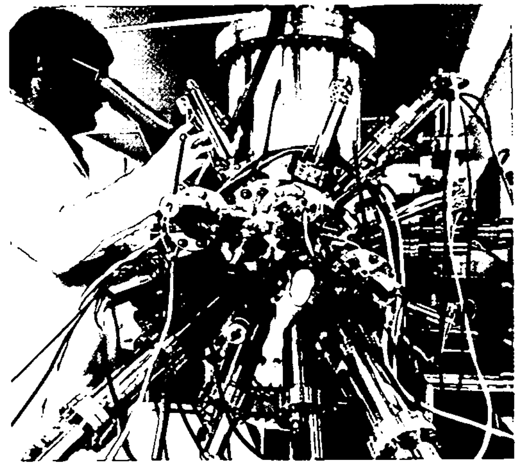
Sandia National Laboratories



Institutional Plan
FY 1992–1997

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Sandia is a multiprogram engineering and science laboratory operated by AT&T for the Department of Energy with major facilities at Albuquerque, New Mexico, and Livermore, California, and a test range near Tonopah, Nevada. We have major research and development responsibilities for nuclear weapons, arms control, energy, the environment, economic competitiveness, and other areas of importance to the needs of the nation. Our principal mission is to support national defense policies by ensuring that the nuclear weapon stockpile meets the highest standards of safety, reliability, security, use control, and military performance.

Sandia National Laboratories

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FY 1992–1997

Albuquerque, New Mexico
Livermore, California

June 1992

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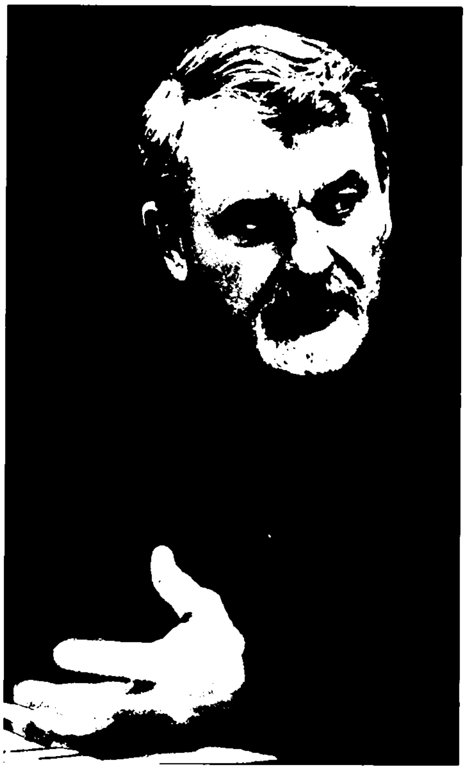
President's statement



The past year has been one of change—for the world and for Sandia. We are hopeful that the threat of nuclear war has diminished significantly and irreversibly. A Strategic Arms Reduction Treaty was signed in July 1991, and two months later President Bush and former President Gorbachev directed that nuclear weapon arsenals be reduced even further.

The dramatic reduction in the stockpile raises an important question: Should capacity at the national laboratories also go down? The United States government spends close to $20 billion per year in support of nearly 700 laboratories, the majority of them engaged in defense R&D. Are the taxpayers getting their money's worth?

It is clear that the federal R&D complex must become more cost-effective. Government should streamline its R&D infrastructure. The federal agencies responsible for technology development should cooperate to eliminate unessential duplication in programs and facilities. Fiscal pressures will surely force these changes over time, but a better way is to manage this process through planning based on national technology goals.

I regard this imperative for change as a formidable challenge. Sandia's industrial management makes it well suited to embracing this challenge constructively and realistically.

American industry is going through a period of restructuring and streamlining to meet the challenges of the future, and we must do the same. Sandia has recently implemented a restructuring plan that will increase our focus on the needs of our sponsors, improve project management, and reduce the levels of management in the communication chain. The result will be a more cost-effective and responsive organizational structure.

We are also performing an examination of our internal service centers to determine where functional consolidations or substitutions can result in better use of resources. For example, we will consolidate our supercomputing operations over the next few years at a single site, while expanding our high-speed communications and networking capabilities to provide service more cost-effectively. We are making changes to our accounting practices to permit more kinds of costs to be allocated to users on the basis of measurable usage. We will become more cost-effective by applying marketplace concepts to the delivery of internal services.

Similarly, DOE should apply marketplace concepts to the management of the national laboratories under its purview. The most daunting long-term problem facing those responsible for the vitality of the DOE laboratories is how to maintain core competencies in the face of tightening budgets. To succeed, they will need to encourage consolidation and cooperation among the federal laboratories and support strategic alliances with industry and universities. These trends are already in evidence with the planned consolidation of nuclear testing, tritium support, and plutonium research activities and the increased effort devoted to technology transfer and teamwork with other sectors.

Notwithstanding these positive changes for greater cost-effectiveness, the national laboratories must retain a strong applied research capability. The problems facing the nation, now and in the future, have technical dimensions that are increasingly complex and multidisciplinary. To solve them we begin with fundamental understanding and then apply this understanding to technology development. Mature, useful technologies result only from sustained research that interfaces effectively with the development process.

A robust technology base is essential to the success of new concepts of deterrence. We can be confident of discouraging adversaries from engaging in expensive and adventurous military developments if our R&D infrastructure remains capable and responsive.

Sandia has worked with DOE, the other nuclear weapon laboratories, and the DOE production plants to develop a process for maintaining nuclear competency. The first level of this process, called Focal Point, evaluates new component subsystem concepts. It draws upon technologies with demonstrated feasibility and determines their fitness for weapon applications. The second level, STEP (Stockpile Transition Enabling Program), advances these concepts to standardized, modular subsystems and components. MAST (Multiple Application Surety Technologies), a prototype warhead system, uses currently available improved surety components and subsystems in a product realization process that will assure that the laboratory/production agency interface remains robust. Programs like Focal Point, STEP, and MAST are cost-effective tools for improving nuclear weapon surety and maintaining the nuclear weapon technology base.

There are also new opportunities that very effectively use the DOE technology base not only for qualitative changes in the stockpile but also for benefit to U.S. commercial R&D. Squeezed by formidable overseas competition and adverse economic conditions, U.S. industry is looking hard at its R&D expenditures. There is a growing awareness of the fact that the national laboratories can be a resource for leveraging industry's R&D efforts. Technology transfer is now regarded more as technology teamwork.

We are working very hard to improve our industrial interface. In the past, national laboratory arrangements with industry were often self-serving. Expectations of laboratory contributions were sometimes unrealistic and delivery of tangible benefits was frequently disappointing. These early experiences revealed that the laboratories lacked an understanding of industry's real needs. A more constructive relationship is now evolving, and we are beginning to earn industry's trust, confidence, and support. The laboratories are learning more about the real challenges faced by industry in technology maturation, product development, and manufacturability. They are learning how to set realistic commitments, meet deadlines, strive for excellence with their industrial partners, and demonstrate greater accountability for investment dollars. As a result, we see encouraging evidence that industry is beginning to appreciate the value of the national laboratories as a resource.

One of the five objectives stated in Sandia's strategic plan is to "become a national leader in quality and quality progress." Candid self-assessment and benchmarking against the best industrial standards are essential to this approach. In order to achieve this objective, we are striving to continuously improve everything we do: our business practices, our management effectiveness, our ES&H performance, our project processes, and our product. Our initiatives in manufacturing development engineering, internal reconfiguration, component standardization, and other areas will provide better value for the taxpayers' investment. I am confident that the result will be a Sandia National Laboratories whose contributions are essential to the nation.

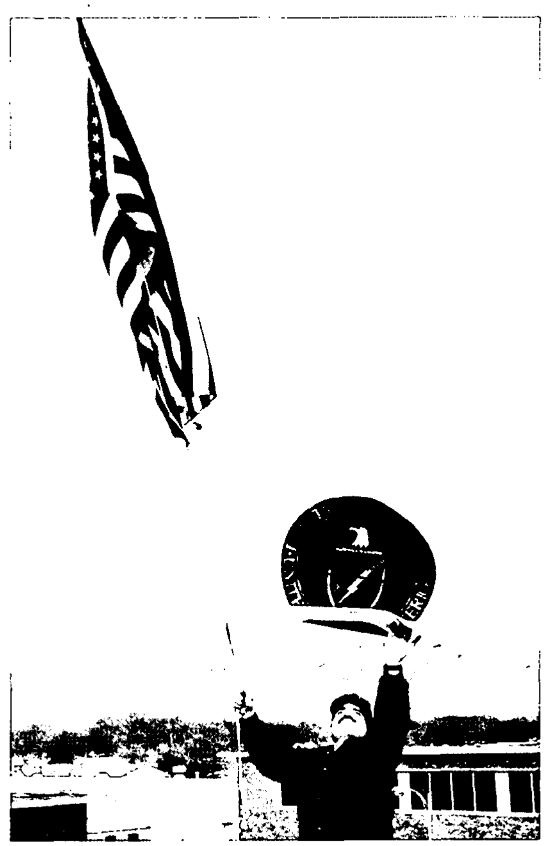
Sandia National Laboratories mission

Our primary mission is to implement the nation's nuclear weapons policies through research, development, and testing related to nuclear weapons, arms control, and weapon surety. As a multiprogram laboratory, we also serve the nation by using our core competencies to make special contributions in other areas of national importance.

Mission statement

As part of its strategic planning initiative, Sandia's Management Council adopted a mission statement that defines a corporate culture and service orientation that we will strive to demonstrate in the execution of all our mission assignments:

> *Sandia National Laboratories is dedicated to enhancing the security, prosperity, and well-being of the nation.*
>
> *We affirm our dedication by valuing our customers in government, industry, and education. As a Department of Energy multiprogram laboratory, we are devoted to leadership in anticipating national priorities and in applying the best integration of scientific and engineering creativity to achieve comprehensive, timely, and cost-effective solutions to our nation's most pressing problems.*
>
> *We pledge ourselves to the high standards of integrity and objectivity demanded of the nation's nuclear weapons program and by AT&T, which operates Sandia. We apply these same standards of excellence to our energy, environment, economic competitiveness, and other national security programs.*
>
> *Our quality standard is meeting customer requirements every time; our performance standard is continuous improvement.*
>
> *Achieving our mission depends on the values of individual growth, creativity, and teamwork, and an enduring commitment to the protection of the environment, safety, and health of all Sandians and the community.*



Albert Alarid raises the DOE flag at Sandia National Laboratories, Albuquerque.

Mission assignments

Our DOE missions encompass five major categories of activity:

1. Research, development, and engineering associated with advancing nuclear explosives to integrated, functional weapons for DoD weapon delivery systems. Activities include evaluation of new weapon concepts; component development, design definition, and systems integration; nuclear weapon surety, including safety, command and control, and security; testing and weapon effects simulation; production and dismantlement support; and stockpile surveillance.

2. Other DOE defense-related programs, including the development of verification and control technologies to support progress towards arms reduction agreements and to provide intelligence on foreign technologies and weapon systems; concepts and systems for the safeguarding and security of nuclear materials.

3. Research, development, and engineering of technologies for safe storage, processing, transport, and disposal of hazardous and radioactive wastes from nuclear materials and weapons production; development of manufacturing processes and substitute materials to minimize hazardous byproducts in the production of nonnuclear components of nuclear weapons; research, development, and engineering of processes and technologies for remediation and restoration of weapon production sites.

4. Implementation of the National Energy Strategy through research and development of concepts for increasing energy efficiency in utilization, storage, and transmission; securing future energy supplies through improved recovery techniques, conversion technologies, and development of alternative energy sources; protecting the environment through characterization and assessment of environmental change phenomena and research and development of cost-effective technology applications for ameliorating environmental degradation; fortifying the foundations of our national energy strategy by deepening our understanding of the basic energy sciences, improving the mathematics and science education opportunities of our youth, and enhancing the general technical literacy of the public.

5. Support the economic security of the United States by helping U.S. industry compete effectively in international markets through the transfer of federally owned or originated technologies to private industry, state and local governments, and universities or other nonprofit organizations so that the prospects for rapid commercialization of such technologies are improved.

