Chapter 5

Research Institutions and Organizations

The Department of Defense technology base program has been described in chapter 4 of this special report, and the contribution of private industry is addressed in chapter 3. This chapter describes the contributions made to the defense technology base by government-funded laboratories—both defense and non-defense—and it also discusses how civilian government agencies foster the technology base that is drawn on by the Department of Defense. In addition, various types of nongovernment, nonprofit laboratories are discussed at the end of the chapter.

DEFENSE DEPARTMENT LABORATORIES

Defense Department laboratories are owned and operated—under a variety of different philosophies-by the military services. Their activities are coordinated, to some degree, by the Office of the Secretary of Defense, and they are staffed mostly by Civil Servants and some military officers rotating through on short tours of duty.

Army Laboratories

Department of the Army technology base work is performed by 31 research and development organizations attached to the Army Materiel Command (7 laboratories, 8 research, development, and engineering centers, the Army Research Office, and the Project Manager Training Device), the Office of the Surgeon General of the Army (9 laboratories), the Army Corps of Engineers (4 laboratories), and the Office of the Deputy Chief of Staff for Personnel (1 laboratory). The major Army laboratories are described below.

Army Materiel Command (AMC)

Laboratory Command (LABCOM).–Laboratory Command, within the Army Materiel Command, operates seven facilities that are responsible primarily for 6.2 and 6.3 research in specialized areas of technology relevant to Army requirements. These are:

Atmospheric Sciences Laboratory (ASL), White Sands Missile Range, NM (390).[1]*–The* Atmospheric Sciences Laboratory is AMC's principal laboratory for atmospheric and meteorological technology and equipment development. Basic investigations into atmospheric sensing technologies and applications are conducted to assess the potential impact of atmospheric conditions on advanced Army weapons and systems.

Ballistic Research Laboratory (BRL), Aberdeen Proving Ground, MD (730). –This laboratory conducts research into the vulnerability and lethality of Army weapons (e.g., guns, cannons, missiles). It addresses weapons systems from the drawing board to the field and from small arms and ammunition to large missiles and their warheads.

Electronics Technology and Devices Laboratory (ETDL), Ft. Monmouth NJ (310).–This is the primary Army laboratory for electronics, electron devices, and tactical power supplies. This laboratory is the lead laboratory for the Army for the Very High Speed Integrated Circuit (VHSIC) and Microwave/Millimeter Wave Monolithic Integrated Circuit (MIMIC) programs.

[1]The numbers in parentheses give the total work force (scientists, engineers, managers, support staff, administration, etc.).

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Harry Diamond Laboratories (HDL), Adelphi, MD (730).—Harry Diamond Laboratories is involved in exploratory and advanced development of a variety of technologies including fuzing, target detection and analysis, ordnance electronics, electromagnetic effects, materials, and industrial and maintenance engineering. This laboratory is AMC's lead laboratory for fluidics and nuclear weapons effects.

Human Engineering Laboratory (HEL), Aberdeen, MD (220).–This laboratory is responsible for the "man-machine' interface for advanced Army systems. It has assumed the role of lead Army laboratory for robotics research and human factors engineering.

*Materials Technology Laboratory (MTL), Watertown, **MA*** (660).–The Materials Technology Laboratory is responsible for managing and conducting research and exploratory development programs in materials and solid mechanics, including basic research in advanced metals, composites, and ceramics.

Vulnerability Assessment Laboratory (VAL), White Sands Missile Range, NM(260). –This laboratory provides an independent assessment of the vulnerability of Army weapons and communications electronics systems to hostile electronic warfare (e.g. jamming).

Research, Development, and Engineering (RDE) Centers.–The six Systems Commands of the Army Materiel Command each operate one or more research, development and engineering centers which conduct exploratory and advanced technology development in support of the specific commands' mission responsibilities. These centers are organizational entities and are not necessarily physically located at a single site. (If there is no single primary site, the location given below is that of the parent Systems Command.) Although the RDE Centers conduct some in-house research and development, the bulk of their work is contracted out to industry (the largest contributor), nonprofit organizations, and some universities. The centers are oriented toward the development end of the technology program, leading to components, products, and systems.

Armament RDE Center (ARDEC), Picatinny Arsenal, NJ (4,150).—ARDEC concentrates its efforts on two main areas-weapons and munitions. ARDEC is managed by the Armaments, Munitions, and Chemical Command (AMCCOM), centered at Rock Island, IL.

Chemical RDE Center (CRDEC), Aberdeen Proving Ground, MD (1,400).–CRDEC is the Defense Department's lead laboratory for chemical and biological defense-related matters. Like ARDEC, CRDEC is an RDE center for the Armaments, Munitions, and Chemical Command.

Aviation RDE Center, St. Louis, MO (1,430). –This center, operated by the Aviation Systems Command (AVSCOM), is responsible for Army aviation research and development including airframes, propulsion systems, and avionics. Two major activities are operated in support of Army aviation R&D efforts. First is the Aviation Research and Technology Activity, co-located with NASA's Ames Research Center, Moffett Field, CA. This Activity has subordinate offices at (or near) two other NASA centers: Lewis Research Center and Langley Research Center. These locations reflect the close relationship between Army aviation and NASA's research into advanced short takeoff and landing (STOL) flight concepts and propulsion systems. The second Activity supporting the Aviation RDE Center is the Avionics Research and Development Activity, Ft. Monmouth, NJ, which is co-located with the Army's electronics and communications experts—the Communications-Electronics Command and the Laboratory Command's Electronic Technology and Device Laboratory.

*Communications-Electronics Command **(CECOM) RDE** Center, Ft. Monmouth, NJ* (1,930).–The CECOM RDE center is responsible for research in the areas of command, control, communications, intelligence, and electronic warfare. In addition to the Ft. Monmouth effort, a number of subordinate facilities and centers focus on specialized electronics and sensor research and development. The Night Vision and Electro-Optical Laboratory, Ft. Bel-

voir, VA, is a recognized leader in infrared and other night vision devices for all three Services. The Signals Warfare Laboratory, Vint Hills Farms Station, VA, conducts programs related to surveillance, reconnaissance, and electronic warfare (including signals intelligence, communications intelligence, electronic countermeasures and electronic counter-countermeasures). Other activities under the CECOM RDE Center include: the Electronic Warfare and Special Sensors group; the Airborne Electronics Research Activity, Lakehurst, NJ; the Center for C^3 Systems; and the Life-Cycle Software Engineering Center.

Missile Command (MICOM) RDE Center, Redstone Arsenal, AL (1 ,470).—This center is responsible for the development, acquisition, and production of all Army missile systems. It is the Army's lead organization for guidance and control, terminal homing, and high power/high energy laser technology. With the capability to carry a concept through to prototype almost without outside help, it is very influential in the overall direction and progress of Army guided weapons programs.

Tank Automotive Command (TACOM) RDE Center, Warren, MI (810).–This center is responsible for technologies and systems associated with vehicular propulsion, structure, and advanced armor. As exemplified by its location, it has a close relationship with the U.S. automotive industry. Substantial exploratory work is also underway on robotics, vetronics (integrated vehicle electronics), propulsion, and vehicle survivability.

Belvoir RDE Center, Fort Belvoir, VA (1,080).–The Belvoir RDE Center is responsible for combat engineering, logistics support, materials, fuels, and lubricants. It falls under the Troop Support Command (TROSCOM), headquartered in St. Louis, MO, which is responsible for developing systems and equipment to support the soldier.

Natick RDE Center, Natick, MA (l,090).– The Natick RDE Center, also falling under the Troop Support Command, is dedicated to ensuring the maximum survivability, supportability, sustainability, and combat effectiveness of the individual soldier in all combat environments.

Office of the Surgeon General (OTSG)

The Army Medical Research and Development Command, under the authority of the Surgeon General of the Army, operates nine laboratories that investigate medical areas of interest to the Army. These laboratories employ a total of 2,710 personnel. The largest is the Walter Reed Army Institute of Research (1,000 personnel), which performs research in the areas of military disease hazards, combat casualty care, Army systems hazards, and medical defenses against and treatments for chemical weapons. Other facilities also examine these topics and others such as crew workload and stress; treatment of dental injuries; investigation of the problems, complications, and treatment of mechanical and burn injury; the biomedical effects of military lasers; the effects of temperature, altitude, work, and nutrition on the health and performance of soldiers or crews; acoustics; and vision.

Corps of Engineers (COE)

The Corps of Engineers operates four laboratories.

Cold Regions Research and Engineering Laboratory (CRREL), Hanover, NH (300).– This facility investigates problems faced by the Corps of Engineers in cold areas of the world.

Construction Engineering Research Laboratory (CERL), Champaign, IL (260).–This laboratory conducts research and development in facility construction, operations, and maintenance.

Engineer Topographic Laboratories (ETL), Fort Belvoir, VA (300).–This laboratory provides the military community with research and development in topographic sciences and terrain analysis.

Engineer Waterways Experiment Station (WES), Vicksburg, MS (1,660).–The five technical laboratories at this facility-the Hydraulics, Geotechnical, Structures, and En-

vironmental Laboratories and the Coastal Engineering Research Center–support the military and civilian missions of the Army, other federal agencies, and allied nations.

Deputy Chief of Staff for Personnell/Army Research Institute for Behavioral and Social Sciences

The Deputy Chief of Staff for Personnel (DCSPER) operates one laboratory, the Army Research Institute for Behavioral and Social Sciences (ARI). This lab, employing 400 personnel, is the Army's lead lab for soldier-oriented research.

Navy Laboratories

The Navy's research and development system, as described in chapter 4, incorporates a greater in-house research and development capability than that of the Army or the Air Force. Many Navy laboratories and development centers not only have the capability to conduct in-house research and exploratory development (6.1 and 6.2), but also can carry a design almost to the production level through the more "mature" stages of advanced systems development (6.3B) and engineering development (6.4). The various Navy laboratories are described below.

