy's 1993 estimates. Most of the job loss is expected to result from downsizing and identified ''workload reductions, rather than consolidation, per se.[17] Consolidation is intended primarily to help improve lab management and eliminate redundancy. The three services operated 73 R&D laboratories and 18 T&E centers in 1990,[18] many of which conducted research in related areas-not just across services, but within services as well. For example, the Navy alone

13 Though the bulk of NADC's functions will be transferred to Patuxent River, Maryland, some unique navigationat facilities will remain in operation in Warminster under control of the Naval Command, Control, and Ocean Surveillance Center. Both of the Surface Warfare Centers slated for closure will be retained as operating sites, but the majority of their functions will be transferred to other locations.

14 The Navy's April 1991 Projections were based on the assumption that only 53 percent of the 4,800 employees (including 2,800 scientists and engineers, 300 of whom hold Ph.D. or equivalent degrees) affectedly consolidation and relocation of laboratory functions would be willing to move. The remaining 47 percent, the Navy estimated, would retire early, leave the government, be lost through normal attrition, or be unwilling to move.

15 U.S. General Accounting Off_ice, *Military Bases: Navy's Planned Consolidation RDT&E Activities* (Washington, DC: U.S. General Accounting Office, August 1992).

16 Michael Davey, *Defense Laboratories: Proposals for Closure and Consolidation*, 91-135SPR (Washington, DC: Congressional Research Service, Jan. 24, 1991), p. 23.

17 For a discussion of employment prospects fo, displaced defense engineers, see U.S. Congress, Office of Technology Assessment, *After the Cold War: Living With Lower Defense Spending*, OTA-ITE-524 (Washington, DC: U.S. Government Printing Office, February 1992), chapter 4.

18 U.S. Department of Defense, Office of the Secretary of Defense, Deputy Director of Defense Research and Engineering/Science and Technology, *Department of Defense In-House RDT&E Activities: Management Analysis Report for Fiscal Year 1990* (Washington, DC: 1991), pp. vii-xiv.

operated three centers, the Underwater Systems Center, the Ocean Systems Center, and the Coastal Systems Center, all of which conducted overlapping research on torpedoes. Under the Navy consolidation plan, all torpedo work will be. transferred to the Undersea Warfare Center.

Nevertheless, lab closure and consolidation, as currently envisioned, will have only a minimal effect on the *nature* of the services' RDT&E facilities and programs. DoD's new acquisition strategy, by continuing to fund the early stages of' R&D (basic research through technology demonstration), will continue to support the kinds of" work currently conducted in the labs. Testing facilities will continue to be maintained to evaluate the performance of upgraded military systems. Moreover, the services will continue to develop many of the same types of weapons and support systems (e.g., tanks, aircraft, radar, communications systems) that they develop today. Consolidation and downsizing of DoD labs will therefore result in a system that continues its defense mission, but in a smaller organizational package. In contrast to some of the suggestions for the future of the Department of Energy's nuclear weapons labs, there have been few if any proposals to give DoD labs central missions related to the civilian economy.

Future changes in lab structure that might more radically alter the mission of DoD labs cannot be entirely ruled out. Numerous suggestions have been made to convert the labs into government-owned, contractor-operated (GOCO) facilities or to centralize control of the labs in the Office of the Secretary of Defense. Many of these proposals are intended only to improve management and coordination of the labs and would not greatly alter the mission of the defense labs, but one cannot rule out the possibility that after reviewing the security requirements of the post-Cold War period and examining the capabilities of universities and industry, DoD may decide to limit its support of in-house work in certain areas in order to protect other portions of its budget. Labs that would be closed under this scenario--especially those that work on dual-use technologies-could conceivably be converted to civilian missions. At present, though, no such plans have been made, and DoD RDT&E facilities will continue to serve their central defense missions.

TECHNOLOGY TRANSFER FROM DOD LABORATORIES

While continuing to pursue their traditional missions, DoD labs can still contribute to U.S. industrial competitiveness. With the passage of the Stevenson-Wydler Act of 1980, Congress established technology transfer as a legitimate mission of every Federal laboratory and has since encouraged DoD labs to enter into cooperative R&D programs with industry. With the Bayh-Dole Act of 1980, GOGO labs, including the DoD labs, were given authority to grant private companies exclusive licenses to patents. The Federal Technology Transfer Act (FTTA) of 1986 expanded these powers by allowing each federal agency to grant directors of GOGO labs the authority to enter into cooperative R&D agreements (CRADAs) with commercial partners and to negotiate licensing agreements. Executive Order 12591, issued in 1987, directed agencies to delegate authority for entering into CRADAs to the labs and issued guidelines for intellectual property rights (see ch. 4 for a more complete discussion of this legislation).

Technology transfer legislation allows DoD labs to contribute facilities, time, and personnel (but not funding) to R&D programs conducted jointly with industry. Industry may contribute facilities, personnel, and/or funding. Such programs can benefit both industry and the labs. From DoD's perspective, cooperative agreements provide a potential source of new technologies that could serve defense missions. They can also provide lab personnel with exposure to commercial technologies and practices that in many cases are more advanced than defense technologies. From the industry side, technology transfer provides a means of gaining access to technologies in which defense requirements may have anticipated commercial markets, of sharing the costs of R&D programs (through in-kind contributions by the labs), and of gaining access to laboratory facilities and capabilities.