An important part of our mission also includes performing work for entities other than DOE when such work contributes directly to a DOE program or is judged to exercise and strengthen Sandia's capabilities in areas germane to our DOE missions. Such work is frequently an effective means of accomplishing technology transfer, a mission assigned to the laboratories by the 1989 amendment to the Atomic Energy Act. It provides access to Sandia's unique facilities, services, and expertise and often makes available technologies developed in the nuclear weapons program that are not obtainable from industry, university, or non-DOE government sources.

Work for others is classified among activity groups:

- *Nuclear weapons-related*—Fuzing, test, or component development work directly related to a nuclear weapon system and studies of nuclear weapon survivability, security, and command and control.

- *Safeguards and security*—Development of physical protection systems for facilities handling special nuclear materials and for nuclear weapons in storage or at deployment locations; anti-terrorist security systems for government and public facilities; technology systems to assist in the national effort for interdiction of illegal drug importation.

- *Verification and control technologies*—Analysis, research, and development to provide systems to verify compliance with arms control treaties.

- *Intelligence*—Hardware development and studies for the U.S. intelligence community, including the study of nuclear effects on intelligence hardware; battlefield intelligence systems.

- *Strategic Defense Initiative*—Studies and concept definition for the Strategic Defense Initiative Organization in the areas of discrimination, countermeasures, space power, pulsed power, threat definition, space survivability, space experiments, and new concepts.

- *Space systems*—Support of the nation's space exploration program through development of nuclear propulsion and power beaming, space vehicle design and flight testing, construction in space, components hardened against cosmic radiation, sensors for earth monitoring, life systems sensors, and data collection and analysis.

- *Advanced military technology*—Conventional military applications of technologies derived from or contributing to the nuclear weapons program, including guidance and navigation, high-performance parachutes, reentry vehicle design, electronic arming, fuzing, and firing systems, teleoperated devices, command and control, energetic materials, and others.

- *Radiation-hardened microelectronics*—Design and fabrication of radiation-hardened microstructures for use in military hardware, satellites and other space applications, and secure communications systems.

- *Particle beam technology*—Development of hardware concepts for the military application of high-power charged particle beams, microwaves, accelerators, and pulsed power.

- *Nuclear Regulatory Commission*—Research, analysis, and technical assistance in the assessment and licensing of commercial nuclear fuel cycle facilities with major emphasis on safety, waste management, and safeguards.

- *Environmental protection*—Support of the nation's environmental quality programs through development of techniques for the minimization and management of hazardous wastes and the reduction of noxious by-products from energy conversion and utilization; and the development of sensing, collection, and data processing systems for the measurement of global environmental change.

- *Activities for nonfederal entities*—Work to facilitate the transfer of technologies to the nonfederal sector and to make available to industry special capabilities, such as Sandia's unique testing facilities.

Parris Holmes operates one of the six radar stations of Sandia's Tonopah Test Range. The range provides extensive flight test capabilities and supports both DOE and DoD mission needs.

Jeremy Sprung checks a high-temperature solar furnace developed as part of Sandia's project to use solar energy to destroy hazardous materials.

Laboratories strategic plan

Sandia and the other DOE Defense Programs national laboratories were originally established to provide the nation with a nuclear deterrent. Since the 1970s these laboratories have also helped meet other national needs, such as developing energy supply alternatives and enhancing the capabilities of conventional weapon systems. Today Sandia is a multiprogram national science and engineering laboratory with a broad base of capabilities applicable to many national priorities, including national security, environmental protection and remediation, and economic competitiveness.

Events of the last few years have left behind the cold war. We are now faced with more dynamic and less predictable international conditions. Given these changes, how can Sandia best continue to render exceptional service in the national interest?

To help prepare for a future with diverse new challenges, management established a strategic planning process in 1989. In early 1990 Sandia's first high-level strategic plan was developed, beginning a process of reassessment and cultural change throughout the organization. In 1991 management continued strategic planning with an examination of the Laboratories' core products, core competencies, and strategic intent. The strategic planning process is now being expanded to include integrated business planning and coordination with the major laboratory initiatives of ES&H, quality, and change management.

Planning assumptions

Sandia's operating environment is very broad. It is affected by changes in international relations as well as by shifts in domestic priorities and social attitudes and directions. Because research and development is our principal activity, trends in science and technology are also important.

Six planning assumptions about Sandia's future operating environment were identified in early 1990 to serve as a basis for our strategic planning. It is interesting to look at those assumptions now, nearly two years later, and see how the trends identified then have continued to evolve. The following are statements of the original assumptions (in italic), followed by a current evaluation.

Planning assumption: *International relations are transforming from a bipolar to a multipolar basis, with increased political uncertainty, shifting threats, and evolving military requirements.*

This statement was written after the dismantlement of the Berlin Wall and before the collapse of the Soviet Union. The leaders of the new Commonwealth of Independent States now face the arduous tasks of moving from autarky to integration with the world economy and building new political institutions and relationships. Clearly, their focus has turned to these problems and away from any ideological or military confrontation with the United States and NATO.

On September 27, 1991, President Bush acted on the opportunity afforded by this change to redirect the nuclear weapons posture of the United States. He announced cuts in theater nuclear weapons worldwide, removed strategic bombers from alert status, and terminated some nuclear weapon programs. The Soviet Union responded with similar actions.

Perhaps even more important than these dramatic cuts was the reorientation of U.S. nuclear weapon policy contained in the President's announcement. While maintaining the importance of deterrence as a strategic principle, the President added arms reduction, nonproliferation, and ballistic missile defense as parallel thrusts of a comprehensive nuclear weapon policy. In his words,

> We can dramatically shrink the arsenal of the world's nuclear weapons. We can more effectively discourage the spread of nuclear weapons. We can rely more on defensive measures in our strategic relationship. We can enhance stability and actually reduce the risk of nuclear war.

Deterrence is no longer the preponderant focus of our nation's nuclear weapons policy. In the future, deterrence, arms reduction, nonproliferation, and ballistic missile defense will be pursued in parallel to enhance stability and reduce the risk of nuclear conflict.

This multifaceted policy reflects the new realities of a multipolar world. Although deterrence did not fail during the tense decades of the cold war, there is no guarantee that it will not fail in a multipolar world with several nuclear-capable nations, some of which might be led by fanatical or desperate regimes. Arms reduction involving the very large stockpiles of Russia and the United States is clearly in the best interests of both parties. Progress in arms reduction is requisite to demonstrate a commitment and provide an incentive for other nations to adhere to nonproliferation agreements. However, intelligence, technology control regimes, and political and economic inducements will need to be pursued in order to thwart rogue nations pursuing nuclear capability clandestinely.

The proliferation of ballistic missile capability is of increasing concern to defense planners. The terror of even fairly unsophisticated ballistic missiles was amply demonstrated by Iraqi Scuds in attacks on Israel and Saudi Arabia during the Persian Gulf war. As President Bush observed in his September 27 speech, "The United States and the Soviet Union are not the only nations with ballistic missiles. Some fifteen nations have them now, and in less than a decade that number could grow to twenty."

The simultaneous proliferation of nuclear weapons and ballistic missiles is an alarming phenomenon and identifies an imperative for affordable and technologically feasible ballistic missile defense. For either to be effective, ballistic missile defense and arms control must be pursued jointly. In the absence of any missile defense system, a nation may depend on the survival value of a large stockpile of nuclear weapons as insurance against cheating. Thus, a viable missile defense technology can reduce reliance on large stockpiles and permit arms reduction to proceed to lower levels than would otherwise be acceptable.

Over time, nuclear weapons will assume a position of lower relative importance in our nation's panoply. The mix of weapons the nation must support to respond to new threats will change. Operation Desert Storm showcased the effective use of advanced conventional weapons in a modern military conflict. The successes of non-nuclear technologies in that campaign reinforce the trend to regard nuclear weapons primarily as a deterrent against first use of weapons of mass destruction, while relying on advanced conventional weapons for virtually all other operational military needs.

Notwithstanding such trends in military planning, nuclear weapons possess an absolute and enduring importance by virtue of their destructive power. It is crucial that they continue to be properly engineered, manufactured, and maintained for safety, security, control, and reliability, regardless of the size of the stockpile.

There are several implications for the nation's nuclear weapons program as a result of the trends discussed above. The President has already started moving us toward a smaller stockpile. The nation is demanding a smaller and more cost-effective nuclear weapons complex. DOE has already announced steps to consolidate nuclear weapon production facilities. Reconfiguration options for the design laboratories are still being examined. Finally, it is clear that the nation's expectations with regard to nuclear weapons are for greater surety (safety, security, and command and control) and enhanced survivability. These expectations will require continued program excellence in a context of greater cost-effectiveness.

Planning assumption: *The declining relative economic position of the U.S. jeopardizes our well-being, our military strength, and our ability to influence international events.*

An appropriate military capability provides a foundation for worldwide security and stability. Yet national security is much more than military security. Economic vitality forms the basis for continuously expanding national wealth and infrastructure investments that sustain and improve the quality of life. A nation's wealth is earned by producing and selling products and services of value in the world marketplace.

The economic security of the U.S. is seriously threatened by our inconsistent ability to compete successfully in high-technology world markets. In addition, U.S. corporations have increasingly become international in ownership and outlook and are able to choose where to locate their production, research and development, and other operations. Currently the United States is experiencing unfavorable investment trends, especially for research and development, plant and equipment, and public infrastructure. The national wealth and material well-being of U.S. citizens may suffer as a result.

A structural component of this problem is the crisis in American education. U.S. schools are not producing enough students with the skills required for success in technical and scientific careers, while schools in several other countries are. This situation will create a shortage of technical and intellectual resources for U.S. industry and public institutions.

Planning assumption: *The central challenge in technology will be to integrate science and engineering to develop products rapidly and effectively.*

An inability to rapidly commercialize new product concepts is considered to be a major weakness in American technology. The gaps between research and development and between design engineering and manufacturing engineering must be closed. As the National Critical Technologies Panel observes,

> Increasingly, successful firms are not necessarily the discoverers and developers of the latest innovation, but are those that are able to swiftly bring associated products to market. . . . Discovery, development, and deployment must be integrated and viewed as concurrent rather than sequential activities.[1]

In the future, the ability of an industrial organization to effectively integrate all phases of the development cycle—research, design engineering, production, and marketing—will be a major competitive advantage.

Planning assumption: *Competing national needs and interests will place great stress on the federal budget, causing taxpayers and Congress to demand greater accountability, broader oversight, and better management of government programs.*

In fiscal year 1992 the United States government will fund approximately 25 percent (roughly $350 billion) of its operations by borrowing money. The federal debt stands close to $4 trillion and is estimated to approach $5 trillion in a few years. Public and, in some cases, governmental resistance to the idea of sustaining so large a debt is growing.

At the same time, urgent new demands, including the war on illegal drugs, the savings and loan bailout, international aid, and a persistent economic recession, are competing for federal budget dollars. As a result, policymakers will likely become more demanding trustees of the public chest and expect a greater return on the investment in the national laboratories. The federal R&D community will have to eliminate duplication where it occurs, share facilities and capabilities where possible, and compete to minimize costs.

Planning assumption: *Energy, environmental, and humanitarian concerns will affect the United States and the world at unprecedented levels during the 1990s and into the next century.*

The United States must urgently provide for energy security. The decades of the 1990s and the early twenty-first century will bring an unprecedented demand, which will stress the already limited world energy resources and may further complicate international relations.

Accompanying this demand for energy is the growing concern over the condition of the natural environment. It is unfortunate that the most abundant energy resource in the United States is coal, by far the largest contributor of gases that lead to "greenhouse" warming. This phenomenon is very likely a serious long-term environmental threat. Innovative approaches to natural resource usage, fossil energy conversion, renewable energy, nuclear power, and conservation will reenter our options mix.

Major new environmental concerns have surfaced during the last decade. The national infrastructure for handling

[1]Report of the National Critical Technologies Panel, March 1991, Government Printing Office.

hazardous and toxic wastes from industry and the DOE nuclear weapon production complex has been shown to be weak, and is drawing heavy criticism. Environmental policy issues will receive more attention from federal, state, and international governments.