Office of Naval Research (ONR)

The Office of Naval Research operates four laboratories.

Naval Research Laboratory (NRL), Washington, DC (3,540/l,550).[2]*-Founded in 1923, NRL is the Navy's principal "in-house" research laboratory. Indeed, in some areas of technology, it is DoD's principal laboratory. NRL conducts a vigorous research program in the fields of computer science, artificial intelligence and information management, device technology, electronic warfare, materials, directed energy weapons, surveillance and sensor technology, and undersea technology. In addition, a major space systems technology effort has recently been undertaken by the Laboratory. Roughly one-fourth of NRL's activity is funded by the Navy's research budget. The balance of the activity is funded as a result of proposals by NRL personnel to conduct R&D for Navy development work, other DoD/Service laboratories, and other U.S. Government departments. The "contracts" won by NRL involve 6.1, 6.2, 6.3A/B, and 6.4 activities. NRL also maintains an active exchange program with other laboratories, both in the United States and internationally, and with universities.

Other ONR Laboratories (490/250).-In addition to the Naval Research Laboratory, the Office of Naval Research operates smaller laboratories conducting research in specialized subject areas. The Naval Oceanographic Research and Development Activity (NORDA) and the Institute for Naval Oceanography (INO), in Bay St. Louis, MS, conduct research, development, test, and evaluation programs in ocean science and technology and in ocean forecasting, respectively. The two labs employ 424 people, 215 of whom are scientists or engineers. The Navy Environmental Prediction Research Facility (NEPRF) in Monterey, CA, conducts research and development in various areas of atmospheric science.

Space and Naval Warfare Systems Command (SPAWAR)

Prior to the 1985 reorganization of the Navy science and technology program, each of the major Naval Systems Commands (e.g., Naval Air Systems Command) had responsibility for the operation of mission-specific development activities and centers. This concept has been replaced by one wherein the Space and Naval Warfare Systems Command (SPAWAR) serves as the focal point for most exploratory (6.2) and advanced technology (6.3A) development activities. The other Systems Commands (e.g., the Naval Air Systems Command, the Naval Sea Systems Command, and the Naval Space Command) have primary responsibility for developing "platforms" (e.g., aircraft,

*The first number in parentheses gives the total number of employees at the lab and the second gives the number of scientists and engineers. Note that the definitions of scientist and engineer may vary from facility to facility, and therefore these numbers may not be directly comparable.

ships, space systems). Basic "safety-of-flight' or "sea-keeping" equipment remain their responsibilities as well, but mission payloads and other specialized equipment are increasingly becoming the responsibility of SPAWAR. In line with this philosophy, all Naval Development Centers and activities have been assigned to that Command. This gives SPAWAR a "high-leverage' role in the Navy's overall strategy for systems development.

In addition to their responsibility to SPAWAR for carrying out the science and technology program, the Centers retain a role in providing technical management for major systems programs. In this capacity, the Centers are responsible to their pre-1985 "masters"; i.e., the Systems Commands charged with developing the respective air, sea, and space systems. Seven major development centers are now the responsibility of SPAWAR.

Naval Air Development Center (NADC), Warminster, PA (2,310/1,510).—This Center is responsible for the development of aircraft and aircraft systems, including electronic warfare and anti-submarine warfare systems. In addition to weapons system development, science and technology programs there involve electro-optic, acoustic, and microwave technologies.

Naval Ocean Systems Center (NOSC), San Diego, CA (2,970/l,540).--The Naval Ocean Systems Center is the Navy's lead Center for surface command and control and for combat direction systems. It has been a continuing leader in ocean surveillance systems (e.g., acoustic, electromagnetic, etc.), and is emerging as a leader in artificial intelligence and knowledge-based systems to support the Navy's combat-decision-aid programs. The Center is also the Navy's development organization for undersea weapon systems. S&T activities include ocean science, bioscience, electronics, and electronic materials research.

Naval Weapon Center (NWC), China Lake, CA (4,970/1,820).-China" Lake is responsible for the development of air-to-air weapons and Naval air-delivered ordnance. The AI M-9 Sidewinder missile was developed initially by China Lake more than 20 years ago, and versions of the missile are still state-of-the-art as a result of the Center's continuing efforts. The development of anti-radiation missile technology and weapons has been carried to a mature state by China Lake. Additionally, China Lake engineers and scientists are considered leaders in sensor technologies (infrared, electro-optic) and missile engineering.

China Lake is of particular interest in that it is one of the sites where the Navy is experimenting with a more flexible salary structure for scientific and technical personnel. Government laboratory managers have stated that Civil Service pay scales for technical personnel, lagging behind industry and even academia, have hampered efforts to maintain high-quality technical staffs.

David W. Taylor Naval Ship Research and Development Center (NSRDC), Carderock, MD and Annapolis, MD (1,130/580).—This Center is responsible primarily for hull designs and advanced ship protection systems (e.g., demagnetizing systems, etc.). It maintains major modeling and test facilities and provides technical management for surface and submarine propulsion systems. Its S&T activities include ship acoustics, magnetics, materials and structures, hydrodynamics, advanced propulsion, and ship survivability.

Naval Surface Warfare Center (NSWC), White Oak, MD (4,870/2,430).—This Center, with its major subordinate facility for weapon systems at Dalghren, VA, serves to develop Naval surface warfare systems, including weapons and systems for the detection and attack of surface and subsurface targets. In addition to weapons system development, NSWC also has a strategic role, serving as the Program Office for the submarine-launched ballistic missile. A broad range of S&T activities are supported at the Center, including energetic materials, charged-particle beams, and sensors.

Naval Undersea Systems Center (NUSC), Newport, RI (3,490/1,930).—AS the Navy's primary organization for anti-submarine warfare, the Naval Undersea Systems Center is responsible for advanced developments in sonar and other undersea detection technologies. The

Center also provides technical direction for submarine combat systems.

Naval Coastal Systems Center (NCSC), Panama City, FL (1,130/580).-This Center is responsible for mine countermeasures and shallow water undersea weapons. Significant test and evaluation facilities are maintained and operated there.

Summary

The Navy's laboratories and Development Centers have historically been influential throughout the acquisition cycle, up to–and including-production phases. The management reorganization in 1985 that eliminated the Chief of Naval Material-the Navy analogue of the Army Materiel Command and the Air Force Systems Command-consolidated all Naval Development Center activity under SPAWAR. Nevertheless, the job functions, reporting responsibilities, and priorities of many of the scientists and engineers in the field did not change substantially.

Air Force Laboratories

Air Force Systems Command (AFSC)

The exploratory (6.2) and advanced technology (6.3A) development elements of the Air Force S&T program are conducted under the five Systems Divisions which report directly to AFSC: Aeronautical Systems Division, Armaments Division, Electronic Systems Division, Human Systems Division, and Space Division. Each Division provides oversight for one or more laboratories, through which research, exploratory development, and advanced technology development are conducted in support of Air Force-wide requirements. The laboratories in the AFSC organization are described below, with staffing levels given in parentheses for each laboratory. Not explicitly described here is the Air Force Office of Scientific Research, also part of Air Force Systems Command. This Office is responsible for the Air Force basic research (6.1) program, which is conducted primarily outside the Air Force laboratories. The AFSC laboratories are:

Air Force Wright Aeronautical Laboratories (AFWAL), Wright-Patterson Air Force Base, OH (see staff breakdown below) .–Under the Aeronautical Systems Division (ASD) is a "cluster" of laboratories which comprise the Air Force Wright Aeronautical Laboratories—four laboratories, a staff and a Signature Technology Office.

The Aeropropulsion Laboratory (490) is responsible for exploring and developing technologies associated with aircraft and aerospace vehicle power, including turbine engines, ramjets, aerospace power components, fuels, and lubricants.

The Avionics Laboratory (870) is the lead Air Force laboratory for the development of avionics systems and technologies. Major efforts are underway in microelectronics, microwave devices, advanced electro-optics, target recognition technologies, radar systems, and electronic warfare.

The Flight Dynamics Laboratory (1,000) is responsible for aerodynamics, aircraft design, aerospace structures (including research into applications of complex composites), and flight-control systems such as fly-by-light systems. Basic investigations are being conducted into advanced flight mechanisms including hypersonic flight, short take-off and landing, and advanced maneuvering technologies. The Forward Swept Wing (X-29) Program has been a major effort in conjunction with DARPA and the NASA Ames Research Center.

The Materials Laboratory (420) is responsible for materials research and development, including electronic and electromagnetic materials, metals, composites, and the recently discovered high-temperature superconductors. The Materials Laboratory conducts comprehensive nondestructive testing and nondestructive evaluation programs as part of its ongoing effort to develop advanced, high-strength, low-weight structures for aircraft and aerospace vehicles.

Air Force Armament Laboratory (AFATL), Eglin Air Force Base, FL (530).—This laboratory reports directly to, and is co-located with,

the Armaments Division. It is charged by the Armaments Division to explore technologies applicable to Air Force non-nuclear weapons, both offensive and defensive. Thus substantial efforts are underway in munitions, seekers (electro-optical, radiofrequency, etc.), structures, and advanced guidance systems for air-to-surface and air-to-air weapons. Although much of the effort involves technology development, a substantial analytical capability can be found there, particularly in the areas of vulnerability, weapons effectiveness, and simulators.