The services, which for the purposes of the FTTA are considered separate Federal agencies, were initially slow to implement provisions of the 1986 act. Two-and-a-half years passed before DoD granted the services authority to enter into CRADAs,[19] and another year and a half went by before the services developed regulations governing the process. Thus, technology transfer initiatives were slow to start during the first 4 years of the program. Part of the problem no doubt stemmed from the DoD limited prior experience with technology transfer programs. Whereas other agencies, such as the National Aeronautics and Space Administration (NASA) and the Department of Agriculture, had longstanding programs of technology transfer, DoD did not; much of its effort was instead directed toward preventing unwanted disclosures of technological innovations to protect national security.

Since 1990, the labs have made considerable progress in their technology transfer activities. Each of the services has developed a model CRADA that they continue to update as they gain experience with the technology transfer process, and each has developed procedural guides for their labs. In addition, Offices of Research and Technology Application (ORTAs) have been established at most DoD labs—though not at all T&E centers—in accordance with the Stevenson-Wydler Act.[20] The Navy now has ORTAs at 47 facilities, including NRL, the four Naval Warfare Centers (including some of the test facilities), the Naval Academy, and the Naval Postgraduate School; but only 15 of these ORTAs are full time. The Army has 48 ORTAs, located at labs and RDT&E facilities but not at T&E centers. The Air Force has just seven ORTAs, located at the headquarters of each of its superlabs and at three of the geographically dispersed labs. Directors of the superlabs sign CRADAs for each of the facilities under their jurisdiction. This arrangement has slowed the signing of CRADAs at some Air Force labs, but change is underway. The Air Force is drafting new procedures that will assign an ORTA to each individual facility with more than 200 full-time scientists and engineers, including Air Force T&E facilities and logistics centers.[21]

The fruits of these efforts are becoming evident. Though still low compared to the size of the labs' RDT&E budgets, revenues from patent licenses have increased every year since 1987 and approached $500,000 in 1992 (figure 6-2). The Navy, led by the Naval Research Lab, has earned the highest returns from patent licenses of the three services, with a cumulative total of over $630,000 between 1987 and 1992. License revenues are by no means a complete or adequate indication of success in technology transfer, partly because of the lag from the time the license is issued to the time companies start reaping income from commercialization of the technology—and paying royalties. More importantly, many other forms of technology transfer, from informal contacts between lab researchers and companies to more formal cost-shared partnerships between the labs and industry, are not measured by patent revenues.

CRADA activity can provide an indicator of the level of cooperative R&D between the labs and industry. Between 1987 and 1989, DoD labs signed only 40 CRADAs. By 1992, however, the number of active CRADAs in service labs had

19 See U.S. Department of Defense, Under Secretary of Defense for Acquisition, ''Domestic Technology Transfer Program Regulation' DoD 3200.12-R-4, December 1988.

20 The Stevenson-Wydler Act requires agencies to establish ORTAs at all Federal R&D facilities with more than 200 full-time science and engineering employees.

21 OTA staff interview with Dr. C. J. Chatlynne, Domestic Technology Transfer Program Manager, U.S. Air Force, Jan. 14, 1993.

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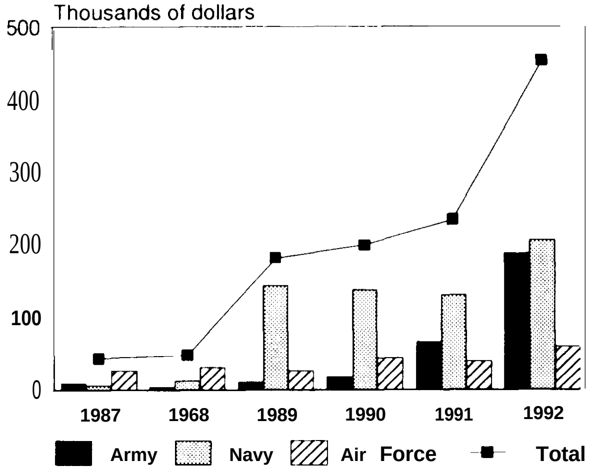
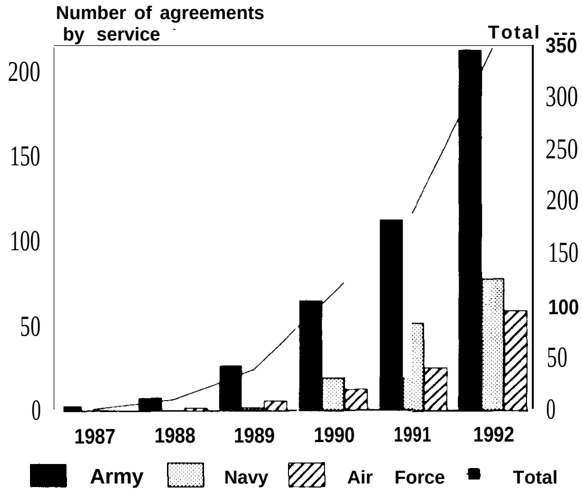
Figure 6-2—Annual Income From Patent Licenses by Service, FY 1987-92



SOURCE: Office of Technology Assessment, 1993; based on official statistics of the U.S. Department of Commerce; Helen Moltz, U.S.Army Domestic Technology Transfer Office, personal communication, Feb. 1, 1993; Lt. Butch Howard, U.S. Navy Office of Legislative Affairs, personal communication, Feb. 2, 1993; Dr. C.J. Chatlynne, Program Manager, Domestic Technology Transfer, U.S. Air Force, "Summary of Air Force Income-Producing Patents," Feb. 9, 1993.

Figure 6-3-Active Cooperative Agreements by Service, FY 1987-92



NOTE: Not all cooperative agreements are included under the provisions of the Federal Technology Transfer Act of 1986. Army figures include 200 CRADAs and 34 other cooperative agreements signed by the Corps of Engineers under separate authority.