Energy and environment directly affect a developing nation's ability to accumulate national wealth that can be applied to solving social problems. Humanitarian issues such as famine and natural disaster response, refugee treatment, public health, and overpopulation make international relations increasingly difficult. The disparity between industrialized and developing countries is growing and threatens world stability. The United States and other industrialized nations may have to define more effective vehicles for humanitarian assistance.

Planning assumption: *New entrants to the work force in the next decade will reflect greater cultural diversity, changing expectations, and insufficient technical training to meet demand.*

Several national studies, including the Department of Labor's report, *Workforce 2000,* have shown that entrants to the work force after 2000 will primarily be women, minorities, and naturalized United States citizens. Employers will have to provide environments, work-related policies, and career opportunities that will attract and retain this new work force.

In addition, the national scientific community, including the national laboratories, will have to sponsor educational outreach activities that will encourage American youth to pursue technical studies. Recent international tests have shown U.S. students to be near last place in mathematics and the physical and life sciences compared not only to our current international competitors, Japan and western Europe, but even to children from many less developed countries. Unless this trend is reversed in the next few years, U.S. competitiveness in high technology will suffer greatly.

Program directions

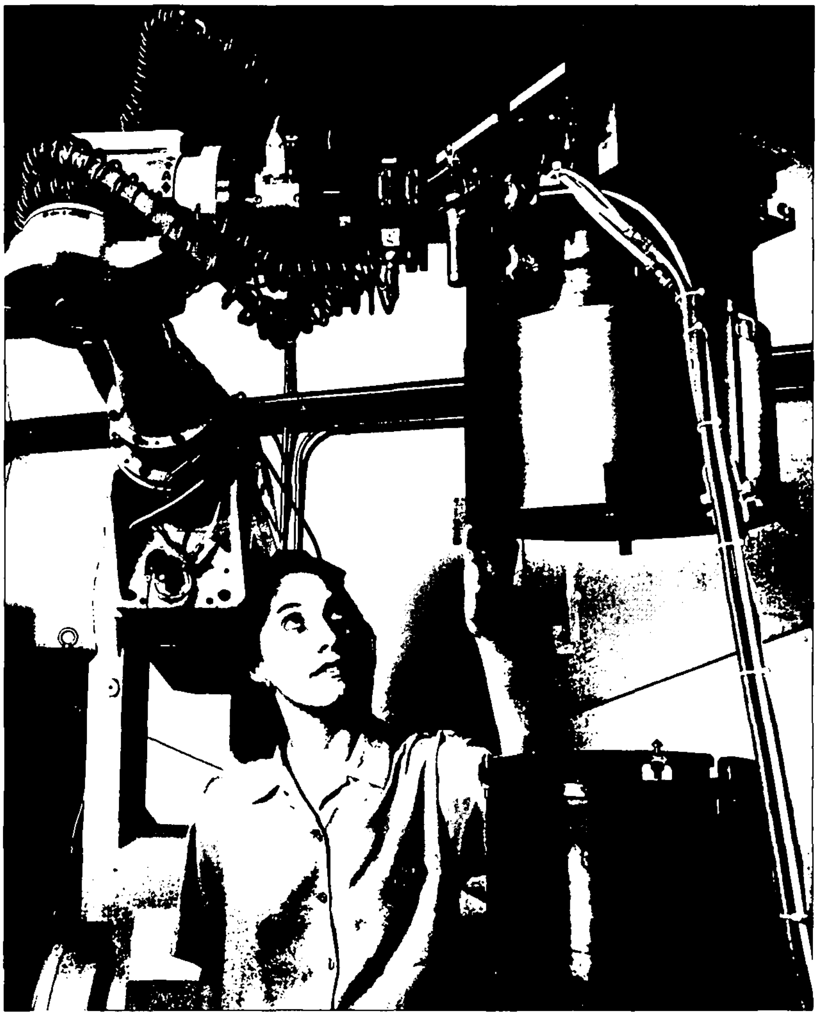
Defense programs

In his address to the nation on September 27, 1991, President Bush reinforced, both directly and by inference, the statutory responsibilities of the departments of Defense and Energy for meeting the demands of an evolving national security strategy. As steward of the stockpile for over forty years, Sandia National Laboratories has a tradition of responsibly anticipating and managing transitions dictated by policy and strategy changes. We have already taken some measures to realign our research, development, and testing activities to support and implement the guidance provided by the President.

The weapons retirement program announced by the President presents several technical and managerial challenges for the Laboratories. We are augmenting our efforts to meet these unprecedented challenges. We have created a team of qualified, experienced personnel to furnish dismantlement process and design support to the nuclear weapons complex—a support capability that is unique to Sandia.

President Bush emphasized the consistency between his current initiatives and the existing National Security Strategy, including the need to preserve both a credible nuclear deterrent and the national capability and capacity to rebuild nuclear forces in response to unforeseen circumstances. To respond to these requirements while preserving nuclear competence will require that we pursue a comprehensive set of current activities as well as a range of new initiatives. We have refocused the efforts in our current programs to capitalize on common design elements and reapply the maximum recoverable value of expended resources toward the modernization and surety of systems that may be required to serve well into the next century.

In identifying new programs to be pursued, Sandia has attempted to recognize the critical issues confronting the nuclear weapons complex, DOE, and the nation. A balanced strategy for addressing these issues has been developed, a strategy that utilizes the unique capabilities of the Laboratories



Jill Fahrenholtz examines a robotic system under development at Sandia that will help disassemble decommissioned nuclear weapons. Recent arms reduction initiatives will multiply the disassembly workload of the nuclear weapons complex.

to respond to constrained resources by offering substantive returns on proposed funding investments. This balanced approach consists of nine distinct but related thrusts:

Dismantlement—A number of formidable technical challenges complicate the extensive dismantlement activities that will occur in the near future. At DOE's direction, Sandia identified many of these challenges during the past several years and has aggressively explored technical solutions for them. This initiative will expand and accelerate the work needed to resolve many of the remaining challenges and support the broad comprehensive planning necessary for the success of the dismantlement process as a whole.

Weapon surety—Surety is an increasingly important area involving issues raised by the House Armed Services Committee's Panel on Nuclear Weapons Safety in their December 1990 report. Weapon surety is generally regarded as comprising safety, command and control, and security. Those concerns extend throughout the entire life cycle of a weapon. We must preserve weapon surety during transportation and handling and the logistics associated with retirement and dismantlement. In addition, we must satisfy new surety demands associated with a smaller and more flexible stockpile. This initiative consists of eight related activities, each of which has been structured to have a focused impact on critical surety areas.

An important challenge for the nuclear weapons complex is the proposed DOE

Weapons Surety Five-Year Plan. The first objective of the plan is to create, with DoD participation, an overarching definition of surety roles, responsibilities, and processes to guide surety efforts within DoD and DOE and facilitate dual-agency surety judgments. The second objective is to ensure that warhead production and modifications of existing warheads emphasize nuclear detonation safety, plutonium dispersal safety, and enhanced security and use control. Simultaneously, R&D must support the third objective of developing and implementing weapon architectures that provide intrinsic safety and enhanced security and use control. We view our participation in this plan as a major, long-term thrust for the Laboratories. While many of the activities outlined in the plan have been part of Sandia's weapons program for decades, the plan will focus and integrate our efforts to ensure that optimizing all aspects of surety is a primary objective.

Weapon design—It will be essential to preserve a robust capability for nuclear weapon design to serve as a virtual or actual deterrent, should the need arise. However, nuclear competence must be based upon a comprehensive approach that ensures the feasibility of producing required quantities of weapons in a timely manner. This initiative stresses both the evolution of new concepts into mature technologies and the systematic prototyping of robust designs. The objectives of this initiative are to maintain the nuclear competence of our staff; reduce the need for exotic, unique, or costly production processes; and maximize weapon surety through the incorporation of improved safety, use control, and security features. We will continue to pursue development of more intelligent, self-monitoring, self-diagnosing weapons that can serve as "wooden bombs" in the stockpile over extremely long life spans with minimal maintenance requirements.

Exploratory technologies—Obtaining the full value of further work in weapons surety, advanced weapons systems, and improved manufacturability will depend upon the evolution of advanced structural, electronic, and optoelectronic materials and technologies. These advanced and exploratory technologies are the enabling mechanisms behind virtually every weapon system and subsystem, including advanced guidance systems, communications, command and control, and arming, fuzing, and firing systems. This group of related programs was assembled on the basis of broad potential applicability and benefit to weapon performance, surety, and manufacturability.

Internal reconfiguration and consolidation—Growing constraints upon available resources have resulted in a shift within the nuclear weapons complex away from a demand for volume and quantity and toward a greater insistence upon quality, value, and increasingly effective use of funds. Sandia has attempted to support these efforts through both improved operational efficiency and the consolidation of some potentially redundant functions. This initiative will accelerate and broaden the consolidation process.

Integrated manufacturing and design—This initiative will develop and refine management tools and build a foundation for implementing a more comprehensive, better integrated, cradle-to-grave approach to weapon design, production, deployment, dismantlement, and disposal. It will link many of the initiatives discussed here and begin the process of better integrating many of the ongoing activities of the Laboratories and the nuclear weapons complex.

Preparation for test limitations—Testing, in the broadest sense, will remain essential to sustaining technological vigilance and ensuring the integrity of the stockpile, particularly as it is reduced and streamlined. Further limitations on underground testing will pose significant challenges. Meeting those challenges with aboveground test simulation facilities will require a major reorientation of effort and new tools. Although efforts outlined in this initiative will lay the groundwork for progress, the construction and calibration of additional facilities will be necessary to accommodate further limits on testing.

Arms control and verification—Future arms control agreements may include provisions for inspecting the stockpile and facilities of the nuclear weapons complex. Complying with such provisions would pose a wide variety of significant challenges. This initiative will assist DOE in meeting these challenges and continue research on technologies for monitoring foreign nuclear weapon activities.

Technical assistance to the Commonwealth of Independent States—The issues and required expertise associated with reducing the stockpile of the defunct U.S.S.R. (including, ironically the need to ensure stockpile security and integrity) are virtually identical to the challenges involved in reconfiguring our own forces. In his speech on September 27, 1991, President Bush proposed discussions with the U.S.S.R. to explore cooperation in 3 areas: (1) safe and environmentally responsible storage, transportation, dismantlement, and destruction of nuclear warheads; (2) physical security and safety of nuclear weapons; and (3) command and control. This initiative will enable us to respond effectively to the President's call for cooperative efforts.

Sandia must be technically strong to successfully pursue these initiatives and meet the nation's changing nuclear weapons needs. Thus, we will adopt a prudent investment strategy for the technologies we pursue and the capabilities, or competencies, we maintain.

A balanced technology portfolio should include mature, growth, and emerging capabilities. In the mature category are proven technologies that can be moved quickly into application. Growth technologies are at a younger phase of the technology life cycle and will be applied as mature technologies expire. Emerging technologies are new concepts with such strong potential for payoff that they demand exploration.

Optical detonation systems and synthetic aperture radars are examples of growth technologies under development today. Massively parallel processing (enabling much greater computational speeds) and compound material semiconductors are examples of emerging technologies that have great potential, not only to the weapons program, but to space exploration and other sectors, including commercial industry.

The keys to a healthy technology base are adequate facilities, a technical staff with superior expertise, and sustained competence in critical capabilities.

Funding for Sandia's nuclear weapons technology base has been decreasing in the past few years. We have had to rely on reimbursable work from other agencies (primarily DoD) to compensate for this decline. A reasonable strategy for the future will be to work more closely with industry to exploit their capabilities where possible and make available unique capabilities of the nuclear weapons program for industrial purposes.

Energy programs

Sandia will seek to expand its energy R&D programs in support of the National Energy Strategy. Operation Desert Storm amply demonstrated that energy security is a crucial component of national security. While the reasons for our involvement in Desert Storm were more complex than simply a "war for oil," our failure to have achieved energy independence during the past twenty years was certainly a major factor. As a national laboratory, Sandia has a special responsibility to research, develop, and transfer technologies that can improve the energy posture of the United States. Improved energy extraction, conversion, and conservation are needed if we are to reduce our dependence on foreign sources and minimize environmental impacts.