Rome Air Development Center (RADC), Griffiss Air Force Base, NY (1,210).–Rome Air Development Center is the only laboratory operated by the Electronics Systems Division. Among its main activities are investigations into advanced C^3 concepts, information processing, and ground-based and strategic surveillance systems. It is conducting a vigorous pro gram in support of SDIO's battle management/ C^3 effort. RADC maintains two directorates at Hanscom Air Force Base, MA—Electromagnetics and Solid-State Sciences. The first is involved in basic investigations into antennas and electromagnetic phenomena, and the second focuses on solid-state electronics, devices, materials, and systems. An effort underway at the latter facility is focused on radiation-hardened electronic technologies—of interest to both SDIO and the Air Force's strategic C^3 missions.

Air Force Geophysics Laboratory (AFGL), Hanscom Air Force Base, MA (560).-This laboratory reports to the Air Force Space Division through the Air Force Space Technology Center, a management headquarters at Kirtland Air Force Base, Albuquerque, NM. It supports the Air Force's mission in developing and deploying space, airborne, and ground-based systems. Research is conducted into atmospheric science, Earth sciences, infrared technology, and other disciplines related to the space and terrestrial environment.

Air Force Weapons Laboratory (AFWL), Kirtland Air Force Base, NM (1,110).—The Air Force Weapons Laboratory, like the Air Force Geophysics Laboratory, reports to Space Division through the Space Technology Center. It is the lead laboratory involved in the development of technologies related to nuclear weapons effects, directed energy weapons, and radiation hardening. A close association has therefore developed between the Air Force Weapons Laboratory and the two Department of Energy laboratories in New Mexico that are involved in nuclear weapons–Sandia National Laboratories and the Los Alamos National Laboratory. The Air Force Weapons Laboratory has assumed an increasingly important role in the SDI program, especially with regard to the weapons development efforts. The Laboratory's experience and ongoing activities in advanced radiation technology and high-power laser technology have placed it as a leader in directed energy weapon research.

Air Force Astronautics Laboratory (AFAL), Edwards Air Force Base, CA (400).-The Astronautics Laboratory, formerly the Rocket Propulsion Laboratory, is the third laboratory reporting through the Space Technology Center to Space Division. It plans and executes research, exploratory development, and advanced development programs for interdisciplinary space technology and rocket propulsion.

Human Resources Laboratory (AFHRL), Brooks Air Force Base, TX (410).—The Human Resources Laboratory manages and conducts research, exploratory development, and advanced development programs for manpower and personnel, operational and technical training, simulation, and logistics systems.

Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL), Wright-Patterson Air Force Base, OH (980).—The three divisions of AAMRL seek to protect Air Force personnel against environmental injury and provide protective equipment; study human physical and mental performance so that human capabilities can be integrated into systems with maximum effectiveness; and identify and quantify toxic chemical hazards created by Air Force systems and operations.

Air Force Engineering and Services Laboratory (AFESL), Tyndall Air Force Base, FL (100)

Not formally part of Air Force Systems Command, the Engineering and Services Laboratory is the lead agency for basic research, exploratory development, advanced development, and selected engineering development programs for civil engineering and environmental quality technology. It is part of the Air Force Engineering and Services Center, which has responsibility for developing and providing the technology base for the tools and training of the military engineer.

Summary

Unlike the Navy, the Air Force philosophy emphasizes developing the expertise to effectively contract with industry, rather than performing substantial research and development in-house. This philosophy brings programs out into private industry earlier, introducing competition at an earlier stage. Therefore, Air Force labs are not generally viewed as being in competition with the private sector; in fact, Air Force exploratory development programs are viewed by industry as important "seed" programs that will serve to build a company's future business base.

DEPARTMENT OF ENERGY NATIONAL LABORATORIES

Background

The Department of Energy's (DOE's) National Laboratory structure is comprised of about 60 facilities, including the nuclear weapons production facilities, that are involved in a broad range of research, advanced development, and production. With activities located in almost every State, the fiscal year 1986 budget for this complex was over $10 billion (excluding the Strategic Petroleum Reserve and the Power Marketing Administrations). Approximately 135,000 people are now employed within this Laboratory system. Only about 5 percent of these are Federal employees; theremainder are employed by the industries and universities which operate most of the facilities. The replacement cost of all field facilities is estimated to total well over $50 billion.

Stemming from the Manhattan Project of World War II, the DOE National Laboratory system has now evolved in several major directions. One major responsibility is the design and production of all U.S. nuclear weapons, including uranium enrichment and special nuclear materials (e.g., enriched uranium and plutonium) production. DOE is also responsible for development and production of nuclear reactors for the Navy's submarine fleet. Research and development, production and maintenance, and nuclear materials production for nuclear weapons and other defense activities are each funded at a level of about $2 billion annually.

The research functions and capabilities of the Department of Energy have also broadened beyond their original concentration on nuclear physics to encompass a wide spectrum of research into fundamental sciences. The present scientific and technological capabilities of the DOE National Laboratories make possible investigations including the study of chemical reactions, cosmology, the operation of biological cells, the process of genetic information coding, the ecosystem, the geosphere, mathematics and computing, and medicine. There are nine "multiprogram" laboratories and some 30 specialized laboratories involved in these fundamental science and technology activities, accounting for slightly more than 40 percent of the total field budget and employing more than 60,000 people—more than half of whom are scientists, engineers, and technicians. DOE research and technology areas of interest, and its major test and evaluation facilities,

make possible significant contributions in areas of direct relevance to the defense technology base.

The DOE laboratories interact with private industry and with the academic community through mechanisms such as cooperative programs, visiting staff appointments, patent licensing, subcontracting, and use of DOE facilities. Major, capital-intensive, and often unique experimental facilities located at the DOE laboratories are made available to academic researchers for fundamental scientific experiments without cost, provided that the research results are published. Cooperation extends to major U.S. universities, industrial researchers, and international scientists.

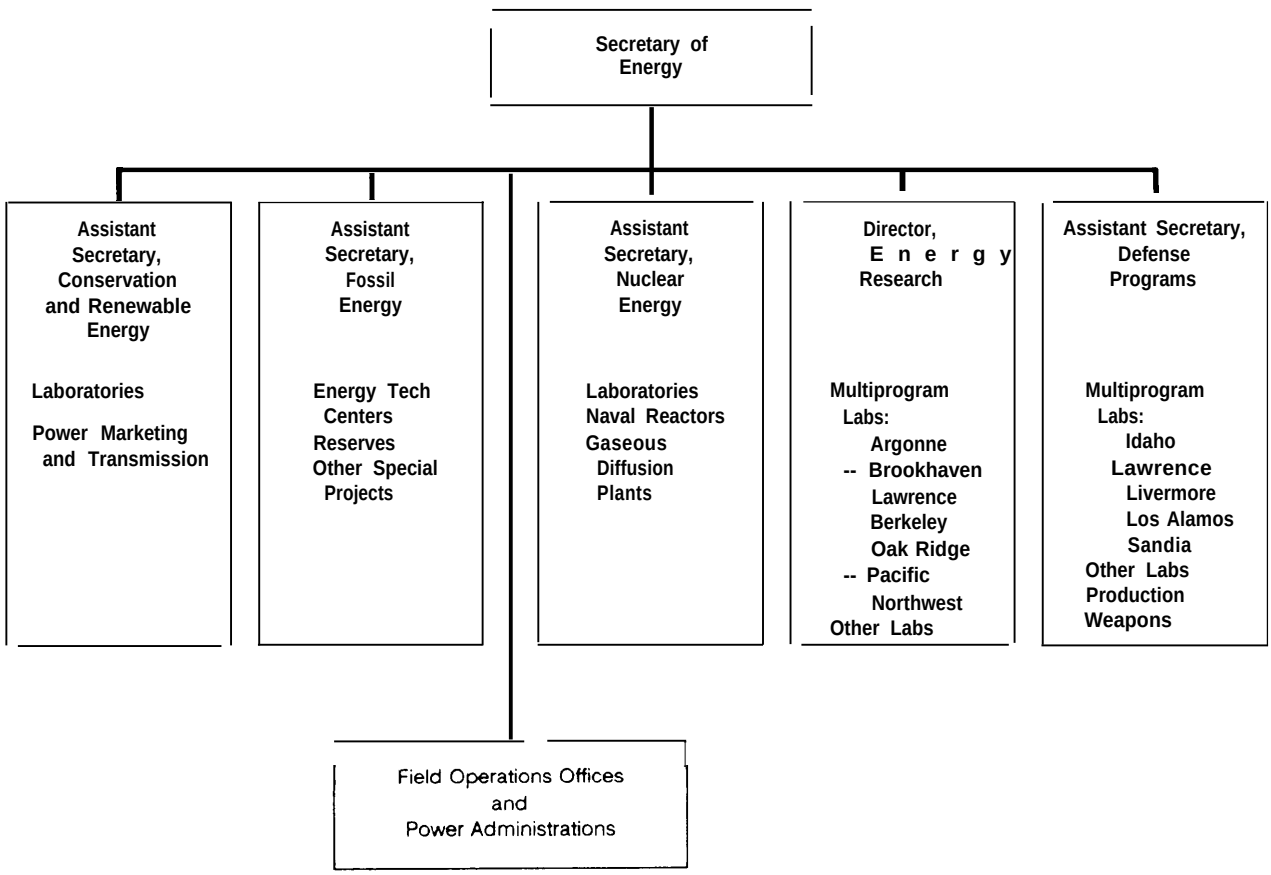
Organization and Management

The complexity of DOE's mission and the diversity of its laboratory complex have resulted in an equally complex management organization. Figure 13 outlines the management structure emanating from the Washington, D.C. headquarters. Of particular concern to the defense technology base are the activities and responsibilities of the Energy Research, Defense, and Nuclear Energy programs. The key functions of the DOE headquarters management offices are summarized below.