SOURCE: Office of Technology Assessment, 1993; based on official statistics from the U.S. Department of Commerce; Helen Moltz, U.S. Army Domestic Technology Transfer Office, personal communication, Feb. 1, 1993; U.S. Navy, Office of Naval Research, "Navy CRDA History: CRDAs Approved by ONR," Feb. 22, 1993; U.S. Air Force, Domestic Technology Transfer Office, "United States Air Fores Cooperative R&D Agreements," Feb. 9, 1993.

risen to 349 (figure 6-3). The Army has been the most active of the services in promoting CRADAs, with 212 active agreements at the end of FY 1992.[22] The Walter Reed Army Institute of Research (a medical lab) and the Electronics & Power Sources Directorate (formerly the Electronics Technology & Devices Lab and now part of the Army Research Laboratory) have been the most prolific of Army labs, having signed 41 and 21 CRADAs respectively between 1987 and. 1992.

Many of the defense labs' CRADAs are not with firms operating in commercial markets. however, but with universities or with traditional defense contractors who may be more interested in military than commercial markets for new products. The Army estimates that about 35 percent of its CRADAs are with commercial partners. The Navy, on the other hand, believes that the majority of its CRADAs are with commercial partners. Service spokesmen say they hope to bring in more commercial companies as they gain experience with the technology transfer process.[23] These companies will then have to incorporate new technologies into commercial products in order for lab partnerships to benefit U.S. industrial competitiveness.

DoD medical labs have implemented a disproportionate share of the cooperative agreements. Medical labs are the top producers of CRADAs in both the Army and the Navy, despite the fact that they receive less funding than most other types of labs (tables 6-5 and 6-6). The Air Force's Armstrong medical lab, though not that service's top performer, has signed more CRADAs than

[22] This figure includes 34 cooperative agreements signed by the Corps of Engineers labs under separate authority granted in 1989.

[23] OTA staff interviews with directors of Army and Navy Domestic Technology Transfer Program managers.

Table 6-5—Signed Army Cooperative Research Agreements by Laboratory, 1992

Laboratory	RDT&E budget[b] (millions)	Total cooperative agreements	Estimated value of CRADAs[a] (thousands) Total	1992
Army Surgeon General	$ 208	94	$ 56,082	$ 2,448
Walter Reed Army Institute of Research		40 1/2[c]	41,305	2,081
Medical Research Institute of Infectious Diseases		NA	NA	NA
Institute of Dental Research		13	1,383	329
Medical R&D Command		10	9,536	—
Medical Research Institute of Chemical Diseases		8	NA	—
Aeromedical Research Lab		4	16	12
Research Institute of Environmental Medicine		3	2,945	26
Letterman Army Institute of Research		2	897	—
Biodynamics Research Lab		1/2[c]	0	—
Corps of Engineers	$ 196	59[d]	$ 29,310	$ 7,786
Cold Regions Research & Engineering Lab		22 1/2	7,335	361
Construction Engineering Research Lab		20 1/2	8,896	2,667
Engineer Waterways Experimentation Station		15	12,929	4,608
Engineer Topographic Lab		1	150	150
Army Research Lab	$ 328	49	$ 13,039	$ 8,524
Electronics and Power Sources Directorate		21	4,396	2,081
Sensors, Signatures, Signals, & information Processing Directorate		18	3,583	2,533
Materials Directorate		6	2,050	850
Structures Directorate		4	3,060	3,060
Research, Development, and Engineering Centers	$1,261	49	$ 23,877	$16,562
Aviation Command		15	580	508
Communications Electronics Command		14	731	318
Natick RDEC		9	21,710	15,050
Tank Automotive RDEC		5	677	639
Chemical RDEC		3	120	20
Missile RDEC		1	NA	NA
Strategic Defense Command		2	59	27
Other	NA	2	$ 340	$ 0
Benet Lab		1	300	—
Uniform Services University of Health Services		1	40	—
Total		*253*	*$122,650*	*$35,360*

NA–not available.
a Includes government's and partner's contributions to 235 of the 257 CRADAs signed between 1988 and 1992.
b Lab RDT&E budgets as of FY 1990.
c The "half-CRADA" indicates a joint CRADA with another lab.
d Includes 34 cooperative agreements signed under the Corps of Engineers' separate authority: 15 by the Engineers Waterway Experimentation Station, 11 by the construction Engineering Lab, 7by the Cold Regions Research& Engineering Lab, and 1 jointly by the Construction Engineering and Cold Regions Labs.
e These facilities are DOD assets, but for administrative purposes report to the Army Domestic Technology Transfer Program Office.

SOURCE: Office of Technology Assessment, 1993; based on data from the Army Domestic Technology Transfer Program Office, "Army Accepted CRADAs/PLAs," Feb. 12, 1993.

labs with twice the funding (table 6-7). With the notable exception of one CRADA at the Walter Reed Army Institute of Research that totals over $33 million (the estimated contribution of both the government and the commercial partner), many medical labs' CRADAs tend to be small—$10,000 to $15,000 or less. The total value of CRADAs signed by Army medical labs averaged less than $100,000 in 1992, compared with almost $450,000 for other Army labs. Nevertheless, they

Table 6-6-Signed Navy CRADAs by Laboratory, 1992

Laboratory	RDT&E Budget (millions)	Number of CRADAs
Naval Medical R&D Command	$ 49	23
Naval Research Lab	495	13
Warfare Centers		
Naval Air Warfare Center	686	9.5[a]
Naval Surface Warfare Center	690	9.5[a]
Naval C^2 & Ocean Surveillance Center	345	5
Naval Undersea Warfare Center[b]	373	6
Universities		
Naval Post-Graduate School	NA	3
U.S. Naval Academy	NA	1
Naval Training Systems Center	120	6
Other	NA	2
Total		*78*

NA = not available.