Research in energy programs by the national laboratories has been shown to be cost-effective:

> Federal support for energy conservation R&D . . . has saved billions of dollars for industry and consumers. For seven case studies . . . , federal investments totaling $16 million generated eventual savings of $68 billion. If these seven projects had to justify the entire federal investment in energy conservation R&D over the past decade, they would represent a 50 to 1 return.[2]

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[2]"The Role of Federal Research and Development in Advancing Energy Efficiency: A $50 Billion Contribution to the U.S. Economy," Howard Geller, Jeffrey P. Harris, Mark D. Levine, Arthur H. Rosenfeld in *Annual Review of Energy,* Vol. 12, 1987. Jack M. Hollander, Ed., Annual Reviews, Inc., Palo Alto.

Funds spent on energy R&D at Sandia since the 1970s have already had positive impact registering in the billions of dollars. In the late 1970s Sandia engineers developed the concept of using synthetic polycrystalline diamond discs manufactured by General Electric in a new type of drill bit for geothermal, oil, and gas drilling. We worked closely with engineers from GE to develop a technique for reliably bonding the diamond discs to metal studs. We used computer codes derived from the weapons program to position the diamond cutters on a drill bit face to ensure proper cooling, balanced cutter wear, and optimum performance. The technology was then demonstrated to the drill bit industry through a concerted technology transfer effort, and the greatly improved performance of the bits was validated through cooperative tests. Today these bits have demonstrated an improvement in drilling productivity of at least 25 percent in hard-to-tap formations. The value of this improvement in the context of total drilling activity around the world translates into a dollar impact in the billions.

In recent years Sandia has applied its expertise in battery technology to energy-related applications. Since the 1950s Sandia has developed batteries with unique performance characteristics for nuclear weapons. Battery researchers are now developing ways to provide power to deep space probes, supply rechargeable batteries for electric cars, and store electricity from photovoltaic cells. The U.S. market share in the battery business has decreased, but Sandia is aggressively pursuing collaborative work with industry. In particular, we are active in DOE's cooperative agreement with the United States Advanced Battery Consortium, an industry-led group.

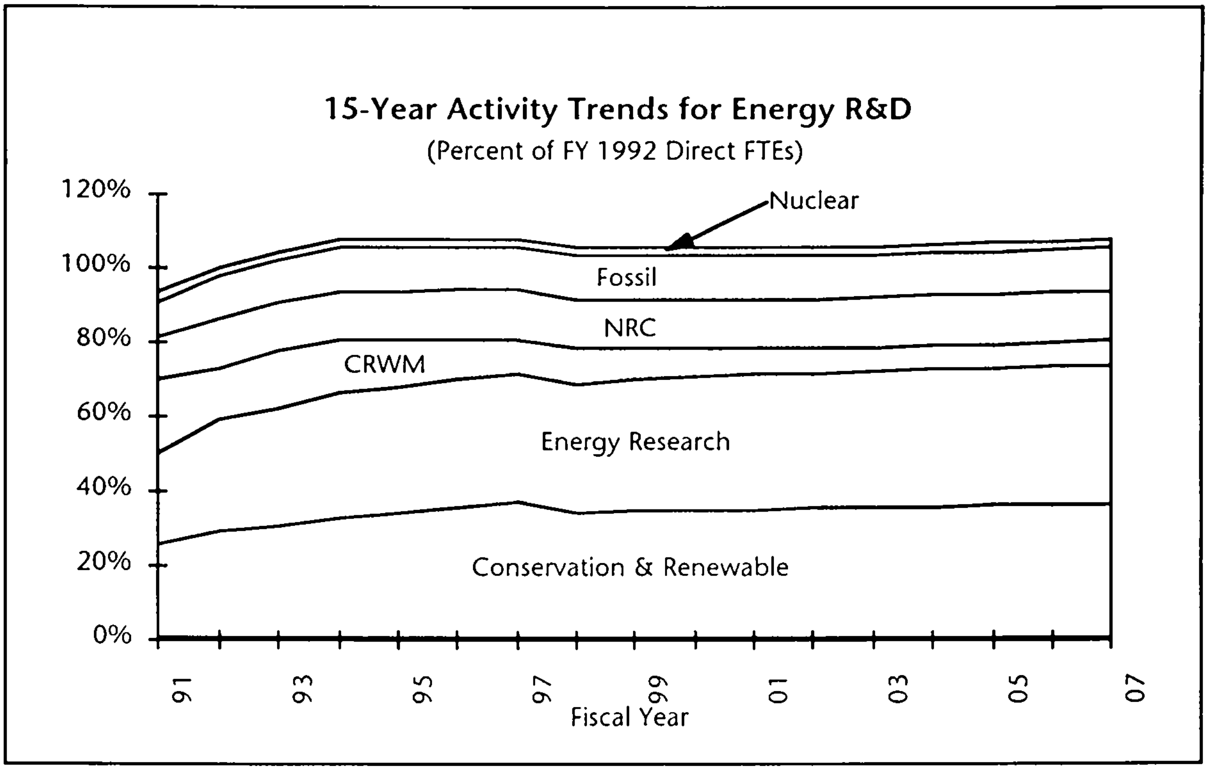
Another high-impact contribution to energy supply is Sandia's technique for optimizing the placement of oil and gas wells to help drain hard-to-tap reservoirs. The technique, anelastic strain recovery, measures stresses in rock formations, allowing fractures from boreholes to be accurately predicted and adjacent wells to be properly positioned. Improper placement of just a single well can cause millions of dollars of oil or gas to be left underground. The impact of the worldwide use of this technique is in the billions of dollars.

These examples demonstrate the enormous leverage afforded by R&D conducted in partnership with industry to improve the performance of specific technologies. With federal funding severely limited, substantial increases in energy programs are highly unlikely. Thus, partnership and teamwork with industry become very important. The market pull afforded by the technology needs of industry is a necessary discipline for federal R&D. It will continue to be our strategy to seek out collaborative arrangements with U.S. industry as we apply our research and development capabilities to energy problems.

The mix in Sandia's energy activities will undergo little change over the planning period. We expect slight growth in Energy Research, primarily in Basic Energy Sciences and Carbon Dioxide Research. We also anticipate modest growth in Conservation and Renewable Energy, primarily in transportation and industrial sector technologies. Fossil Energy will maintain a steady, robust program, and our Nuclear Energy and Nuclear Regulatory Commission activities will require continued commitment. Work for the Office of Civilian Radioactive Waste Management will decrease as the repository project advances from site characterization to construction. These trends are shown in the chart.

Our strategy in Basic Energy Sciences (BES) is to sustain research thrusts in scientifically tailored materials, computational materials science, superconductivity, beam-enhanced growth of semiconductor materials, and geoscience research. Combustion research will accelerate development of technologies for fuel use, equipment design, and mitigation of environmental effects. DOE responsibilities under the national High-Performance Computing and Communications Program impact several BES programs and should experience strong growth. The magnetic fusion program will maintain an emphasis on materials and component development, and we expect increasing demand for support of both domestic and international programs.

We will continue vigorous development of catalytic coal conversion processes that can significantly reduce the undesirable by-products of coal combustion. Continued improvement in catalyst design will permit large-scale commercial processing of cleaner burning fossil fuels with greater hydrogen content and reduced nitrogen and sulfur.



The potential market value of such catalysts when transferred to industry will be in the hundreds of millions of dollars per year. We will form alliances with industry to address key issues in coal utilization.

Sandia's nuclear waste management efforts support the relatively near-term goals of the defense and civilian waste management programs. The Yucca Mountain Project has become a major activity for us and will receive greater support over the next five years. By the late 1990s our involvement in nuclear waste programs will decline, and programs in nonnuclear hazardous waste and toxics disposal will receive more emphasis.

We will continue with selected roles in other energy technologies such as conservation, energy storage, solar, wind, and geothermal, where we have historically shown strong participation. These programs can provide significant benefits in the twenty-first century, and the nation needs to keep these energy options open. We will also continue to develop the oil and gas technology partnerships and pursue advanced technology for environmentally compatible coal utilization.

Programs for sponsors other than DOE

Since the early 1970s DOE has recognized that work for other agencies is essential for sustaining the technology base required for the nuclear weapons mission. Sandia and the other DOE Defense Programs laboratories have a continuing broad mission responsibility for nuclear weapons. However, a formidable management problem is how to sustain the required core competencies for this mission over the long term. Fortunately, many of the constituent technologies for nuclear weapons also have significant value for the broader defense and commercial sectors. In principle, facilities that simultaneously serve multiple needs can be more cost-effective from a federal R&D investment standpoint and have greater benefit-realization potential than those serving a single user.

In the 1990s such synergism will become especially important if budgetary authorizations for nuclear weapons activities decline. Consequently, we intend to manage our work for the customary non-DOE sponsors (principally DoD) close to its historical level of about 30 percent of laboratory direct effort throughout the planning period.

Sandia also intends to contribute actively to any new, major technology initiatives that may be planned by the federal government in the future. Such initiatives—whether in transportation, space, infrastructure redevelopment, energy, environment, or other arenas—must coordinate the core competencies of many agencies and sectors to be successful and cost-effective. We refer to this integrated approach to federal technology sponsorship with the acronym GUILD (Government-University-Industry-Laboratory Development). The objective of GUILD is to accelerate the development of solutions to major national problems by joining the DOE national laboratories with teams involving government, industry, and academia. Wide application of the GUILD concept will promote a stronger science and technology base in which synergistic talents are shared cost-effectively among partners with complementary strengths.

GUILD will provide an effective strategy for addressing major technological issues on a larger scale than has been possible with the traditional approach. The potential advantages are compelling:

- A unified approach to structuring major national initiatives, such as space exploration, transportation, advanced manufacturing, biomedical engineering, energy security, and environment;

- A national team approach to problem-solving;

- A mechanism for reducing development risks for industry and exploiting economic opportunities for the nation through strategic programs to demonstrate precompetitive technologies in a realistic market-oriented setting.

To effectively practice GUILD, the national laboratories must improve their interface with the nation's other major technology sectors: industry and universities. In September 1990 the President's Office of Science and Technology Policy released a document entitled *U.S. Technology Policy* that outlines the imperative of cooperation and teamwork among government, industry, and academia. This vision of partnership between the federal government and the private sector provides a workable foundation upon which the DOE national laboratories can build to play a stronger role in applying technology to national needs.

Frank Zanner and Phil Sackinger of Sandia examine an ingot removed from a vacuum arc remelting furnace. Twelve companies have teamed with Sandia to increase U.S. competitiveness in the world specialty metals market. The Specialty Metals Processing Consortium brings together private industry, universities, and DOE.

Managerial implications

Sandia management has continued and broadened its strategic planning efforts into an integrated process for charting current and future laboratory activities. Efforts at defining Sandia and its future activities began in 1989 when we laid the foundation with a "Vision Statement." In 1990 Sandia developed its first corporate strategic plan, which formally defined Sandia's corporate values of teamwork, integrity, quality, leadership, and respect for the individual. The strategic plan also presented a set of five long-term objectives for Sandia. These objectives are global statements of desired results that will serve as strategic guidance to managers, organizations, activity committees, and employees:

1. Achieve an empowered Sandia culture: Sandia will be a customer-oriented, energetic, dynamic, enthusiastic, participative organization in which people have the freedom to have an impact.

2. Demonstrate our leadership with comprehensive, innovative, creative, and cost-effective solutions in areas of vital national importance.

3. Exhibit leadership in defining, creating, and exercising stewardship of the nuclear weapons stockpile for a changing world.

4. Become a national leader in quality and quality progress.

5. Strengthen and broaden the Department of Energy's mission.

Phase I of strategic planning established the groundwork on which major change initiatives at Sandia are based. They include our change management, ES&H Improvement and Compliance, and Total Quality Management programs.

In FY 1991 Sandia completed its Phase IA strategic planning process, which defined a concept we call 'strategic unity' and proposed an initial identification of core competencies. Strategic unity is a customization of the concept 'strategic intent' introduced by business scholars Gary Hamel and C. K. Prahalad.[3] According to them, strategic intent is a statement of an organization's ultimate goal as well as an active management process for achieving it. Our customized concept focuses on the distinguishing ways in which Sandia will be accomplishing its missions in the future. In particular, it acknowledges the important role we expect industry to play in characterizing the degree to which Sandia continues to provide "exceptional service in the national interest."