Energy Research

The Office of the Director of Energy Research (figure 13) manages the bulk of DOE

Figure 13.– Management Structure for DOE Field Facilities



SOURCE: Department of Energy

fundamental scientific research programs, including: high-energy physics; nuclear physics; the physical, biological and mathematical sciences; magnetic fusion energy; and environmental and health effects. It also supports university research and university-based education and training activities. Moreover, the Director of Energy Research serves as scientific advisor to the Secretary of Energy for all DOE energy research and development activities. The Office also maintains oversight of the multiprogram and other laboratories under the jurisdiction of the Department, with the exception of the nuclear weapons laboratories. Five multiprogram laboratories and 14 program-dedicated facilities are administratively assigned to the Office of Energy Research.

Defense Programs

The Office of the Assistant Secretary for Defense Programs (figure 13) manages DOE's programs for:

- . nuclear weapons research, development, testing, production, and maintenance;
- laser and particle-beam fusion;
- safeguards and security programs;
- international safeguards programs; and
- information classification.

In addition, this Office is responsible for the nuclear materials production program, the defense nuclear waste programs, and oversight of the DOE nuclear weapons production complex.

Nuclear Energy

The Office of the Assistant Secretary for Nuclear Energy (figure 13) manages DOE programs for:

- nuclear fission power generation and fuel technology;
- the evaluation of alternative reactor fuel-cycle concepts, including nonproliferation considerations;
- development of space nuclear power generation systems;
- Navy nuclear propulsion plants and reactor cores; and
- nuclear waste technology.

Much of the Nuclear Energy effort is directed toward technology and engineering development programs.

Conservation and Renewable Energy

The Office of the Assistant Secretary for Conservation and Renewable Energy (figure 13) manages a series of programs focused on developing technologies to increase usage of renewable energy sources (including solar heat and photovoltaic energy, geothermal energy, biofuels energy, and municipal waste energy) and to improve energy efficiency (e.g., transportation, buildings, industrial, and community systems, etc.). These programs involve the support of high-risk, high-payoff research and development that would not otherwise be carried out by the private sector; results of this research are disseminated to private and public sector interests.

Fossil Energy

The Office of the Assistant Secretary for Fossil Energy (figure 13) has the responsibility to develop technologies that will increase domestic production of fossil fuels. Specifically, this office supports long-term research toward an improved capability to convert coal and oil shale to liquid and gaseous fuels, and to increase domestic production and use of coal.

Laboratory Management

Eight major operations offices and a series of specialized field offices provide administrative services and day-to-day oversight of the management and operation of DOE's field complex. Much of DOE contracting for R&D and other services is done by these operations and field offices. With the exception of its national security activities, DOE uses its budget more as a catalyst for the development of generic technologies than for acquiring goods and services for its own use. This process involves a significant Federal assistance effort with universities, non-profit organizations, and state and local governments.

A unique feature of DOE laboratory management philosophy is the "Government Owned–Contractor Operated" (GOCO) con-

cept in extensive use throughout the laboratory system. This concept, which was initiated during the Manhattan Project, permits DOE to provide the massive capital investment necessary to create and maintain field facilities and, at the same time, obtain experienced management under contract with industry and universities.

Multiprogram Laboratories

DOE nuclear weapons R&D and nuclear materials production are of obvious interest to DoD, but the DOE multiprogram laboratories also make extensive contributions to the defense technology base in general. These laboratories all conduct defense-related research and development not directly associated with nuclear weapons. Some of them–notably Lawrence Livermore, Los Alamos and Sandia National Laboratories–have DoD as a significant "customer," with an average of 15 percent of these laboratories' work done under contract to DoD. However, DOE restricts the amount of "work-for-others" that its laboratories can perform to keep them from becoming too dependent on funding not under DOE control. The missions and program priorities for the nine multiprogram laboratories are described below.

Sandia National Laboratories (SNL), Albuquerque, NM; Livermore, CA; Tonopah, NE (8,250 total employees)

The principal mission of Sandia National Laboratories is to conduct research, development, and engineering for DoD's nuclear weapon systems—except for the nuclear explosive itself. Operated by AT&T Technologies, Inc., Sandia also conducts energy research programs in fossil, solar, and fission energy and in basic energy sciences. In these and other fields, Sandia has the capability to conduct large, interdisciplinary engineering projects that are sophisticated, but are considered technologically risky. Sandia's management seeks to combine fundamental understanding with technological development—thus generating new products and processes that are unlikely to be produced as readily in universities or industrial laboratories. Nearly 60 percent of Sandia's work is dedicated to nuclear weapon development and production, and 17 percent represents more broadly based research and advanced development for DoD. Much of this research is related to SDI.

Los Alamos National Laboratory (LANL), Los Alamos, NM (8,010)

The Los Alamos National Laboratory was established in 1943, as part of the World War II "Manhattan Engineer District," to develop the world's first nuclear weapons. Operated by the University of California, Los Alamos' primary mission today is the application of science and technology to problems of nuclear weapons and related national security issues. Nuclear weapon R&D thus remains a primary responsibility, including the design and test of advanced concepts. A broad spectrum of energy-related research in nuclear fission and nuclear fusion technologies is also conducted at Los Alamos, with additional programs in life sciences, health, environmental sciences, and basic energy sciences. The latter involve materials; chemical, nuclear, and engineering sciences; and geoscience.

Nuclear weapons research and development accounts for nearly one-half of Los Alamos' DOE-supported activity; an additional 15 percent is in support of DoD programs including SDI, non-nuclear weapons research, conventional ordnance, and materials technology. An emerging role for Los Alamos, in conjunction with the Air Force Weapons Laboratory and Sandia National Laboratories, is support of the SDI program. The Laboratory has also been conducting research into the manufacture of high-temperature superconductors and is seeking a major national role in this area.

Lawrence Livermore National Laboratory (LLNL), Livermore, CA (8,060)

The University of California operates the Lawrence Livermore National Laboratory as a scientific and technical resource for the Nation's nuclear weapons programs. While Livermore is involved in other programs of national interest, the Laboratory's primary role—like that of Los Alamos–is to perform research, development, and testing related to design

aspects of nuclear weapons at all phases in a weapon's life cycle. Other important programs underway at Livermore involve inertial fusion, magnetic fusion, biomedical and environmental research, isotope separation, and applied energy technology.

Nuclear weapons-related programs at Livermore account for nearly 50 percent of the Laboratory's DOE-funded activities. Another 12 percent of the lab's activity is "on-contract" work for DoD.

Oak Ridge National Laboratory (ORNL), Oak Ridge, TN (4,960)

This Laboratory is primarily involved in all aspects of the nuclear fission fuel cycle, with a secondary but growing involvement in the development of nuclear fusion energy technology. Oak Ridge National Laboratory also conducts generic research into problems related to energy technologies such as materials, separation techniques, chemical processes, and biotechnology. Energy technology development includes residential and commercial energy conservation, renewable energy sources, and coal conversion and utilization. The Laboratory is also the major national source of stable as well as radioactive isotopes. Oak Ridge is operated by Martin Marietta Energy Systems, Inc.

Argonne National Laboratory (ANL), Argonne, IL (3,900)

Established by the Atomic Energy Act of 1946, Argonne National Laboratory conducts applied research and engineering development in nuclear fission and other energy technologies. A primary Argonne role is to develop and operate research facilities for members of the scientific community. In doing so, it maintains a close relationship with universities and industry and aids in the education of future scientists and engineers. To fulfill this role, Argonne directs scientific and technical efforts in several related areas. Nuclear fission programs focus mainly on breeder and other advanced reactor systems. These programs emphasize fast-reactor physics, reactor safety and analysis, steam supply, and the exploration of new design concepts for reactor facilities using "inherently safe" features and cost-competitive design. In the field of fossil fuel energy, ANL concentrates on advanced conversion systems, including instrumentation and control and related technologies. Argonne also has applied research programs in nuclear applications, materials, and solar conversion systems.

Argonne conducts a variety of basic research projects in areas such as chemistry, atomic and nuclear physics, materials science, and biological and environmental sciences concerning nuclear and non-nuclear effects on organisms. The laboratory is operated under contract by the University of Chicago and performs nearly 90 percent of its work for DOE; 2 percent of the laboratory's work is "on-contract" for DoD.

Brookhaven National Laboratory (BNL), Upton, NY (3,220)

The Brookhaven National Laboratory, operated by Associated Universities, Inc., designs, develops, constructs, and operates research facilities for studying the "-fundamental properties" of matter. Brookhaven also conducts basic and applied research in related technology areas, including high energy, nuclear, and solid-state physics; chemistry; and biology. The physical, chemical, and biological effects of radiation, and chemical substances involved in the production and use of energy, are also studied. Other research programs are directed toward combustion research (processes and emissions, physical and chemical cleanup of combustion gas, meteorological dispersion, etc.), atmospheric chemistry, structural biology, the development of radiopharmaceuticals, and nuclear medicine applications. The research facilities at Brookhaven include: the 33 GeV Alternating Gradient Synchrotrons; the High-Flux Beam Reactor; the Tandem van de Graaf Facility; and the National Synchrotrons Light Source. In addition, there are several smaller accelerators, a medical research reactor, and two scanning transmission electron microscopes. DoD work, such as evaluating the

effects of radiation on microcircuits, constitutes 1 percent of Brookhaven's budget.

Lawrence Berkeley Laboratory **(LBL), Berkeley, CA (2,520)**

Operated by the University of California, the Lawrence Berkeley Laboratory was founded in 1931 to advance the development of the cyclotron invented by Ernest Lawrence. Today, LBL's primary endeavors include conducting multidisciplinary research in energy sciences, developing and operating national energy experimental facilities, educating and training future scientists and engineers, and linking LBL's research programs to industrial applications. The Centers for Advanced Materials and X-Ray Optics have been created to enhance interaction with industry.