[a] The additional "half-CRADA" indicates a joint CRADA with another Navy lab.

[b] Includes the Naval Civil Engineering Lab, which had a budget of $34 million in 1992 and has signed 4 CRADAs.

SOURCE: Office of Technology Assessment, 1993; based on data supplied by the U.S. Navy, Office of Legislative Liaison, 1992.

are mostly with commercial industry or universities rather than defense companies.[24] Although the medical labs conduct some research of solely military interest (e.g., effects of chemical weapons), much of their research is inherently dual-use. Moreover, the military is the largest single health care provider in the Nation; DoD medical researches well-funded and wide-ranging.

The Army Research Lab and the Navy Research Lab have also signed large numbers of CRADAs relative to the size of their budgets. As of 1992, laboratories now under the Army Research Laboratory had signed 53 CRADAs, and the Naval Research Lab had signed 13—more than any of the 4 naval warfare centers, all of which have larger budgets (tables 6-5 and 6-6). ARL's planned contribution to CRADAs signed in 1992 will total about $4.5 million, most of which comes from the Structures Directorate and the Electronics and Power Directorate. ARL's partners will contribute an additional $4 million in-kind.[25] Corporate labs have an advantage over the more mission-oriented labs in forming partnerships with commercial industry. Not only do the corporate labs work on a broader range of technologies, they also tend to focus primarily on basic and applied research, which are more likely to have commercial applications than more advanced development of weapons systems.[26] In basic and applied research, many technologies are general enough that they are dual-use in nature.[27] Despite the fact technologies in this stage are far from marketable products, they are often the most suitable for cooperative work.

24 U.S. Army, Domestic Technology Transfer Program Office, "Agency CRADA Information" response to U.S. General Accounting Office data request, December 7, 1992.

25 Includes the estimated value of resources dedicated to the CRADA, other than cash contributions.

The seven laboratories now under the Army Research Lab spent 55 percent of their combined $362 million budget on basic and applied research in FY 1992. Most of the remainder was spent on weapons analysis and evaluation including testing at the White Sands Missile Range.

27 Whereas a basic research program might investigate methods of growing crystals and an applied research program might explore ways of growing single crystal turbine blades for jet engines, subsequent development programs would focus on the growth and demonstration of a single-crystal turbine blade for a specific military jet engine.

Table 6-7-Signed Air Force CRADAs by Laboratory, 1992

Laboratory (activity)	RDT&E budget (millions)	Number of CRADAs
Armstrong (Medical and Personnel)	$148	9
Phillips (Space)	317	10
Rome (Electronics)	111	22
Wright (Aviation and Weapons)	572	7
Air Force Office of Scientific Research	217	3
Air Force Academy	NA	5
Air Force Surgeon General	NA	3
Other[a]	NA	4
Total		63

NA= not available.

[a] Includes the Civil Engineering Support Agency, Electronic Systems Center, and Lincoln Labs (an FFRDC).

SOURCE: Office of Technology Assessment, 1993, based on information supplied by the Assistant Secretary of the Air Force, Directorate for Science and Technology.

In comparison, mission-oriented labs can be more limited in their ability to work with industry by their greater emphasis on development activities. wholesome support applied research as well as advanced development activities, much of their work is directed specifically to military systems. Some of the centers work on technologies that are almost exclusively military—missiles, chemical weapons--for which few commercial applications exist. On the other hand, mission-oriented centers that specialize in electronics and communications and in biological sciences—inherently dual-use technologies—have been successful in working with industry. The Air Force's Rome electronics lab has signed 22 CRADAs, more than any other Air Force lab despite having the smallest budget. Labs operated by the Army's Aviation Command and Communications Electronics Command have signed a total of 31 CRADAs, and the Natick RDEC has signed 9. In 1992, Natick led all Army labs by contributing $3.6 million to CRADAs and attracting $11,4 million in in-kind contributions from industry. Its CRADAs address topics such as biodegradable packaging, irradiation of food, and microwave sterilization of packaged food products.

Some mission-oriented labs and test centers have unique capabilities or facilities unequaled in the commercial sector. The former Naval Ocean Systems Center (now part of the Naval Command, Control, and Ocean Surveillance Center) is reputed to have the most advanced capability in the country for manufacturing silicon semiconductor devices on sapphire substrates. The center has already signed two CRADAs with companies interested in further developing this technology for their own applications. The Air Force's Arnold Engineering Development Center houses some of the most advanced wind tunnels and turbine engine test cells in the country .28 The Army's Corps of Engineering labs have several unusual facilities that attract industry and university researchers. The Cold Regions Research and Engineering Lab has 23 active CRADAs for researching and testing the performance of materials and systems at low temperatures. Under one CRADA, the lab will work with the University of Alaska to test the durability of paving materials after repeated freezing and thawing. The Engineer Waterways Experiment Station and the Construction Engineering Research Lab lagged only the Natick RDEC and the Structures Directorate of AR-L in the estimated value of their

28 As of April 1993, the Air Force had not yet granted Arnold the authority to enter into CRADAs.

contributions to cooperative R&D programs in 1992.