Core competencies[4] are the distinguishing integration of skills, technologies, and facilities Sandia requires to achieve its strategic objectives. They provide us with access to a variety of opportunities for unique service in the national interest. In addition, they make significant contributions to our sponsors' appreciation of the value of the products and services we provide and are not widely duplicated by other organizations.

Core competencies were the subject of much discussion throughout the Laboratories during and after the Phase IA process. Insights gained during this debate led us at length to visualize a structure with core competencies as the foundation supporting a set of integrated competencies which in turn support generic product realization capabilities. Phase IA identified the following set of core competencies:

- Engineered materials and processes
- Computational simulation and high-performance computing
- Microelectronics and photonics
- Pulsed power
- Physical simulation and engineering sciences

These core competencies do not solely exist as discrete entities but are also integrated into intelligent manufacturing,

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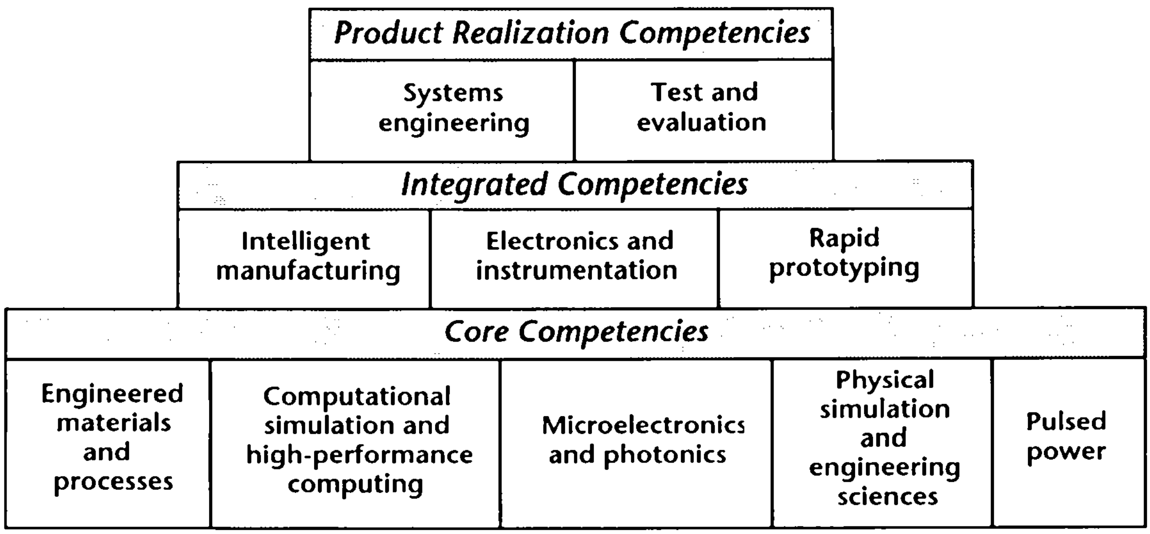
[3]Gary Hamel and C.K. Prahalad, "Strategic Intent," *Harvard Business Review* (May-June 1989): 63-76.

[4]C.K. Prahalad and Gary Hamel, "The Core Competence of the Corporation," *Harvard Business Review* (May-June 1990): 79-91.

Core Competencies Support Product Realization



electronics and instrumentation, and rapid prototyping. Integrated competencies in turn support our product realization activities, which may be generically characterized as systems engineering and test and evaluation. Thus, core competencies alone do not make Sandia excellent; rather, it is the integration of core competencies into our product realization process that makes Sandia an outstanding R&D laboratory. This concept is illustrated in the figure.

Sandia is about to enter Phase II of its strategic planning work. Phase II will begin a process for making decisions on investment or disinvestment in laboratory functions and activities. The process, designed using AT&T's Process Quality Management and Improvement (PQMI) Guidelines,[5] will focus on how we make resource allocation decisions. Based upon insights gained during Phase I and Phase IA, major programmatic sectors and organizations at Sandia will be challenged to create operational plans for the purpose of quantifying expected programmatic activity and requirements and establishing accountability for strategic objectives. At every juncture of this process, decisions will be influenced by ES&H goals and requirements as well as other boundaries, including Sandia's corporate values. It is envisioned that the process will be iterated each year.

Sandia, with DOE/AL, is also establishing and prototyping a rigorous self-assessment and performance improvement program to ensure high standards of excellence. The appraisal program is integrating line organization self-assessments, internal independent assessments, and external assessments to appraise overall performance in three broad areas: compliance with corporate requirements, commitment to strategic goals, and conformance to program requirements. The four-phase program, covering two fiscal years per cycle, will help meet the Laboratories' goal of continuous improvement:

- **Phase 1:** Selection of activities and programs to be appraised during a fiscal year.
- **Phase 2:** Performance assessment to identify strengths and areas for improvement. (A subset of the processes identified for improvement becomes part of annual agreements between Sandia and DOE on specific programs and functions to be improved and appraised during the following year.)
- **Phase 3:** Process improvement, drawing upon the previous year's assessment to establish and implement improvement strategies.

[5]AT&T Quality Steering Committee, *Process Quality Management & Improvement Guidelines*, AT&T, (1988).

- **Phase 4:** A DOE/Sandia appraisal to evaluate compliance with previous year's agreements and define a quantitative score reflecting that degree of adherence.

We believe that our efforts to integrate strategic and operational planning and our development of a self-assessment program will permit us to effectively continue our contributions to U.S. scientific and technological needs. It is becoming increasingly clear that the major technology challenges in defense, energy, environment, and economic competitiveness are interrelated. The problems of the 1990s will only be successfully addressed if U.S. technology programs embrace much greater cooperation, permitting industry's competitive energies to be focused more strongly on meeting specific market needs. For this change to happen, we need strong technology advocacy at the federal level. DOE and its national laboratories have the potential to become catalysts for realizing national strategic intent in technology, based on an approach that stresses teamwork and partnership among all members of the U.S. technology community, public and private sector alike.

In the Nuclear Weapons Complex, many tasks require the use of remote systems controlled by an operator. Sandia has developed the COPILOT controller, in which robot control is shared by both a human operator and a computer to ensure safe operations at all times —even when the robot is under manual control.

Initiatives

This section presents initiatives for consideration by DOE or reimbursable sponsors. Their inclusion here does not imply DOE approval, nor does it represent a commitment by Sandia to implement any of the initiatives. Funding and personnel increments required for these initiatives are in addition to ongoing programmatic funding summarized in the resource projection tables located at the end of this plan.

Initiatives for Defense Programs

Robotic manufacturing science and engineering for nuclear weapons complex modernization

The imperative to minimize waste, enhance occupational safety, and improve quality in the nuclear weapons complex—all at less cost—will require innovative management and technology. Advanced robotics can help achieve these goals.

DOE contractors have found standard industrial robots (designed primarily for high-volume manufacturing) to have limited applicability to their operations. However, with appropriate research and development, robotic systems can be designed that will be specifically applicable to DOE requirements.

Sandia has been closely involved with weapon production for many years, providing product definition data, assembly procedures, and consultation to DOE production facilities. The Defense Programs laboratories have a continuing responsibility to provide the production plants with technologies and processes to permit them to perform their jobs safely and effectively. Sandia's robotics engineers are knowledgeable of both the DOE complex and the range of disciplines needed for the development of advanced robotic systems.

The Robotic Manufacturing Science and Engineering Project will draw upon Sandia's base of robotics technology expertise. During the past several years, Sandia has carried out robotics development for the Office of Civilian Radioactive Waste Management, the Office of Environmental Restoration and Waste Management, and the Assistant Secretary for Defense Programs. We are currently transferring robotic technologies to several DOE sites, including Pantex, Mound, Y-12, Savannah River, Allied Signal, and Rocky Flats.

Anticipated Funding Requirements for Robotic Manufacturing Science and Engineering for Nuclear Weapons Complex Modernization
(Dollars in constant FY 1992 millions; personnel in FTEs)

	FY93	FY94	FY95	FY96	FY97
Operating	6.0	10.0	12.0	12.0	12.0
Capital Equipment	1.0	2.0	1.0	1.0	1.0
Total Cost	7.0	12.0	13.0	13.0	13.0
Direct Personnel	25	40	50	50	50

Furthermore, we are consulting with several other groups in the production complex and are performing ongoing R&D in advanced manufacturing for DOE mission applications.

In many ways, DOE's design and production activities are a microcosm of much of U.S. manufacturing. The Robotic Manufacturing Science and Engineering Project (in its relation to reconfiguration and modernization of the nuclear weapons complex) offers an opportunity for DOE to become an important contributor in assisting U.S. industry in solving some of the manufacturing problems associated with a decline in competitiveness.

The project will conduct research in automated programming and planning, geometric modeling and reasoning, and high-speed, sensor-driven control—areas key to the broad application of robotics to DOE problems. In addition, it will construct prototypes of advanced systems targeted for specific applications within DOE Defense Programs. The laboratory will be organized to ensure that managers from across the complex are regularly consulted, particularly with respect to developmental activities. In order that technology may be efficiently transferred, engineers from the DOE production plants will be involved in prototyping machines, and Sandia designers will continue to be active as full-scale production systems are built, brought up, and operated.

Preparation for testing limitations

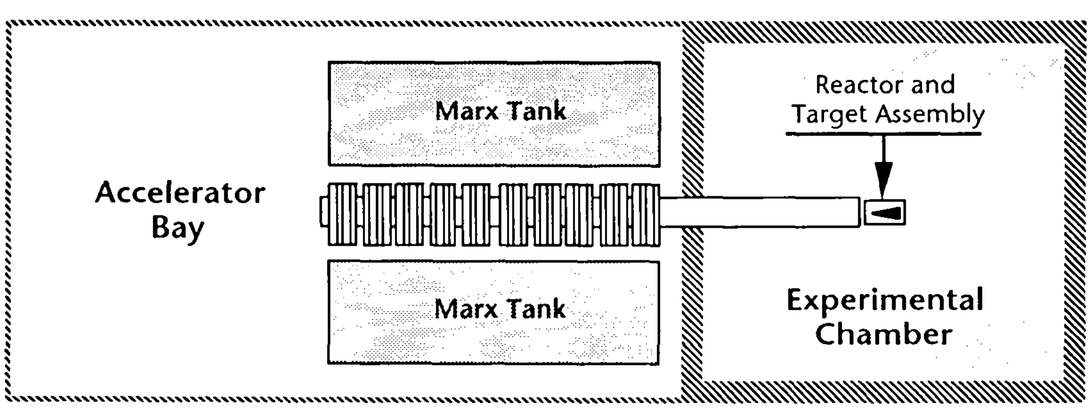
There is a critical need to improve our aboveground radiation testing (AGT) capabilities in preparation for further restrictions on the conduct of underground nuclear tests. We must be able to certify all nuclear weapon subsystems provided by Sandia in radiation environments now obtainable only through underground testing (UGT). The construction of two new simulation facilities will significantly improve our capability to cover the testing levels that can now be conducted only underground.

The first new facility required is the Externally-Driven Nuclear Assembly (EDNA), which would employ a state-of-the-art linear induction accelerator and a fast-burst reactor. EDNA represents a unique aboveground capability to test systems in gamma and neutron radiation threat environments. EDNA will operate in four radiation modes, which will provide testing flexibility currently not available in aboveground simulation. These modes are:

1. Reactor driven by the accelerator to provide very short-pulse neutron testing of an entire warhead system and subsystems;

2. Accelerator pulsing independently in the *bremsstrahlung* mode to provide

Externally-Driven Nuclear Assembly (EDNA)
(Schematic representation)



gamma-ray testing or source region electromagnetic pulse (SREMP) testing over large volumes;

3. Reactor pulsing independently to provide large-volume neutron and prompt-dose testing;

4. Reactor and accelerator pulsing independently to provide both neutron and gamma-ray beams for endoatmospheric synergistic testing.