In addition to LBL's experimental programs, major research efforts are underway in nuclear and high-energy physics, materials science and chemistry, medical and biological science, energy conservation and storage, environmental dynamics, instrumentation, and advanced accelerator designs. Advanced electron microscopes and heavy-ion accelerators are operated at LBL and are available for use by industrial and other researchers. DoD-sponsored research constitutes a very small fraction of LBL activities.

Idaho National Engineering Laboratory (INEL), Idaho Falls, ID (5,750)

This Laboratory was established in 1949 primarily to build and test nuclear reactors and support equipment. The Idaho National Engineering Laboratory now focuses on nuclear waste management. Among its tasks are reprocessing and recovering of spent nuclear fuel from selected test reactors, the Navy's nuclear fleet, and other nuclear noncommercial reactors, and the processing of liquid waste into calcine form for intermediate storage. To accomplish these tasks the laboratory operates a radioactive waste management complex for storage and disposal of low-level waste, and it conducts associated programs in materials testing, isotope production, irradiation services and training, and test support. Other INEL activities include:

- serving as the lead laboratory for the multi-megawatt space reactor program and fusion reactor safety research;
- supporting DOE non-nuclear energy research (e.g., research and development in geothermal and industrial conservation);
- supporting R&D by other laboratories (at INEL) on defense and civilian nuclear power; and
- directing the Three Mile Island "Technical Information and Examination Program. "

With the exception of nuclear waste transportation and management, INEL conducts virtually no work for DoD—basic research or otherwise.

Pacific Northwest Laboratory (PNL), Richland, WA (2,570)

The Pacific Northwest Laboratory has two principal missions: first, to develop and apply technologies for energy security; and second, to provide technical support and environmental surveillance for operations at the colocated Hanford weapons material production reactors. Current applied research programs include advanced nuclear reactor systems, nuclear waste management, dense materials production, energy conservation, and renewable energy systems. PNL also studies the environmental and health effects of radionuclides, inorganic chemicals, and complex organic mixtures encountered in energy production.

PNL maintains a staff of scientists and engineers skilled in the relevant disciplines. These disciplines are grouped to form technical "centers-of-excellence" in life sciences, materials sciences and technology, earth sciences, chemical technology, engineering development, and the information sciences. Operated by Battelle Memorial Institute, PNL works closely with the private sector and also maintains strong ties with university research teams. PNL's activities include a substantial percentage (10 percent) dedicated to DoD research and development.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION LABORATORIES AND CENTERS

Background, Organization, and Management

The National Aeronautics and Space Administration (NASA) was established in 1958 as a successor to the National Advisory Committee for Aeronautics (NACA) to oversee the Nation's efforts in the research and exploration of technologies related to aeronautics and space flight. The program has grown into a multidisciplinary effort which involves the management of a diverse complex of laboratory activities and flight test centers. For fiscal year 1988 the NASA budget is $9.0 billion.

NASA Headquarters in Washington, DC, exercises management over the space-flight centers, research centers, and other installations through six program offices. These offices formulate programs and projects; establish management policies, procedures, and performance criteria; and evaluate progress at all stages of major programs. Because of the highly public nature of NASA's work and the resulting political sensitivity, there appears to be a stronger "top-down" management emphasis than in DOE—or even DoD.

The Office of Aeronautics and Space Technology is responsible for planning, executing, and evaluating all of NASA's research and technology programs. These are programs conducted primarily to provide a broad fundamental technology base and to evaluate the feasibility of a concept, structure, component, or system which may have general application to the Nation's aeronautical and space objectives. This office is responsible for Ames Research Center, Mountain View, CA; Langley Research Center, Hampton, VA; and Lewis Research Center, Cleveland, OH.

The Office of Space Flight is responsible for developing concepts and systems for manned space flight and other space transportation systems. The Office plans, directs, executes, and evaluates the research, development, acquisition, and operation of space flight programs. Included in these programs is the National Space Transportation System, of which the Space Shuttle is a key element. The Office of Space Flight also develops and implements policy for all shuttle users and promotes improvements in safety, reliability, and effectiveness. Further responsibilities of the Office of Space Flight include the use of expendable launch systems for NASA and other civil government programs and other developmental space-based transportation systems. The Office of Space Flight has institutional responsibility for the Johnson Space Center, Houston, TX; the Kennedy Space Flight Center, FL; the National Space Technologies Laboratory, Bay St. Louis, MS; and other facilities such as the White Sands Test Facility in New Mexico and the Slidell Computer Complex in Louisiana.

The Office of Space Station is responsible for overall policy and management aspects of the Space Station program. This has become a highly visible office in light of the "political and fiscal heat" the program is taking-heat that is likely to continue. The goals of the program include developing a permanently manned Space Station by the early 1990s, encouraging other countries to participate in the program, and promoting private sector investment in space through enhanced space-based operational capabilities. NASA centers responsible for the Segments, or principal portions, of the Space Station are the Johnson Space Center, Marshall Space Flight Center, Goddard Space Flight Center, and Lewis Research Center.

The Office of Space Science and Applications is responsible for NASA's unmanned space-flight program. Directed toward scientific investigations of the solar system, the program utilizes ground-based, airborne, and space techniques, including sounding rockets, Earth satellites, and deep-space probes. This has historically been one of the most successful and cost-effective U.S. space programs, and its sci-

entific contributions have been continuous and substantial.

This Office is responsible for research and development leading to the application of space systems, space environment, and space-related or space-derived technology. These activities involve engineering and scientific disciplines such as weather and climate, pollution monitoring, Earth resources survey techniques, and Earth and ocean physics; active programs are also underway in life sciences and microgravity sciences and applications. The Office is responsible for the Jet Propulsion Laboratory, Pasadena, CA, and Goddard Space Flight Center, Greenbelt, MD.

The Office of Space Tracking and Data Systems is responsible for activities related to the tracking of launch vehicles and spacecraft–and for the acquisition and distribution of technical and scientific data obtained from them. This Office is also responsible for managing NASA's communications systems and for operational data systems and services.

The Office of Commercial Programs is responsible for encouraging the commercial use of space. The Office is responsible for the "Technology Utilization Transfer" program, the Small Business Innovative Research program, new commercial applications of existing space technology, "unsubsidized" initiatives for transferring existing space programs to the private sector, and establishing Centers for the Commercial Development of Space.

Field Centers

Ames Research Center, Moffett Field, CA (3,500 employees at Moffett and Dryden facilities)

Founded in 1940 by the National Advisory Committee for Aeronautics as an aircraft research laboratory, the Ames Research Center became part of the new NASA organization in 1958. In 1981, the Dryden Flight Research Center (see below) was merged with Ames, and the two installations are now referred to as "Ames/Dryden" and "Ames/Moffett."

Ames/Moffett specializes in scientific and exploratory research and applications for space and aeronautics in a wide and growing number of fields. Today, the Center's program interests include computer science and applications, computational and experimented aerodynamics, flight simulation, flight research, hypersonic aircraft, rotorcraft and powered-lift technology, aeronautical and space human factors, space sciences, solar system exploration, airborne science and applications, and infrared astronomy. As the lead NASA center for research in the life sciences, continuing programs relate to medical problems of manned flight, both space and atmospheric.

The Center also provides technical support to DoD programs, the Space Shuttle, and civil aviation projects. Recent NASA/DoD efforts include providing design leadership for the airframe studies for an advanced, supersonic short take-off/vertical landing (STOVL) aircraft, a joint U.S./U.K. study effort. These "extramural" projects and responsibilities will evolve as NASA's internal needs (and budgets) change.

Roughly 60 percent of the personnel at the two Ames facilities are Federal employees, with the balance being contractor personnel. Ames maintains a close link with universities through cooperative projects; a significant number of university students and university faculty members work at the center.

Ames Research Center/Hugh L. Dryden Flight Research Facility, Edwards, CA **(staff included in Ames/Moffett total)**

Ames/Dryden provides NASA with a highly specialized capability for conducting flight research programs. The facility's location, at Edwards Air Force Base in California's Mojave Desert, is at the southern end of a 500-mile high-speed flight corridor and is adjacent to a 65-square-mile natural surface for landing. The site provides almost ideal weather for flight testing.

Primary research tools include a B-52 "carrier" aircraft, several high-performance jet fighters, and the X-29 Forward Swept Wing

aircraft. Ground-based facilities include a high-temperature, loads-calibration laboratory for ground-based testing of complete aircraft and structural components under the combined effects of loads and heat, an aircraft flight instrumentation facility, a flight-systems laboratory (capable of avionics system fabrication, development, and operations), a flow visualization facility, a data-analysis facility for processing flight research data, a remotely piloted research vehicles facility, and extensive test range communications and data transmission capabilities. The Facility participated in the approach and landing tests for the Space Shuttle Orbiter Enterprise and will continue to support Shuttle orbiter landings and ferry flights.

A close association has naturally evolved between Ames/Dry den and DoD S&T programs —especially with Dryden's "collocation" at Edwards AFB with the Air Force Flight Test Center. One of Ames/Dryden's major DoD cooperative projects is the X-29, in which NASA and DARPA are exploring a variety of advanced technologies. Another joint NASA/ DoD program is the Advanced Fighter Technology Integration F-1 11, conducted in conjunction with the Air Force Flight Dynamics Laboratory.

Lewis Research Center, Cleveland, OH
(3,690 total staff)

NASA's Lewis Research Center was established in 1941 by the National Advisory Committee for Aeronautics, and developed an early reputation for its research on early jet propulsion systems. Today Lewis is NASA's lead center for research, technology, and development in aircraft propulsion, space propulsion, space power, and satellite communications. In this role, numerous joint programs have been conducted with DoD components, with one of the most recent being the development of engines to power advanced supersonic STOVL aircraft. Lewis also had managed two launch-vehicle programs, the Atlas-Centaur and the Shuttle-Centaur; however, the Shuttle-Centaur program was terminated after the explosion of the Space Shuttle Challenger.