Nevertheless, cooperative R&D represents only a small fraction of the activities underway in DoD labs. Army labs provided less than $15 million in in-kind contributions to cooperative agreements in 1992, and industry contributions totaled about $22 million, mostly in the form of in-kind contributions. Unlike the Department of Energy labs which received a $50 million appropriation specifically for CRADAs in 1992 and $141 million in 1993 (see ch. 4), DoD labs have not received funding designated specifically for CRADAs. Hence, DoD lab managers have funded only those cooperative R&D programs that fit in with defense programs that are already underway. Defense labs are unlikely to take on strictly civilian missions in the foreseeable future, but will continue to conduct R&Din some areas with dual-use potential. These areas will provide the labs with an opportunity to work with commercial industry in support of U.S. industrial competitiveness. As the recent growth in CRADA activity among the DoD labs suggest, industry is interested in, and capable of, working with defense labs in these areas.

Appendix A: R&D Institutions in Germany

If this Nation seriously undertakes a new approach of partnership between government and industry for technology development, foreign countries might provide possible models. Germany has long-established government research and development (R&D) institutions whose main purpose is to advance civilian technologies, often in tandem with industrial partners. Ninety-five percent of German R&D spending is for nondefense purposes. A greater share of German gross domestic product (GDP) is devoted to nondefense R&D (2.7 percent) than is the case in the United States (1.9 percent).[1] Private companies are the principal funders and performers of R&D but government institutions also play a prominent role.

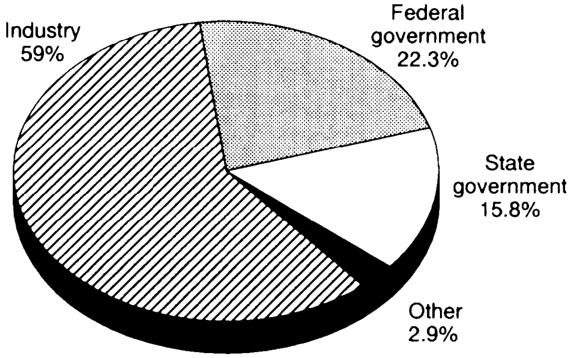
Public R&D Institutions in Germany

Public R&D institutions are a major factor in Germany's total public and private research establishment. The national R&D budget amounted to 76 billion Deutsche marks (DM) in 1990, or about $35.3 billion.[2] Industry paid for 59 percent of this, the federal government 22 percent, and state governments 16 percent (figure A-l). Although most of the R&D (66 percent) was done in industry labs, government-sponsored

[1] National Science Board, *The Competitive Strength of US. Industrial Science and Technology: Strategic Issues, NSB-92-138* (Washington, DC: National Science Foundation, 1992), table A-10.

[2] The purchasing power parity (PPP) exchange rate developed by the Organization for Economic Cooperation and Development for 1991 of 2.15 DM per $1 US is used here. At the market exchange rate of about 1.5 DM per $1 US, German R&D expenditures would equal about $46.7 billion. Neither exchange rate is ideal, but the PPP rate probably better reflects differences between the United States and Germany in laboratory costs and is therefore used throughout this section. Most of the material on R&D institutions in Germany is drawn from "Research Institutions in Germany" (October 1992), report to OTA by Engelbert Beyer, a visiting scholar, under the auspices of the National Science Foundation, from the German Federal Ministry for Research and Technology (Bundesministerium für Forschung und Technologies, BMFT).

Figure A-l-German R&D Funding by Source, 1990



Total R&D budget: 76 billion DM ($35 billion)

SOURCE: German Federal Ministry for Research and Technology.

research institutions were major performers, nearly as prominent as universities (both 15 percent, as shown in figure A-2).

Since the turn of the century, there has been strong support in Germany for public research institutions that can undertake work beyond the competence of universities or not profitable enough for private companies to attempt. The reasons put forward at that time for public R&D are familiar today: the need for interdisciplinary research, the changing boundaries of research fields, the need for large basic research facilities.[3]

Funding for public research institutions comes from both the federal and state governments in Germany, but the single agency with most responsibility and influence is the Federal Ministry for Research and Technology (Bundesministerium für Forschung und Technologies, or BMFT). BMFT is unusual among research funding agencies in that its responsibilities cover both scientific research and national technology policy. BMFT's 1992 budget was 9.4 billion DM ($4.4 billion), more than half the 17.9 billion DM that the German federal government spent for R&D that year. (Other principal German government funders of R&D are the Defense Ministry, the Economics Ministry, and the Ministry of Science and Education.)

The research policy of the BMFT has these overall goals:

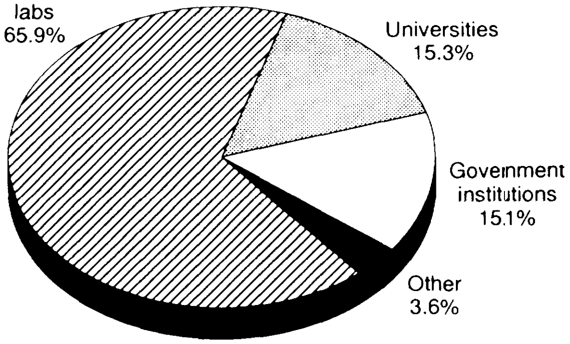
- Contribute to innovation to environmental and economic goals;
- Pursue long-term technological developments such as nuclear fusion, space exploration, and advanced transportation technologies;
- Increase the pool of knowledge of mankind, e.g., in high energy physics;
- Expand knowledge about environmental threats (e.g., global climate change) as a basis for appropriate policies.