Sandia recently developed the 18 million volt, 650,000 ampere Hermes III accelerator using linear induction techniques. This technology can be extrapolated directly to support the EDNA concept, providing an accelerator that will operate at 50 million volts, 1.2 million amperes, and produce a 20 nanosecond gamma pulse (FWHM). Such a burst of energetic gamma radiation focused on the correct target will produce a very fast source of 5.0 X 10^{15} neutrons. The nuclear assembly will be a thin-walled, cylindrical reactor that will multiply the source neutron burst by a factor of 1000 but remain below prompt critical, thus providing a substantial margin of safety. The cavity of the reactor will be large enough to accept full warhead systems, and the neutron environment will create a fission density in excess of 2.0 X 10^{15} fissions/kg in the warhead subsystems. The neutron pulse width from this design will be approximately 30 microseconds, far shorter than can be achieved anywhere aboveground over such a large test volume. In both gamma and neutron testing, EDNA will provide excellent simulation fidelity with the actual threat environments.

The second new facility required is a cold and warm x-ray facility that would permit testing of materials and components that currently can only be tested in UGTs. The facility will be an extension of new technology developed in the long-pulse Plasma Opening Switch (POS) Program. This facility will have a 600 trillion watt pulsed power generator to drive a 60 million ampere z-pinch implosion to produce x-ray energies from one thousand to twenty thousand electron volts over much larger exposure areas than are now possible with current aboveground simulators. This

Anticipated Funding Requirements for Preparation for Testing Limitations
(Dollars in constant FY 1992 millions; personnel in FTEs)

	FY93	FY94	FY95	FY96	FY97
EDNA					
Operating	10.1	11.0	12.7	8.1	2.5
Construction		4.2	29.7	28.1	20.8
Total Cost	10.1	15.2	42.4	36.2	23.3
Direct Personnel	40	40	40	40	40
X-Ray Simulator					
Operating	5.7	6.3	7.3	4.6	1.4
Construction		2.5	17.2	16.3	12.0
Total Cost	5.7	8.8	24.5	20.9	13.4
Direct Personnel	25	25	25	25	25

capability will provide excellent simulation fidelity for the testing of optics, materials, and many components.

Providing these testing capabilities is fundamental to nuclear weapon systems certification and survivability analysis, especially if additional limitations are placed on underground testing or in the event of a comprehensive test ban. Obviously, with the decision to maintain a much smaller stockpile, each weapon becomes more valuable and its survivability is critical.

Reuse of existing stockpile components in new configurations represents a major certification effort. Fratricide effects from closely spaced warheads can also be addressed. SREMP effects are very important to the military services employing surface tactical equipment. In addition, x-ray effects on reentry vehicles and space systems, which now can only be tested underground, may be tested aboveground in high-fidelity environments. EDNA and the new x-ray facility are the keys to ensuring a survivable nuclear stockpile and the supporting space and ground based systems.

Projection x-ray lithography using a laser plasma source

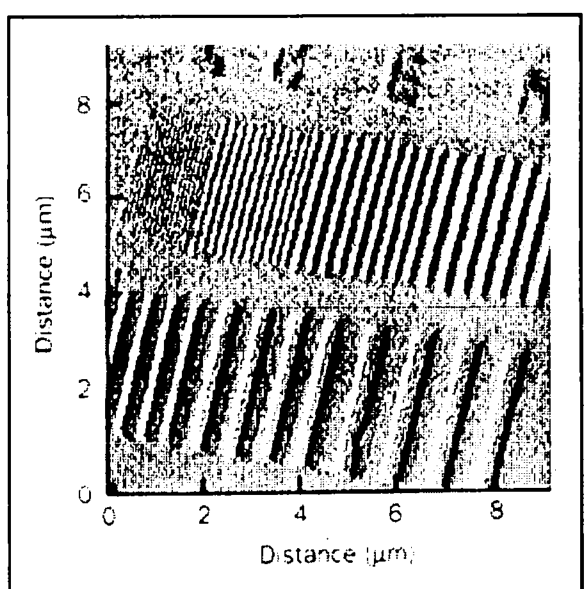
U.S. industry must develop new lithographic patterning technologies to remain competitive in the production of future high-density integrated circuits (ICs) with feature sizes below 0.2 microns. It is well recognized that minimum line widths of 0.35 microns will be required for 64-megabit IC devices planned for the near future. Beyond this, new pattern transfer technologies need to be developed for chips as large as one gigabit, anticipated to be in production by the year 2000.

Electron beam, direct-write technology has recently been demonstrated by Hitachi to produce the first 64-megabit memory prototype. Volume production of memory chips at this density, however, is still several years away. While the direct-write electron beam method is capable of high resolution, it and focused ion beam techniques suffer from the fact that they write in a serial mode and thus are not suitable for large-scale production.

In addition to direct-write techniques, projection electron beam lithography, x-ray lithography, and deep ultraviolet lithography using excimer lasers are now being considered for 64-megabit memory chips and beyond. While debate continues as to which patterning technique will be the one of choice, it is clear that x-ray lithography is a strong contender for volume production with feature sizes down to at least 0.2 micron and possibly below.

At present, two lithographic approaches using x-rays are under development worldwide. The first, proximity x-ray lithography, utilizes a one-to-one, shadow printing approach and is the x-ray technology currently receiving the greatest attention. Japan is the worldwide leader in development of this technique, which relies on synchrotron radiation sources. While these sources are extremely intense, they are also exceedingly costly and complex. The difficulty of integrating them into existing production lines has become a formidable barrier to implementing proximity x-ray lithography using synchrotron radiation sources.

The second x-ray lithography approach, soft x-ray projection lithography (SXPL), holds the promise of achieving 0.1 micron line widths. This technique, which only recently has received serious attention,



Atomic-force microscope image of results obtained using the Sandia laser-plasma source system.

Anticipated Funding Requirements for
Projection X-Ray Lithography Using a Laser Plasma Source
(Dollars in constant FY 1992 millions; personnel in FTEs)

	FY93	FY94	FY95	FY96	FY97
Operating	4.5	7.5	10.0	10.0	7.5
Direct Personnel	10	15	25	25	25

employs a reduction method utilizing all reflective optics. The ability to grow nearly atomically smooth multilayer films has enabled fabrication of highly reflective coatings for the soft x-ray region of the spectrum and thus has been a key factor in the development of SXPL.

Sandia, in collaboration with industry, has achieved exciting experimental results using a laser plasma source for x-ray projection lithography, including printed feature sizes as small as 0.05 micron. These results represent a significant breakthrough.

Sandia intends to pursue the next step of SXPL development in collaboration with industry. The program will address such issues as high-reflectance condenser and illumination optics capable of printing over large-areas, evaluation and testing of high-power lasers for producing soft x-rays, reduction of plasma target debris, and optimization of the plasma conversion efficiency. It is our goal to demonstrate with industry the feasibility of SXPL for commercial fabrication of circuits with feature sizes between 0.1 and 0.2 microns.

If this program is successful, it will place advanced U.S. chip manufacturing on a very competitive footing vis-a-vis foreign manufacturers. Within the past year, both the Japanese and the Europeans have initiated research and development projects to couple laser plasma sources to soft x-ray projection lithography. To date only the Sandia effort has demonstrated diffraction-limited reduction printing using a laser plasma source. The vigorous pursuit of the program is critical to retaining the U.S. lead in soft x-ray projection lithography driven by laser plasma sources.

The potential benefits to the U.S. microelectronics industry are enormous. If this development program is successful, the technique of SXPL with a laser plasma source can be incorporated in a chip production line. This initiative will develop a laboratory prototype that could ultimately lead to direct replacement of optical steppers in operation on existing IC manufacturing lines. The capability to manufacture one-gigabit SRAM devices will place the U.S. microelectronics industry in a very competitive position with respect to Japanese manufacturers, who are currently heavily committed to a competing x-ray lithography approach.

Flat panel display technology

A critical need exists for DOE laboratory assistance to U.S. industry in the area of electronic display technology. As society advances through the information age, the display monitor will become the primary vehicle by which people will interface with microprocessor-controlled equipment. Rugged, compact, reliable, and inexpensive flat-panel displays (FPDs) with superior image quality will universally displace conventional cathode-ray tubes within the next several years.

Display technology will ultimately control the electronics industry as a whole. The display is typically larger than other electronic components, and it already incorporates a substantial amount of electronic function. Displays will increasingly include large quantities of semiconductor memory and microprocessors for signal processing and image decompression. Ultimately, the display will become the total system package for many products.

As more proprietary features of end

products are embedded in displays, end product companies will need access to manufacturing sources to stay competitive. Because the cost of a display is typically leveraged by a factor of five in commercial products (e.g., a $400 display in a notebook computer selling for $2,000), and by a factor of fifteen in military systems, the $4 billion per year display market controls at least $20 billion per year in sales and represents tens of thousands of high-quality manufacturing jobs. For these reasons, the development of a high-volume display industry within the United States is one of the most critical of all the current high-technology battlegrounds.

A U.S. organization, the Optoelectronics Industry Development Association (OIDA), has outlined a national program to establish a competitive U.S. manufacturers' position in flat-panel display technology. The OIDA plan calls for a major private sector investment in exchange for a federal government commitment for complementary funding and support from the national laboratories. The objective is to create a new technology and secure a commanding share of a new market. Thus, the OIDA program differs fundamentally from existing national efforts, such as SEMATECH, MCC, and SRC, which exist to preserve U.S. market share in established technologies.

The national laboratory support envisioned by the OIDA plan involves cooperative R&D on manufacturing processes for current FPD technologies and R&D on successor technologies. The plan calls for the creation of a National Center of Excellence (NCE) at a national laboratory to serve as the focal point for industry/laboratory collaboration. The NCE would coordinate activities within the national laboratories and universities. A major purpose of the NCE would be to assure that federal R&D is connected to the real needs of the private sector, with particular emphasis on robust manufacturing processes and equipment.

Sandia possesses an infrastructure and advanced capabilities that are directly applicable to industry's requirements for generating and sustaining manufacturing technologies for flat-panel displays. The state-of-the-art Microelectronics Development Laboratory (MDL), with over 12,500 square feet of better-than-Class-1 clean-room space, represents a capability unrivaled within the national laboratory system. MDL programs benefit from access to the broad technology base of scientists and specialized facilities that supports Sandia's multiprogram science and technology mission. Manufacturability will have equal weight with technology content in determining the fate of high-volume production of flat-panel displays. In that regard, Sandia is already coupled to the relevant U.S. manufacturers through collaborations with SEMATECH, Semiconductor Research Corporation, and Sandia's Microelectronics Quality Reliability Center, an industry support program.

The liquid-crystal displays that predominate today are a market completely controlled by Japanese industry. Japanese companies have also invested heavily in the development of the newer, active matrix, liquid-crystal displays (AMLCD) as a successor technology, and they control the world market for them as well. However, AMLCDs are deficient in several important qualities, including scalability to large areas, true color, brightness, and power economy.