Lewis has recently assumed the responsibility for developing the space power system for the Space Station, the largest ever designed. In addition, the center will support the Station in other areas, such as auxiliary propulsion systems and communications. In support of the Department of Energy's Solar Energy programs, Lewis is working on wind energy systems. Initial testing is on a 100-kilowatt wind turbine—with larger sizes to follow. Solar photovoltaic arrays are also being tested and demonstrated under this effort.

Major facilities include a zero-gravity drop tower, wind tunnels, space environment tanks, chemical rocket-thrust stands, and chambers for testing jet-engine efficiency and noise. Lewis also operates NASA's Microgravity Materials Science Laboratory, a unique facility to qualify potential space experiments. The Center is staffed by 2,690 Federal employees and approximately 1,000 onsite contractors.

Goddard Space Flight Center, Greenbelt, MD
(3,680 Civil Service personnel)

This Center has one of NASA's most comprehensive programs of basic and applied research directed toward expanding NASA's knowledge of the solar system, the universe, and the Earth. It is responsible for the development and operation of several near-Earth space systems, including the Cosmic Background Explorer, which will measure radiation generated early in the universe's history when the universe was much hotter and denser than it is today; the Gamma Ray Observatory, which will gather data on the processes that propel energy-emitting objects of deep space (e.g., exploding galaxies, black holes, and quasars); and the Upper Atmosphere Research Satellite, which will look back at the Earth's upper atmosphere to gather data on its composition and dynamics. Goddard also has responsibility for the development of science instruments and the operations, maintenance, and refurbishment of the Hubble Space Telescope—a large, space-based optical telescope to be deployed by the Space Shuttle.

Goddard is also the responsible Center for NASA's worldwide ground and spaceborne communications network, one of the key elements of which is the Tracking and Data Relay Satellite System with its orbiting Tracking and Data Relay Satellite and associated ground tracking stations. One of the prime missions for this system will be to relay communications to and from the Space Station.

For the Space Station, Goddard is responsible for Segment III, an external, free-flying platform to be placed in polar orbit. The Center is also responsible for developing instruments attached to the outside of the Station and the orbiting platform.

A portion of the Center's theoretical research is conducted at the Goddard Institute for Space Studies in New York City. Operated in close association with universities in that area, the Institute provides supporting research in geophysics, astronomy, and meteorology. Goddard's Wallops Island Facility, located off the coast of Virginia, prepares, assembles, launches, and tracks space vehicles, and acquires and processes the resulting scientific data. Its facilities are utilized by NASA's scientists and engineers, other governmental agencies, and universities.

Jet Propulsion Laboratory (JPL), Pasadena, CA (4,110 total **staff)**

The Jet Propulsion Laboratory, a federally funded research and development center managed by the California Institute of Technology, is engaged in activities associated with automated planetary and other deep-space missions. These activities include subsystem and instrument development, data reduction, and data analysis. JPL also has the capability to design and test flight systems, including complete spacecraft, and to provide technical direction to contractor organizations. In addition to the Pasadena site, JPL operates the Deep Space Communications Complex, one station of the worldwide Deep Space Network located at Goldstone, CA.

Current JPL projects include the planetary/solar probes Voyager, Galileo, Magellan, and the Mars Observer, and major instruments for other NASA missions. Non-NASA work at JPL currently includes tasks for DoD, DOE, and the Federal Aviation Administration. JPL has been supporting DoD programs in many areas, including artificial intelligence, tactical-data fusion, and specialized training systems based on "Expert System" technology.

Langley Research Center, Hampton, VA (2,910 Civil Service personnel)

Langley's primary mission involves applied research and development in the fields of aeronautics, space technology, electronics and structures. The Center also conducts programs for environmental monitoring, having developed a range of instruments for atmospheric measurements.

In aeronautical technologies, programs have been directed primarily toward improving the efficiency of transport aircraft and high performance supersonic military aircraft. The Center is also developing technology for future transonic transport aircraft and has been active in studies of hypersonic powerplants. A variety of wind tunnels are available to support basic and applied aeronautical research.

Research interests at Langley include materials, flutter, aeroelasticity, dynamic loads and structural response, fatigue fracture, electronic and mechanical instrumentation, computer technology, flight dynamics, and control and communications technology. Langley is now assuming a role in developing technologies for the National Aerospace Plane, and has continuing work on the Space Shuttle and Space Station (e.g., experiments, sensors, communications equipment, and data handling systems). Other research programs include investigations of effects such as heat, vacuum, noise, and meteoroids on space vehicles; the use of advanced composite and polymeric materials for structures and thermal control systems; and electronics technology.

Marshall Space Flight Center, Huntsville, AL (3,450 Civil Service personnel)

Marshall serves as one of NASA's primary centers for the design and development of

space transportation systems, elements of the Space Station, scientific and application payloads, and other systems for present and future space exploration. It has the principal role for large rocket propulsion systems, Spacelab mission management, the design and development of large, complex, and specialized automated spacecraft, solar and magnetospheric physics, and astrophysics. Using the gravity-free environment of space, Marshall seeks to develop materials processing techniques to enhance Earth-based processes and to fabricate space-unique materials.

Marshall has responsibilities for manned space vehicle development such as the Spacelab and has sustaining engineering duties in support of the Space Shuttle. Advanced program efforts focus on the analysis and definition of propulsion/transportation systems to meet the nation's needs over the next 25 years. Marshall is currently leading the planning for an unmanned cargo version of the Space Shuttle called Shuttle-C; efforts for an Advanced Launch System are also underway.

Marshall also plays a principal role in payload development, instrument development, and mission management for space science and applications missions as assigned. Responsibilities include the Hubble Space Telescope, the Advanced X-Ray Astrophysics Facility, and automated servicing/resupply/retrieval kits. Its Space Station responsibilities include the development of pressurized structures, crew and laboratory modules, logistics, environmental control, and life support.

Two other sites are managed by Marshall: the Michoud Assembly Facility, New Orleans, LA, where the Space Shuttle external tanks are manufactured, and the Slidell Computer Complex, Slidell, LA, which provides computer services support to Michoud and Marshall.

Lyndon B. Johnson Space Center, Houston, TX (3,440 Civil Service personnel)

Johnson Space Center manages the design, development, and manufacture of manned spacecraft; the selection and training of astronaut crews; and the conduct of manned space flight missions. Its principal roles include Space Shuttle production and operations, production of the replacement Orbiter, and support to NASA Headquarters management for the Shuttle system. It also has responsibility for the development of new manned space vehicles and supporting technology.

Johnson is a major development center for specific Space Station elements, including the truss structure, airlocks and nodes, and additional subsystems. It has principal program activity in the field of life sciences and medical research to solve space medical problems, and it has supporting roles in lunar and planetary geosciences, technology experiments in space, and remote sensing. It is also responsible for directing the operations of the White Sands Test Facility, located on the western edge of the U.S. Army White Sands Missile Range in New Mexico.

Kennedy Space Center, FL (2,200 Civil Service personnel)

Kennedy Space Center, located east of Orlando on the Atlantic Ocean, serves as the primary NASA center for the test, checkout, and launch of space vehicles. This responsibility includes ground operations for Space Shuttle preparation, launch, and landing and refurbishment. Other responsibilities include Expendable Launch Vehicle operations. The Space Station effort at Kennedy Space Flight Center includes system integration and engineering, operational readiness, and delegated ground support equipment program management.

National Space Technology Laboratories, Bay St. Louis, MS (150 Civil Service personnel)

The National Space Technology Laboratories provide NASA's prime test facility for large liquid propellant rocket engines and propulsion systems such as the Space Shuttle main engines. It also conducts applied research and development in the fields of remote sensing, environmental sciences, and other selected applications. The Laboratory provides facilities and support through interagency agreements to other Federal government agencies and the States of Mississippi and Louisiana.

OTHER FEDERAL ACTIVITIES

By far, the majority of Federal Science and Technology activities with potential defense applications are conducted within DoD, DOE, and NASA. There are "pockets" of S&T activit y within other government departments and agencies which contribute to the defense technology base. However, because of the magnitude of investment in military technology by DoD, one often finds the reverse is the case; for example, U.S. Coast Guard technologies and systems often result from U.S. Navy research and technology programs.

A major exception in which non-DoD funding dominates research in a field of relevance to the defense technology base is medical technologies. The National Institutes of Health (NIH) of the Department of Health and Human Services will finance more in health research in its fiscal year 1988 budget than DoD will spend in its entire research and exploratory development (6.1 and 6.2) program. NIH's fiscal year 1987 research budget was near $6.0 billion, $3.6 billion of which supports university research. For reference, the entire Federal FY87 budget for basic research was $9 billion, of which the DoD 6.1 program constituted less than $1 billion. Less than $0.5 billion of those DoD 6.1 funds supported university research.

In the past, biological sciences have not been as important to the defense technology base as physical sciences and engineering. In the future, however, biotechnology will likely become increasingly important to the defense technology base, and more of the government investment in life sciences may have direct rele vance to DoD needs.

National Science Foundation

The National Science Foundation (NSF) was established in 1950 to advance scientific progress in the United States. NSF supports scientific and engineering research and related activities, and under congressional pressure has more recently devoted some attention to improving science and engineering education. NSF does not conduct research itself nor does it typically contract for research. It provides most of its support in the form of grants in response to unsolicited research proposals. Proposals are evaluated through a review process that selects primarily on the basis of scientific or technical merit. Most NSF grants result from proposals submitted by academic institutions. Small businesses also submit unsolicited research proposals and receive awards; however, most NSF awards to small businesses are grants made in response to proposals under the Small Business Innovative Research program.