The BMFT is the main funder for Germany's four major publicly funded research institutions, and its priorities are reflected in the research areas they cover. The institutions are:

- The Grossforschungseinrichtungen (GFEs), or large research organizations, working in a variety of fields from energy to advanced materials, information technology, environment, aeronautics and space. The GFEs are similar in some ways to the U.S. Department of Energy laboratories, but dissimilar in having no nuclear weapons responsibilities. The 16 GFEs were funded at 3.5 billion DM ($1.6 billion) in 1992 and had 24,000 employees.
- The Max Planck Society (Max Planck Gesellschaft, or MPG), founded in 1911 as the Kaiser Wilhem Society to perform basic scientific research, mostly in the natural sciences. The MPG maintains 62 research institutes with a total budget of 1.3 billion DM ($605 million), a permanent staff of 8,700, including 2,400 scientists, plus nearly 3,000 scholarship holders and guest scientists (from Germany and elsewhere).
- The Institutes of the Blue List, a miscellaneous collection of independent research organizations, jointly founded and financed by the federal and state governments, and working in such various fields as social science, economics, medicine, biology, history, and scientific museums. With reunification, 24 new East German institutes were added to the Blue List; most of these work in fields of natural science and environmental sci-

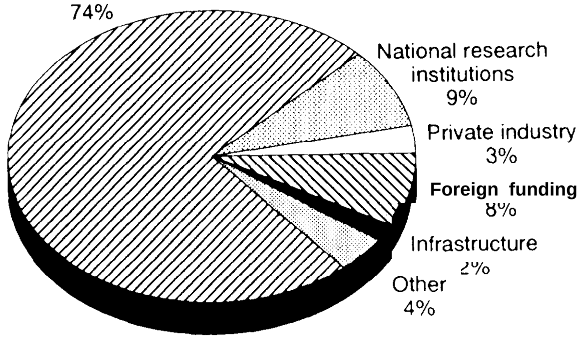
[3] Hans Winy Hohn and Voider Schneider, "Path Dependency and Critical Mass in the Development of Research and Technology: A Focused Comparison" *Science and Public Policy*, vol. **18,** no. *2*, 1991, pp. 111-122, cited in Engelbert **Beyer,** "Research Institutions in Germany," paper prepared for the Office of Technology Assessment (October 1992).

Figure A-2-German R&D Performers, 1990



SOURCE: German Federal Ministry for Research and Technology.

Figure A-3-Total Funding for German GFE's, 1990



SOURCE: German Federal Ministry for Research and Technology.

ence and technology. The overall budget of these institutes is about 975 million DM ($453 million).

- The Fraunhofer Society (Fraunhofer Gesellschaft, or FhG), probably the best-known and most admired feature of Germany's public research,[4] but also the smallest of the four major research institutions. The FhG's mission is to transfer research results into practical use by private industry, promoting innovation in products and production technology as rapidly as possible. The FhG's total budget is about 975 million DM ($453 million) and its staff numbers about 6,000, including 2,000 scientists and engineers and 1,200 graduate students.

Of these four German institutions, the GFEs and the Fraunhofer institutes are of most interest to this report, since the former have many points in common with the U.S. DOE labs, and the latter represent a very different approach to cooperative government-industry R&D-one with little parallel in the United States.

THE GFEs

By far the largest of the four government-supported R&D institutions is the group of 16 GFEs. Three-quarters of their funding is "basic financing" (e.g., institutional support, not tied to individual projects) from the national and state governments, and most of the rest comes from specific projects funded by the national government or the European Community (figure A-3).

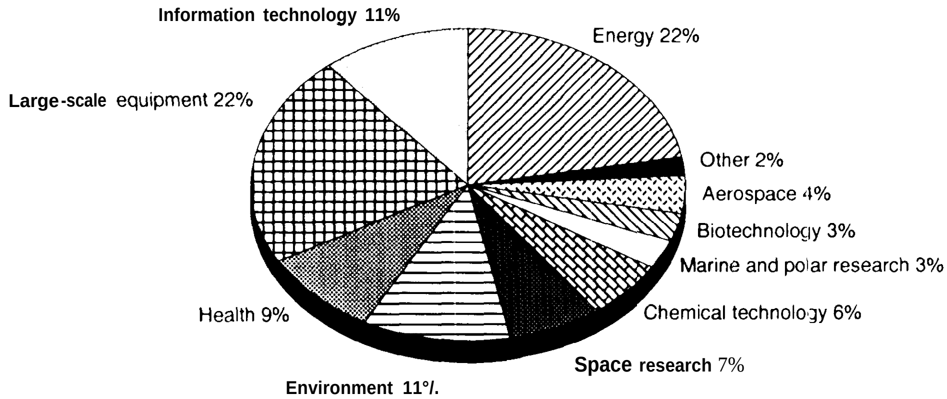
Like the U.S. DOE 17 major laboratories (including 9 multiprogram national laboratories and 8 large single program laboratories), the GFEs occupy the most prominent position in their nation's R&D establishment. They are funded at levels roughly comparable to the DOE labs in relation to their national economy.[5] They were first founded in the late 1950s mainly to do research in nuclear energy technology and high energy physics, though energy has since declined in relative importance. They are strongest in large team, long-term research, and a substantial part of their budget is devoted to large research facilities (e.g., synchrotrons colliders) that are open to use by private industry. Since the early 1980s, government policy has emphasized cooperation with industry as a primary task, but they have made little headway; industry projects are still a minuscule part of their total budgets.

There are important differences with the U.S. DOE labs too. Besides the fact that GFEs have never had any part in designing nuclear weapons, their missions are more broadly delineated than the energy and weapons related missions of the U.S. DOE labs. Their R&D covers some fields that are mostly the province of other agencies in the United States, i.e., space and aeronautics, health and biotechnology, oceans and polar

[4] See, for example, Council on Competitiveness, *German Technology Policy : Incentive for Industrial Innovation* (Washington, DC: 1992); "UK Science Policy—Parties Discover Technology," *Nature*, Feb. 27, 1992, p. 757.