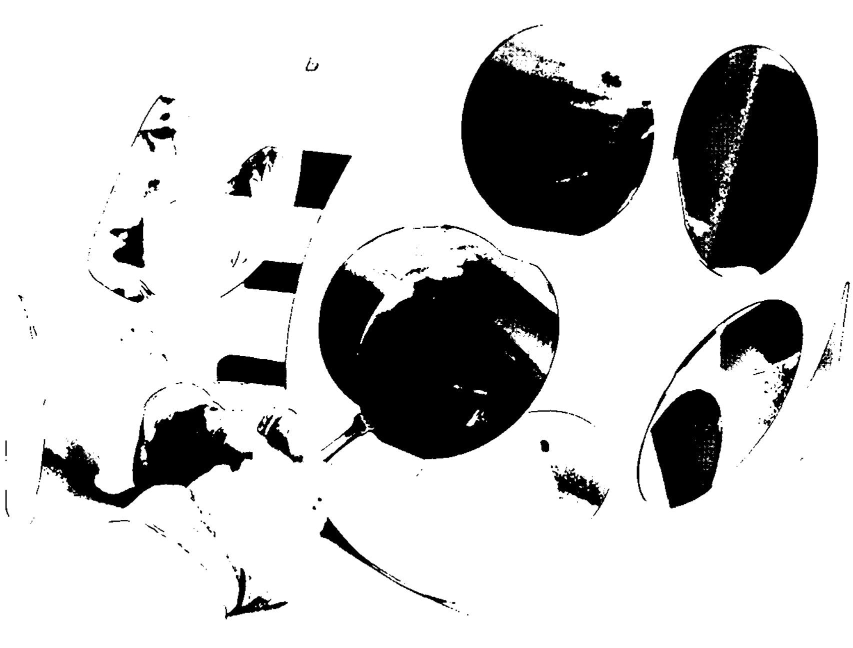
Anticipated Funding Requirements for Flat panel display technology
(Dollars in constant FY 1992 millions; personnel in FTEs)

	FY93	FY94	FY95	FY96	FY97
Operating	10.0	16.0	60.0	60.0	60.0
Direct Personnel	70	100	140	140	140

Scientists at Sandia's Microelectronics Development Laboratory have invented a field-emission array cathode that holds the potential for improved efficiency, better manufacturability, and scalability to larger areas than the AMLCD technology favored by the foreign competition. MDL scientists have also investigated the silicon-on-insulator and smart-power integrated circuits that will be needed to drive displays based on either field-emission, plasma-discharge, or thin-film electroluminescence. Sandia also pioneered and continues to improve the thick selective metal deposition process for more manufacturable, higher reliability, and lower resistance interconnections required for every matrix-addressed flat-panel display technology. Sandia already participates in cooperative programs with small U.S. manufacturers to understand and improve the performance of plasma display panels. This breadth of capabilities has led the OIDA to propose that Sandia play a major role in the national initiative to develop a competitive U.S. display industry.

The proposed national program would begin with immediate support for those display technologies now in production by U.S. manufacturers. The program would also immediately begin assessment of technology options for future displays. An industry-led governing board would select several candidates for further development. After a two or three-year research phase, a few alternative display technologies would be selected for prototype production. Those technologies that survived the prototype phase would then go into pilot manufacturing at a shared facility. The final phase of the program, seven to nine years after program inception, would develop a support infrastructure to sustain the domestic display industry, just as SEMATECH and other organizations now help sustain the domestic microelectronics industry.

Since volume production of domestic displays is the goal of the national program, a parallel effort should begin at once to provide support for specialized manufacturing equipment, processes, and inspection techniques for flat-panel display fabrication. As alternative technologies demonstrate viability, their custom equipment, processes, and inspection needs should be addressed by the national effort. Assistance for display manufacturing equipment should continue as the domestic display industry reaches maturity.



Ellen Lemen loads silicon wafers onto a platen in Sandia's Microelectronics Development Laboratory (MDL). The MDL is a state-of-the-art research and development facility for advanced, special-purpose microelectronic components.

Microelectronics and Photonics Application Center

The rapid pace of development in microelectronics and photonics and the large investment required to be competent in these fields have strained the existing mechanisms for meeting government microelectronics needs. Government systems often require unique components that may be unprofitable for private industry to develop. Production requirements for a component may be so small that prototypes built to establish manufacturing methods may fulfill the application demand. Moreover, electronics for government systems must operate in harsh environments, including radiation and high acceleration, and they may require very high reliability and long lifetimes.

The existing microelectronics consortia (SEMATECH, SRC, and MCC) currently do not address government needs for unique and rugged parts. The Microelectronics and Photonics Applications Center (MPAC) will address this need. The center will use a multifaceted approach to developing the rugged microelectronic and photonic technologies critical to the specialized requirements of defense systems. It will also transfer commercially useful research advances to domestic manufacturers.

MPAC activities will include:

1. Design, fabricate, package, test, and certify rugged silicon and compound semiconductor integrated circuits.
2. Fabricate and evaluate emerging photonic and microelectronic components.
3. Research and develop new materials, systems, and devices for enhanced performance.
4. Establish the base technology for design and manufacture of fabrication equipment.

The center's initial projects would include the emulation of standard microprocessors in environmentally rugged technology, microwave processing using optoelectronic techniques, advanced microelectronics and photonics processing equipment, ferroelectric memory development, periodic table groups III–V compound semiconductor complementary logic, far-IR detector arrays, advanced sensor systems for environmental monitoring of DOE's complex, and technology transfer.

Funding should be provided by the federal government, the primary customer for this work. Initial funding should be $50 million per year, with funding for eight microelectronic and photonic projects essential to the needs of the government. It should grow to $100 million per year in five years. After five years, if industry has found that working with the center has strengthened its competitiveness, it is reasonable to expect it to contribute matching funding to allow growth to $200 million per year within the following five years.

Anticipated Funding Requirements for Microelectronics and Photonics Application Center
(Dollars in constant FY 1992 millions; personnel in FTEs)

	FY93	FY94	FY95	FY96	FY97
Operating	45.0	82.5	90.0	125.0	150.0
Capital Equipment	25.0	30.0	35.0	35.0	35.0
Total Cost	70.0	112.5	125.0	160.0	185.0
Direct Personnel	90	165	180	250	300

Initiative for Defense Programs and Energy Research

Massively Parallel Computing Research Laboratory: Research, design, and development through simulation

High-performance computing and computer simulation are becoming increasingly important for DOE missions. For a variety of reasons, DOE's historical dependence on experimentation and large-scale testing for performing nuclear weapons R&D is becoming problematic. In many cases, large-scale tests are becoming economically, environmentally, or politically less feasible. At the same time, DOE is faced with the need to shorten development cycles and reduce costs without sacrificing innovation or quality. One way to achieve these goals involves relying on simulation as the major design tool.

Unfortunately, simulation capabilities are not yet adequate for reliable design. In addition, increased focus on weapons surety introduces extraordinary design requirements. The very detailed, three-dimensional physical simulations that are required to address surety issues cannot be performed using today's supercomputers and vectorized simulation models.

This initiative will expand capabilities in computational simulation and create computing infrastructures needed to realize the full advantage of such capabilities for DOE programs. Over the next five years, the national High-Performance Computing and Communications Program (HPCCP) is targeting increases of three or more orders of magnitude in the size and complexity of problems that can be accurately simulated. It is also targeting the development of ultra-high bandwidth communications and networks for broad access to those capabilities.

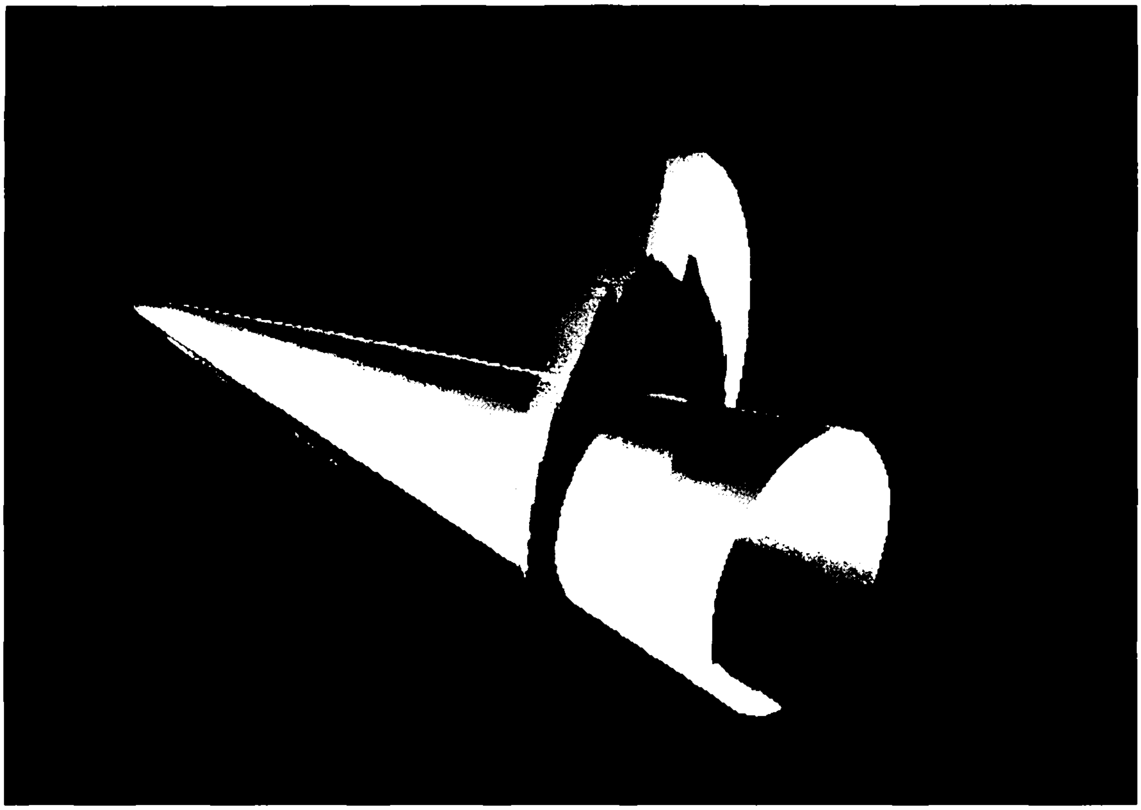
The first key to achieving such increases will be the incorporation of massively parallel (MP) computing. The second and more challenging key is the development of efficient, scalable software and algorithms for new MP architectures, as well as the development of software infrastructures to create a true MP production computing environment.

Sandia pioneered the early use of MP computers and was first to successfully demonstrate the application of MP computing to real scientific and engineering problems. In 1988 we won the Gordon Bell Prize for parallel computation for our work in developing scalable MP software and efficient infrastructures. That same year we also won the Karp Challenge by being the first to achieve speed-ups in excess of a factor of 200 using MP computers on real problems. Our work won R&D-100 awards in 1989 and 1990. Several individual awards have been received by Sandia researchers for advances in MP computation. In 1992 we have received a patent for our scalable MP software structures.

Sandia's research has been so successful that we are now prepared to begin the larger task of bringing MP technology into the mainstream. When Sandia's MP technology is routinely used for large-scale simulation, we will be able to use simulation in a new, dominant role in our DOE programmatic R&D tasks. In particular, we will be able to carry out detailed and accurate three-dimensional, time-dependent simulations of virtually all aspects of new designs. This capability will increase reliability and shorten development cycles by identifying problems before products enter the expensive prototyping phase. It will spur additional innovation by making it easy to evaluate new ideas on the computer rather than having to fabricate prototypes. It will also reduce dependency on testing as a design tool by permitting engineers to carefully plan a few tests to verify the accuracy of a design or a process model, rather than performing an extensive battery of tests for every new design.

Sandia is carrying out advanced research in MP software and algorithms under the DOE/ER HPCCP program. In the HPCCP, we are also developing MP models for use in DOE/CHAMPP Global Climate Change studies. Sandia is the lead laboratory for Computer Design of Materials and Molecules, a DOE HPCCP computational "Grand Challenge." The goal of this grand challenge is to create new computational

A computer simulation of a reentry flow field for a conical vehicle flying at Mach 8. The bow shock is clearly visible, as is a contour slice depicting variations in flow field density. The massively parallel computation used 64 NCUBE-2 processors and achieved a parallel efficiency of 86%. MP processing can attain much higher resolutions of the flow field, permitting engineers to "test" design changes without a wind tunnel.



structures that enable design of new materials using computer simulation as the principal design tool.

These high-performance computing and computational simulation activities are to be centered in the Massively Parallel Computing Research Laboratory (MPCRL) at Sandia Albuquerque. The MPCRL will:

1. Provide prototypes of advanced, high-performance computing technology.

2. Provide advances in scalable MP algorithms, MP graphics and visualization, and MP systems software.

3. Lead the Computer Design of Materials and Molecules project, an interdisciplinary partnership of national laboratories, industry, and universities.

4. Serve as a vehicle for interagency collaboration in defense computing with groups such as the Defense Supercomputing Research Alliance, a consortium of DoD laboratories, industry, and Sandia.

5. Form interdisciplinary partnerships with Sandia's Defense Programs and Energy Research applications groups to create new simulation capabilities.

6. Provide innovative educational structures and partnerships with universities, school systems, and industry.

7. Turn DOE advances in computing technologies into competitive advantage for American industry through technology transfer. The MPCRL will

collaborate with the Computer Science Policy Project (CSPP), a consortium of major computing manufacturers.