NSF supports basic research projects in nearly every conceivable area of science and technology, including physics, chemistry, mathematical sciences, computer research, materials research, electrical, computer, and systems engineering, chemical and processing engineering, civil and environmental engineering, mechanical engineering and applied mechanics, physiology, cellular and molecular biology, biotic systems and resources, behavioral and neural sciences, social and economic sciences, information science and technology, astronomical sciences, atmospheric sciences, earth sciences, ocean sciences, and interdisciplinary combinations of these. NSF also supports science resources studies, policy research and analysis, and studies in industrial science, technological innovation, and other scientific and technical areas.

For fiscal year 1987, NSF-sponsored university basic research totaled about $1 billion, approximately twice that of DoD. The total NSF R&D budget that year was $1.5 billion.

Department of Commerce

National Bureau of Standards

The National Bureau of Standards (NBS) is the Nation's central reference laboratory for physical, chemical, and engineering measurements. The measurement and data services that NBS provided in 1987 included calibrations, production and distribution of standard

reference materials and data, and laboratory accreditation. The Army, Navy, Air Force, and Defense Agencies (including their contractors) make extensive use of these services.

While the Federal Government has a substantial capital investment in instrumentation and facilities at NBS, the actual research budget is modest and is augmented by cooperative research projects conducted jointly between NBS and other organizations. NBS conducts specialized research programs for the Department of Defense on a contractual basis. These programs draw on NBS's unique capabilities, and range from fundamental physics and chemistry studies to more applied work, such as developing calibration techniques for a particular piece of defense hardware. Research topics encompass fields such as electro-optics, microwave and millimeter wave measurements, electronics, physical measurements (e.g., temperature, pressure, shock, and vibration), automated metrology, materials characterization, and applications of computer systems. NBS also hosts technical conferences and workshops for DoD and consults on a variety of subjects, particularly those relating to instrumentation and measurement.

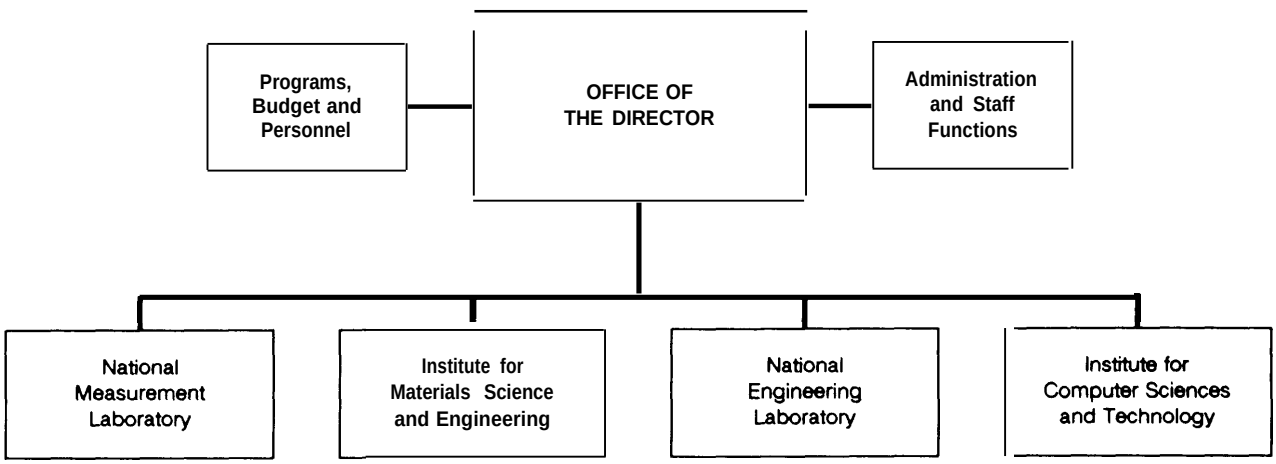
NBS is the only Federal laboratory with a primary mission of supporting U.S. industry. To accomplish this mission, NBS is organized into four laboratories and institutes (figure 14): the National Measurement Laboratory, the National Engineering Laboratory, the Institute for Materials Science and Engineering, and the Institute for Computer Sciences and Technology.

The National Measurement Laboratory (NML) conducts research in physics, radiation chemistry, analytical chemistry, and chemical properties and processes. NML produces fundamental measurements and data that underlie national measurement standards. It also furnishes advisory and research services to other government agencies and provides standard reference data and calibration services.

The National Engineering Laboratory (NEL) conducts research in electronics and electrical engineering, chemical engineering, manufacturing engineering, mathematical sciences, and the construction and performance of buildings and fire protection. This laboratory produces new engineering knowledge, techniques, and databases for the design, development, prediction, and control of industrial processes. Improved quality assurance and reduced costs of manufacturing are two principal goals of the work.

The Institute for Materials Science and Engineering (IMSE) performs research in ma-

Figure 14. –National Bureau of Standards



SOURCE: National Bureau of Standards

terials characterization, nondestructive evaluation, metallurgy, polymers, and ceramics; it produces measurement methods, standards, data, and other technical information on processing, structure, properties, and performance of materials. The goal of these activities is to support generic materials technologies to permit manufacture of advanced materials with increased reliability and quality and reduced cost.

The Institute for Computer Sciences and Technology (ICST) performs research in computer sciences and engineering. This research is designed to establish Government-wide standards and guidelines for automated data processing systems. The Institute also provides technical support for the development of national and international voluntary standards.

Under Public Law 100-202, the Final Omnibus Appropriation Bill for fiscal year 1988, NBS is to establish "Regional Centers for the Transfer of Manufacturing Technology. " These centers will be designed to accelerate technology transfer to organizations that need to implement new automated manufacturing techniques. Such techniques are being developed for the Navy in NBS's Automated Manufacturing Research Facility. This facility is developing applications of automated manufacturing technology in piece-part manufacturing at shipyards and depots.

NBS fiscal year 1988 appropriations are $145 million. Total resources for the same year, totaling $314 million, include $95 million in work for other Federal agencies, $22 million from the sale of calibrations, testing services, and standard reference materials, and $52 million in private sector contributions of staff and equipment. Total full-time equivalent NBS staff for fiscal year 1988 is 3,090.

National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration (NOAA) explores, maps, and charts the global oceans and their mineral and living resources. The agency monitors and predicts the characteristics of the physical environment and warns against impending hazards such as hurricanes, tornadoes, floods, seismic sea waves, and other destructive natural events. NOAA monitors the gradual changes of climate and environment and predicts the impact of such changes on food production, resource management, and energy utilization.

NOAA provides a focus within the Federal Government for the objective scientific assessment of the ecological consequences of specific actions, such as petroleum exploration, development, and shipment, and marine mineral extraction. The major operating elements of NOAA are:

- the National Weather Service,
- the National Ocean Service,
- the National Marine Fisheries Service,
- the National Environmental Satellite, Data, and Information Service,
- the Environmental Research Laboratory, and
- the Office of Oceanic and Atmospheric Research.

Department of Transportation

The Federal Aviation Administration and the U.S. Coast Guard-components of the Department of Transportation (DOT) –develop and acquire hardware and systems. However, the bulk of DOT's research is analytical in nature and is directed toward setting and enforcing regulations and toward investigating deviations (e.g., accidents). DOT's research branch is the Research and Special Programs Administration, which has the responsibility for planning and management of programs in all fields of transportation research and development.

Research and Special Programs Administration

The Research and Special Programs Administration (RSPA) maintains the capability to perform program management, "in-house" research and development, analysis in transportation planning and socioeconomic effects, and technological support in response to DOT policies. Particular efforts are made on transportation systems problems, advanced transportation concepts, and on "multi-modal"

transportation. RSPA also develops and maintains vital statistics and a related transportation information database.

RSPA is composed of the following functional groups:

- The Transportation System Center provides support to DOT and other Federal agencies in the fields of technology assessment, industry analysis, strategic planning support, and research management for transportation systems.
- The Materials Transportation Bureau is responsible for the safe transportation of all hazardous materials. As part of this mission, it establishes and enforces hazardous materials and pipeline safety regulations.
- The Office of Program Management and Administration coordinates the university research program, which focuses on high-priority transportation problems (e.g., issues pertaining to transportation systems engineering, advanced transportation planning, and telecommunications). Its Transportation Safety Institute, located at the Mike Monroney Aeronautical Center in Oklahoma City, OK, develops and conducts training programs.
- The Office of Emergency Transportation coordinates the development and review of emergency preparedness policies, plans, and related programs.

Federal Aviation Administration

The Federal Aviation Administration (FAA) has a research and development program that is largely oriented toward establishing standards for the design and performance of aircraft monitoring, communications, and navigation equipment and toward the acquisition and management of air traffic control systems. In this regard, there is a substantial convergence of interest and activities with DoD—especially the Air Force. For example, the structure and management of the Nation's air traffic control system and planned conversion to the microwave landing system require close cooperation with the Air Force. Because of the size of the Air Force budget in these areas, the "technology transfer" from the Air Force to the FAA may be substantially greater than vice versa. However, the joint USAF/FAA responsibilities and interests remain, with attendant contributions to defense technology.

U.S. Coast Guard

The U.S. Coast Guard is involved in the development and acquisition of the communications systems and facilities, aircraft, and vessels which are required to accomplish its coastal monitoring mission. A close association naturally exists between the Navy and the Coast Guard in this regard and a significant technology transfer process exists. The Coast Guard simply does not have a budget of sufficient size to conduct a broad and independent R&D program; it must rely on the Navy research budget. However, Coast Guard requirements and deployment concepts contribute to the formulation and execution of Naval and other DoD research science and technology projects. Thus there is, as with the FAA/Air Force relationship, a synergistic effect–albeit not substantial in financial terms.