[5] The German GDPof 2.6 trillion DM ($1.2 trillion) in 1991 was about one-fifth the size of the $5.7 trillion U.S. economy. The GFEs' 1992 budget of 3.5 billion DM ($1.4 billion) is about one-fourth the $5.7 billion ($4.7 billion from U.S. DOE and about $1 billion from other government agencies) of the U.S. DOE lab complex.

Figure A-4-Research Performed at German GFE's, 1991



SOURCE: German Federal Ministry for Research and Technology.

research (figure A-4). Nevertheless, at least three-quarters of their combined R&D budgets are devoted to energy, environment, information technology, materials research, and large facilities-all of which are major research areas for the U.S. DOE labs. The two largest of the GFEs, the Forschungszentrum Julich, or KFA, and the Kernforschungszentrum Karlsruhe, or KfK, are most similar to the DOE labs. They are multipurpose, with research encompassing nuclear energy and fusion, environmental and safety technologies, materials research, information technology, health and biotechnology, and systems analysis. They have budgets of 445 million and 470 million DM respectively ($206 and $219 million), and each employs over 3,000 people.

Germany's postwar technology policy is reflected in its R&D institutions. In the 1950s and 1960s, the government supported technologies-especially nuclear energy and aerospace--that were seen as important in re-establishing Germany as a world power.[6] When the Social Democrats took over from the conservative Christian Democrats in the 1970s, they added an emphasis on industrial technologies and transportation. In the early 1980s, nuclear energy programs were drastically cut back, partly because the technology had matured, and partly because of growing public resistance to nuclear power. In the 1980s the two biggest GFEs added major programs in so-called key technologies (information technology, materials research) and in renewable energy, nuclear safety and waste disposal research, and environmental research.

At the same time, a conservative government now returned to power directed the GFEs to focus on cooperation with industry. The mandate produced little change. From 1983 to 1990, industry projects barely edged up from about 2 to 3 percent of GFE funding sources (figure A-5). By contrast, the Fraunhofer Society's contract research with industry thrived. In fact, some of the GFEs' difficulty in expanding their contracts with industry was probably due to competition from the FhG institutes, which were growing rapidly in the 1980s and even managed to gain a near monopoly position in some contract research markets. In addition, to encourage regional development, state governments expanded their investments in Institutes of the Blue List and in applied research institutes at universities. However, the GFEs did improve relations with universities; senior researchers now teach at nearby universities and the labs are training young scientists.

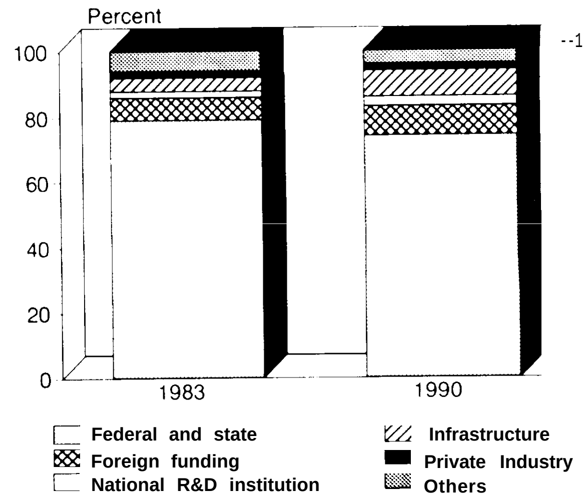
With the high costs of reunification in the early 1990s, budgets for all the publicly supported R&D institutions were tightened, except for new spending by a unified German Government in East German facilities.[7] For the years through 1995, new R&D guidelines require the GFEs to concentrate on research

6 John A. Alic, Lewis M. Branscomb, Harvey Brooks, Ashton B. Carter, and Gerald L. Epstein, *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (Boston, MA: Harvard Business School Press, 1992), pp. 228-229.

7 A review of East German research facilities by the West German Wissenschaftsrat (a science policy advisory body) found a number of them well qurdi.tied to join a united German public R&D system. Three new single purpose GFEs (for geology, health, and environmental research) were added in East Germany, as were 24 @tire@ of the Blue List, 9 institutes and 12 subsidiaries of the Fraunhofer Society, and 2 institutes and 29 working parties of the Max Planck Society.

fields where they have a comparative advantage over competing institutions. This means more emphasis on environmental and health research, high energy physics, and multidisciplinary basic science. On the other hand, GFE projects in technology development will have to be specially justified in the future. In the East German states, Institutes of the Blue List, which are more flexible and closer to state economic development policies, will have primary responsibility for technology development.

Figure A-5-Total Funding for German GFE's, 1983 and 1990



SOURCE: German Federal Ministry for Research and Technology.

THE FRAUNHOFER SOCIETY

Despite its renown, the Fraunhofer Society (FhG) is the smallest of Germany's four major publicly funded research institutions. It fosters application-oriented research, often focused on the needs of regionally concentrated industries, and forges links between universities, industry associations, and private companies. It comprises 47 institutes throughout Germany, including 9 new ones in the East German states. In recent years, about 30 percent of the FhG budget has been basic funding from the national and state governments; the actual amount depends on the individual institute's success in getting contracts from industry and government.[8] Industry contracts provide another 30 percent of FhG funds, and government projects a bit more than 30 percent.

The FhG buys equipment and builds up in-house research abilities with its basic financing from the government, and then sells its expertise in the marketplace--typically to individual fins, but sometimes to consortia of small and medium-sized enterprises (SMEs). About half of the FhG's industry contracts are with SMEs.