Other Federal Agencies

There are scores of other Federal agencies, departments and special groups involved in some way in science and technology which would have applications to and could contribute to the defense technology base. The Department of Agriculture and the Department of the Interior/U.S. Geological Survey conduct modest research programs which can have defense technology base fallout.[3] Examples are the remote sensing programs which are sponsored in these departments. Utilization of data from LANDSAT, defining collection requirements, and supporting spacecraft and sensor development programs can complement DoD's

[3]The Department of Agriculture supports a university research program which amounts to roughly $200 million per year.

image processing and remote sensing requirements. Although the magnitude of funding available on the defense side may "overpower' these programs, the expertise growing in applications and the cost-effective utilization of remote sensing systems could have beneficial returns to defense programs.

The Federal Communications Commission exerts influence over telecommunications policies, which can affect DoD programs. Thus, the Commission's activities are closely coordinated with DoD, and its actions impact on requirements (if not on actual programs themselves).

Small Business Innovative Research (SBIR) Program

An interesting government program offering incentives to the private sector that can stimulate contributions to the defense technology base is the Small Business Innovative Research program.[4] The SBIR program was established with the enactment of the Small Business Innovation Development Act in 1982. In 1986, the program was reauthorized through fiscal year 1993. Under SBIR, Federal agencies with research and development budgets which exceed $100 million must establish an SBIR program, with the funding contribution derived from fixed percentages established for each participating agency. Eleven Federal agencies now participate in SBIR:

- Department of Agriculture,
- Department of Commerce,
- Department of Defense,
- Department of Education,
- Department of Energy,
- Department of Health and Human Services,
- Department of Transportation,
- Environmental Protection Agency,
- NASA,
- National Science Foundation, and
- Nuclear Regulatory Commission.

The program consists of three phases of contracting and is designed to encourage small business to overcome their "angst" when dealing with the Federal Government (e.g., too much paperwork, complete auditing procedures, etc.). Phase I contracts are focused on evaluating the scientific and technical merit and/or feasibility of an idea. Awards are normally up to $50,000, with an average period of performance of 6 months. Under Phase II the results of Phase I feasibility studies are expanded to pursue further any development opportunities. Only those small businesses which have conducted Phase I contracts are eligible for Phase II. The size of the contracts are normally $500,000 or less and the period of performance roughly 2 years. Under Phase III, the government seeks to commercialize the results of Phase II through the use of private, or non-SBIR Federal, funding (e.g., DoD RDT&E funds).

The participating agencies and departments publish their lists of SBIR solicitation topics on a quarterly basis. DoD—the Departments of the Army, Navy, and Air Force; the Defense Advanced Research Projects Agency; the Defense Nuclear Agency; and the Strategic Defense Initiative Organization-lists hundreds of topics. Most of these topics would be classed in the research and exploratory development categories of DoD's S&T program. Since the program's inception in fiscal year 1983, more than 5,000 Phase I and 1,000 Phase II contracts have been awarded and the total dollar amount is in excess of $655 million. In fiscal year 1986,$98 million in Phase I and $200 million in Phase 11 programs were awarded and roughly $400 million will be awarded for both phases in fiscal year 1987. A quick review of the DoD topic list reveals that the return in defense-related technology development could be substantial.

[4]For additional information on this program, see the Science Policy Study Background Report No. 8, "Science Support by the Department of Defense, " prepared by the Congressional Research Service for the Task Force on Science Policy, Committee on Science Policy, U.S. House of Representatives, 99th Cong., pp. 310-314.

PRIVATE NONPROFIT LABORATORIES

A considerable amount of DoD technology base work is performed by federally funded research and development centers (FFRDCs) and other nonprofit laboratories that, in many ways, have organizational characteristics between those of government laboratories and those of private corporations. Like government laboratories, these facilities need not consider potential profitability in their choice of research activities. However, they have more flexibility in their operating procedures—and particularly in their personnel policies—than do government laboratories.

FFRDCs serve various branches of the Federal Government. Ten are sponsored by Department of Defense. Six of these–the Center for Naval Analyses, the Institute for Defense Analyses, three divisions of the Rand Corp. (Project Air Force, Rand National Defense Research Institute, and the Arroyo Center), and the Logistics Management Institute —primarily conduct studies and analyses for the Services and the Office of the Secretary of Defense and do not perform much technical research or development. The other four—The Aerospace Corp., the MITRE Corp. C^3I Division, the Software Engineering Institute, and Lincoln Laboratory–have a significant technical role and are described below.

Other nonprofit institutions, organized differently than FFRDCs, also perform significant technical work for the Defense Department and other federal agencies. Their management structures range from university affiliates to independent, nonprofit organizations. Selected examples of these institutions are also presented below.

Federally Funded Research and Development Centers

The Aerospace Corp., **El Segundo, CA (3,800/2,100)**[5]

The Aerospace Corp. performs technical work on military space systems and related technologies. Its services are provided principally for for the Space Division of the Air Force Systems Command, although it also works for other agencies. Aerospace Corp. provides general systems engineering and integration services, which involve formulating requirements, designing specifications, monitoring technical progress, resolving problems, certifying completion, and assistance during operation. Its single largest responsibility involves certifying spacecraft and launch vehicles for launch.

The MITRE Corp., C^3I Division, Bedford, MA **and Washington, DC (4,000/2,140)**

The C^3I division of MITRE Corp. performs systems engineering and integration services in the field of command, control, communications, and intelligence (C^3I) under Air Force sponsorship. Its primary sponsor is the Electronic Systems Division of the Air Force Systems Command. (Metrek Division, another division of MITRE Corp., serves as a nonprofit contractor for civil agencies of the government.)

Software Engineering Institute, Pittsburgh, PA (14O/1OO)

The Software Engineering Institute is operated by Carnegie Mellon University under contract to the Electronic Systems Division of the Air Force Systems Command. However, it works for all the Services to promote use of the most effective technology to improve the quality of operational software in mission-critical computer systems.

Lincoln Laboratory, Lexington, MA (2,100/760)

Lincoln Laboratory's particular emphasis is on electronics. It is operated by the Massachusetts Institute of Technology under prime contract with the Electronic Systems Division of the Air Force Systems Command. Established in 1951 to assist the Air Force with the then-emerging technology of digital computers, it continues as a pioneering technical center in the areas of radar, communications, and com-

[5](Total Staff/Scientists and Engineers).

puters. Programs range from fundamental solid state science to the design, development, and demonstration of prototype systems. It works for all the Services and for several DoD agencies. The Air Force limits the degree of participation of other clients to less than 50 percent.

University Affiliates

Many federally funded laboratories are managed by universities under a variety of different structures such as FFRDC (e.g., Lincoln Laboratory, managed by MIT for the Air Force) and management contract (e.g. Los Alamos, Lawrence Livermore, and Lawrence Berkeley National Laboratories, managed by the University of California for the Department of Energy). Yet another management approach is as an independent university division, such as the Johns Hopkins Applied Physics Laboratory. This laboratory, and other examples of university-affiliated research centers, are described below.

Johns Hopkins Applied Physics Laboratory, Howard County, MD (2,800/1,600)

The Applied Physics Laboratory is a division of the Johns Hopkins University, operating in parallel with the university's academic divisions. The lab is run primarily under a single contract with the Navy's Space and Naval Warfare Systems Command, but it performs work for all DoD-sponsored activities and most other Federal activities. With a history of work in proximity fuzes, guided missiles, and systems engineering, the lab currently works in the areas of Navy ship systems, submarine systems, strategic systems, naval warfare analysis, space research and development, aeronautics, and biomedical research. Basic and applied research are also conducted in a number of areas that underlie current and future laboratory interests.

Georgia Tech Research Institute, Atlanta, GA (1,360/580)

The Georgia Tech Research Institute is a nonprofit organization affiliated with the Georgia Institute of Technology. It performs engineering, scientific, and economic research in electronics, electromagnetic, energy, materials sciences, and a number of other areas. Various defense and non-defense government agencies are the principal clients, but up to 20 percent of the work is done for private industry.

IIT Research Institute, Chicago, IL (1,750/1,200)

The I IT Research Institute is a nonprofit research organization affiliated with the Illinois Institute of Technology. It works for both government and private clients, with the number of projects about evenly split between the two, but with Federal contracts representing about 80 percent of its funding. Research topics include electronics, communications, toxicology, chemical defense, environmental science, petroleum research, ordnance, and advanced manufacturing technology.

Independent Nonprofit Laboratories

Battelle Memorial Institute, Columbus, OH (7,800)

Battelle is an independent, nonprofit, international organization providing research and development, technical management (primarily management of the Department of Energy's Pacific Northwest Laboratory), and technology commercialization services. Battelle's research and development is now being concentrated primarily in the areas of advanced materials, biological and chemical sciences, biotechnology, electronics, engineering and manufacturing technologies, and information systems.

Charles Stark Draper Laboratory, Cambridge, MA (2,000/1,000)

Draper Labs, at one time affiliated with the Massachusetts Institute of Technology, is now an independent nonprofit research institution. Its major business activities are avionics, strategic systems, undersea vehicle systems, precision pointing and tracking, and advanced space systems. Draper has had major responsibility for guidance, navigation, and control

systems for strategic ballistic missiles, NASA spacecraft, and a variety of Air Force systems.

SRI International, Menlo Park, CA (3,600)

SRI International is an independent nonprofit research institute once affiliated with Stanford University. It is organized into four divisions–Engineering; International Business and Consulting; Sciences (Physical and Life); and the David Sarnoff Research Center. The Sarnoff research center, originally the RCA corporate research laboratory, was sold to SRI when RCA was acquired by General Electric. About 60 percent of SRI's work is for the Federal Government, with the remainder for private clients.