The strength of the FhG system is in its responsiveness to industry's needs and its ability to go beyond the research capacities of individual firms. This is due in part to FhG's funding scheme, which rewards institutes with more government funds the more they succeed with industry contracts, but also provides generous startup funding for new institutes and a continuing solid infusion of funds for general institutional support-in effect, a subsidy for industrial contract work. The clear mission to work with industry is another source of strength, So is the close linkage with universities, which allows the FhG to tap into university research and employ large numbers of students, who often go on to work in the industries served by the FhG.

The institutes are not universally successful. According to a report by the Council on Competitiveness,[9] institutes that concentrate on technologies with immediate applications in industry are likely to flourish while those focusing on longer term, riskier research may have trouble generating industry interest.[10] The Council compared two FhG institutes in Stuttgart. The thriving Fraunhofer Institute for Manufacturing Engineering and Automation does R&D in such fields as flexible manufacturing systems, automation of assembly and handling, industrial robotics and sensors, and quality engineering; it gets 84 percent of its funding from industrial firms, mostly in the auto industry. By contrast, the Fraunhofer Institute for Surface Phenomena and Bioengineering Technology is struggling. Its research includes work in physical chemistry and biochemistry, with possible applications of surface and membrane technologies in medicine and microbiology. With its focus on sophisticated

[8] The share of government basic funding is higher in new institutes, such as those in the East German states.

9 A private [illegible] organization made up of leaders from business, labor, and academia.

10 Council on Competitiveness, *German Technology Policy: Incentive for Innovation* (Washington, DC: 199[illegible]) p. [illegible]

research with a longer term and less certain payoff, this institute is far from financial self-sufficiency and only about 20 percent of it work is repeat contracts with industry.

Moreover, the present success of the FhG was by no means assured in its infant years. Created in the state of Bavaria in 1949, the FhG floundered for several years, losing its backing from Bavaria and lacking federal support. It barely survived on meager subsidies from another state (Baden-Wurttemberg) and was not able to attract industrial clients. Rescue came at the end of the 1950s, in the form of funding from the Ministry of Defense for four university-connected institutes.[11] By the 1960s, about half the FhG's budget came from military funds. With this backing, the FhG was able to branch out a bit, subsidizing some civilian research projects of its own with cross-subsidies from the military and laying the groundwork for attracting industry contracts. Even so, the FhG's total funding remained below 100 million DM into the early 1970s.

Then, under the social democratic government and policies of the 1970s, the BMFT gave industry-oriented applied research much stronger emphasis, and chose the FhG--virtually the only German institution with relevant experience-as the organization to build for the purpose. This helped the FhG take off. Growth rates shot up exponentially, with annual funding reaching 800 million DM ($372 million) by the early 1990s. Today, 7 of the 47 FhG institutes still perform military research, but the rest are firmly established in work with civilian industries.

In the United States, there is little to compare with Germany's Fraunhofer Society. Some States have supported regional centers that link local industries and universities to promote the commercialization of new technologies; Pennsylvania's Ben Franklin Partnership and Oregon's Key Industries Initiative are examples. Federal support of regional centers working with local industries on application-oriented R&D and technology demonstration has scarcely existed,[12] but a new program of Regional Technology Alliances (RTAs) may develop into that kind of system.

Authorized in fiscal year 1992, the RTAs received their first funding in fiscal year 1993, at the very substantial level of $97 million. This new program was part of a $1-billion defense conversion package to encourage technology development and diffusion in both defense and civilian sectors. Funding for RTAs comes from the U.S. Department of Defense (DoD), with the Federal share limited to not more than half the total cost of any center, and to last no longer than 6 years.[13] The law states the main purpose of the program as helping U.S. firms apply critical dual-use technologies to enhance national security; it is also meant to foster the emergence of new firms that are capable of applying dual-use technologies.

With its strong emphasis on national security and its home in the Department of Defense, the RTAs might be constrained from developing the frankly commercial character of most of the FhG institutes.[14] The Fraunhofer Society also had its beginnings in military R&D, but it has long since outgrown that identity. It should also be noted that, although the RTA program is starting off with much higher funding than the FhG had in its earlier years, that support is limited to 6 years. Unlike the FhG institutes, the RTA centers will have no continued public funding to maintain their institutional base.

This account of the FhG's early history is drawn mainly from Hans-Willy Hohn and [illegible] Schneider, "Path-Dependency and [illegible] Mass [illegible] the Development of Research and Technology: A Focused Comparison" *Science and Public Policy*, vol. 18, No. 2, April 1991, pp. 11 [illegible]22.

An exception is the National Apparel Technology Center in [illegible]eigh, North [illegible]rolina, which demonstrates a [illegible] modern apparel-making equipment to its member companies and arranges seminars with the apparel engineering faculty of nearby North Carolina State University. The center is an outgrowth of the TC[2] (Textile/Clothing Technology Corporation) project, an unusual government/industry R&D partnership founded in 1979 to develop automated sewing equipment.

The RTAs were originally named critical technology application centers, in the 1992 act; they were renamed regional technology alliances in the 1993 act, and the limit for Federal funding of the centers was raised from 30 percent to 50 percent. Department of Defense Authorization Act for Fiscal Years 1992 and 1993, section 2524, and Department of Defense Authorization Act for Fiscal Year 1993, section 2513.

14 The Advanced Research Projects Agency, the DoD agency charged with supervising the RTAs, [illegible] working closely with [illegible] U.S. Government agencies to establish the system in early 1993.