8. Provide technical leadership of Sandia's MP[4] (MP Prototype Production Project) partnership, comprising research computing, production computing, Sandia's computing applications community, and Thinking Machines Corporation, to bring MP computing into the DOE mainstream within a two-year time frame and turn advances in simulation and modeling to DOE advantage.

9. Along with the Center for Network Research at Sandia Livermore, provide a major test bed for ultra-high bandwidth communications and networking technology under the HPCCP.

The MPCRL will be funded by DOE Defense Programs in support of its national security missions. It will also be funded by DOE Energy Research Scientific Computing staff to carry out research in support of the HPCCP. These two efforts will leverage each other, and by coordinating research programs they will achieve more than they possibly could separately. Funding participation is also expected by DoD, DARPA, and other agencies for work that augments the overall defense technology base. Finally, funding will also come from partnerships with American industry, both as work-for-others agreements and through the CRADA process. Funding for a core team of MPCRL researchers is being requested. On-going funding will also be required for the continued acquisition of "beyond-the-state-of-the-art" research computing resources.

Anticipated Funding Requirements for Massively Parallel Computing Research Laboratory
(Dollars in constant FY 1992 millions; personnel in FTEs)

	FY93	FY94	FY95	FY96	FY97
Operating	6.0	8.0	10.0	10.0	10.0
Capital Equipment	6.0	10.0	6.0	10.0	6.0
Total Cost	12.0	18.0	16.0	20.0	16.0
Direct Personnel	20	25	50	50	50

Initiatives for Energy Research

Climate change research and remote sensing

In FY 1990, Sandia started an important new program in global change research. The thrust of the program is to join our expertise in instrumentation, systems engineering, and massively parallel processing with complementary expertise at other laboratories to address three key areas: (1) three-dimensional remote sensing of the atmosphere, primarily of clouds, water vapor, and aerosols; (2) data management of large climate data sets; and (3) significant increases in the computational throughput of climate models.

Initial efforts are directed at two new DOE initiatives to improve the general circulation models (GCMs) used to guide policy. One of these initiatives, the Atmospheric Radiation Measurement (ARM) program, seeks to test and refine our understanding of such key processes as radiation transport and the role of clouds. The other program, Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP), has as its goal a major increase in the computational throughput of a wide range of climate models.

We are involved to various degrees in the major elements of the ARM program: the development of advanced lidar instrumentation; the implementation of atmospheric probes to test CART (Cloud And Radiation Test bed) sites; science team experiments; and a major new initiative involving small climate satellites (ARMsat) and unmanned aerospace vehicles (UAVs).

In addition to these activities, we are pursuing a broader range of laser remote sensing applications, including space-based lidars and aircraft-deployed systems for detecting drug processing, chemical weapons use and manufacture, and so forth.

Combustion Dynamics Initiative

The Combustion Dynamics Initiative (CDI) is a joint proposal by Sandia National Laboratories and Lawrence Berkeley Laboratory in support of DOE's national role in combustion research. The goal of the initiative is to enhance the efficiency of combustion processes while minimizing pollutants and other undesirable effects.

The CDI comprises two important facility requirements: completion of the unfinished Combustion Research Facility (CRF) Phase II at Sandia and construction of the Chemical Dynamics Research Laboratory (CDRL) at Lawrence Berkeley.

Work at the CDI will involve advanced combustion modeling. This activity will use data from experimental and theoretical studies to develop reliable, predictive

Anticipated Funding Requirements for Climate Change Research and Remote Sensing
(Dollars in constant FY 1992 millions; personnel in FTEs)

	FY93	FY94	FY95	FY96	FY97
Operating	9.0	14.0	14.0	15.0	15.0
Capital Equipment	1.0	2.0	2.0	1.0	1.0
Total Cost	10.0	16.0	16.0	16.0	16.0
Direct Personnel	25	28	30	30	30

computational models for combustion systems. Such models could be very useful to U.S. industry in designing next-generation combustion systems. Work at the CRF will emphasize development of optical diagnostics for combustion, studies of chemical kinetics and reacting flows, and complementary studies in chemical physics. CDRL research will focus on elucidating the production, structure, and reactivity of critical combustion species, and on the dynamics of chemical reactions. In conjunction with researchers from universities and industrial laboratories, Sandia and Lawrence Berkeley will develop the most advanced instrumentation that can be brought to bear on research pertinent to combustion.

These activities will result in new insights into the elementary reactions involved in hydrocarbon combustion, the structure and dynamics of highly excited molecular species and reactive intermediates, and molecular energy flow processes, all of which are critical for advancing combustion technology. Research results from fundamental studies of chemical reactivity and fluid mechanics will be incorporated into models that can improve the design of engines, burners, boilers, furnaces, and gas turbines. The proposed CDI modeling effort already has several industrial participants, including Allison Gas Turbine Division of General Motors, Cummins Engine, the Gas Research Institute, and the John Zink Company.

The CDI will offer unparalleled resources for users to study fundamental and applied combustion processes. Researchers at Sandia's CRF will be able to utilize advanced laser systems to study ultrafast processes in chemistry and combustion and perform two and three-dimensional imaging of the physical and chemical properties of turbulent reacting flows. At Lawrence Berkeley's CDRL, an advanced infrared free electron laser and the Advanced Light Source will provide photons over the entire spectral range of interest.

Management responsibility for the CDI will reside with a director at each site. A steering committee of external advisors will be appointed to provide advice on broad scientific and policy issues, and a program review panel of scientific peers will ensure that the facilities are used for the most innovative and productive lines of research.

Anticipated Sandia Funding Requirements for Combustion Dynamics Initiative
(Dollars in constant FY 1992 millions; personnel in FTEs)

	FY93	FY94	FY95	FY96	FY97
Operating	5.0	5.0	5.0	5.0	5.0
Construction	11.0	7.5			
Total Cost	16.0	12.5	5.0	5.0	5.0
Direct Personnel	25	25	25	25	25

Initiative for the DOE Office of Arms Control

Nonproliferation technologies

Preventing the proliferation of weapons of mass destruction, especially nuclear weapons, has been an important policy and technology problem for decades. Recent international developments make the concern especially acute. Unfortunately, the principles of nuclear weapon design are no longer arcane, and the technology for nuclear weapon development and production is increasingly accessible to determined governments.

Sandia has one of the oldest and largest programs in support of arms control and nonproliferation. Since the 1950s we have developed instrumentation to verify compliance with the Limited Test Ban Treaty. We continue to improve the sensitivity of satellite-borne sensors that can detect and locate nuclear bursts in the atmosphere, and to assist Los Alamos National Laboratory in providing an enhanced capability for detecting and locating bursts in space. Our seismic detection systems represent the leading technology for monitoring underground nuclear testing on a regional or worldwide basis. We support the DOE Office of Intelligence by conducting technology assessments of foreign weapon development capabilities, and we consult with the departments of State and Commerce on the development of export controls to inhibit transfer of nuclear weapon technologies and industrial capabilities. We have designed and transferred to industry a variety of systems that are used by the International Atomic Energy Agency (IAEA) in support of its containment and surveillance responsibilities for nonproliferation safeguards.

Sandia's initiative in nonproliferation technologies targets improvements in our national capability to detect and characterize clandestine nuclear activities, including materials production, weapon engineering development (weaponization), and weapon proof testing. In addition, it proposes improvements in our capability to monitor declared nuclear activities.

The need for better technologies for detecting nuclear materials production was underscored by the startling discovery in 1991 of the extent to which Iraq had pursued the production of weapon-grade uranium. Sandia has developed promising new concepts for advanced sensors that may significantly improve our detection capability in this difficult area. Ground-based or airborne air-sampling systems, and airborne or space-based imaging radiometry and differential absorption LIDAR may be effective. Advanced seismic, electromagnetic pulse, and radiometric sensors would be useful for detecting low-yield weapon proof tests.

Technologies for monitoring declared nuclear activities can provide significant information on undeclared activities as well. Moreover, confidence in transparency technologies (surveillance measures approved by the host country) is essential to providing incentive and assurance to nations that pledge not to build nuclear weapons.

The recently signed Open Skies Treaty offers an opportunity to strengthen the international nonproliferation regime and augment its cogency as a force for arms control. The treaty opens up most of the western hemisphere to overflights by aircraft equipped with surveillance instrumentation. A variety of airborne sensor systems can be developed to obtain data that can be analyzed for evidence of weapon development activity.

Sandia's nonproliferation initiative will also address the formidable problem of how to manage and synthesize the deluge of sensor data and other information to generate useful knowledge about a country's weapon activities. Patterns formed by seemingly unrelated activities may sometimes combine synergistically to reveal the spoor of a covert weapon development program. Sandia is developing systems to manage the fusion of data from multiple sensors and sources or consisting of multiple formats. Knowledge synthesis systems based on neural networks and rule-based proliferation profiles have the potential to increase analysts' productivity.

The Sandia initiative is a broad-based program designed to bolster the U.S. nonproliferation regime through advanced technology development. It addresses known deficiencies in capability and proposes specific technology enhancements that can provide new classes of proliferation data. The availability and reliability of such information will become increasingly important in the new multipolar world.

Anticipated Funding Requirements for Nonproliferation Technologies
(Dollars in constant FY 1992 millions; personnel in FTEs)

	FY93	FY94	FY95	FY96	FY97
Operating	75.0	115.0	140.0	140.0	140.0
Direct Personnel	200	330	400	400	400

Initiatives for DOE in partnership with other federal agencies

National Center for RSTAKA

Conventional deterrence, to be credible, must demonstrate the ability of U.S. forces to dominate a battlefield quickly and achieve military objectives with very few casualties. The 1991 war with Iraq displayed many strengths along these lines. However, it also revealed some weaknesses.

The acronym RSTAKA stands for Reconnaissance, Surveillance, Target Acquisition, and Kill Assessment. It is an integrated concept that implies control of the regional battlefield as a system. The system requires responsive sensor inputs, rapid data reduction, and very fast command and control of strike weapons. While the idea is impressive as a military science concept, only a demonstrated capability will have value as a deterrent. Demonstrating a supreme RSTAKA competence will require innovative R&D teamwork and continuous improvement of hardware, software, and interfaces.

Contemporary battle management systems are severely challenged in several ways. Reconnaissance systems provide limited coverage and are not directly taskable by warfighting commanders. Command and control systems are too slow to acquire, assimilate, and reduce data, present action options to commanders, and direct responses to targets. Strike systems lack the speed and accuracy to destroy mobile and fixed assets with low collateral damage with impunity from stand-off positions.

Improving RSTAKA capabilities will require advances in ground, air, and space-based sensors to characterize an enemy's order of battle deep behind his lines. Command and control systems must be made extremely responsive with rapid data fusion and real-time decision capability. Fast, high-precision, retargetable, stand-off strike weapons must be developed with kinetic-kill or focused conventional lethality. Moreover, such advances must be closely integrated and furnished with a facile user interface for theater commanders.

A coordinated RSTAKA program should be managed by a DoD office tasked to identify critical needs and the R&D initiatives required to meet them. The management should seek the best technical solutions for RSTAKA problems from industry, universities, and the federal laboratories. Teamwork arrangements that permit certain advanced technologies spawned in the federal laboratories to be fully developed and exploited will require cooperation among sectors. Such partnerships should be encouraged and managed for the optimum benefit to the program. Industry partnerships can be very useful for engineering producibility into rapidly prototyped demonstration projects.

Sandia has developed competency in advanced technologies that would be important to a RSTAKA program. Unique capabilities that have emerged from our ongoing technology base activities include

- Unattended ground-based sensors systems to detect and classify vehicle movements;
- Day and night imagery that is two to three orders of magnitude more sensitive than conventional night vision systems;
- Synthetic aperture radar systems for high-resolution, all-weather, day or night target identification;
- Fast sensor data fusion software to shorten the time from detection to weapon tasking and outpace an adversary's response time;
- Technology for high-accuracy, hypervelocity, kinetic energy penetrator (KEP) weapons that can reach targets extremely fast, thus reducing the need for risky aircraft strikes; and
- Combined KEP and advanced command and control systems for an integrated quick, precision attack system (QPAS).

Sandia's Tonopah Test Range is equipped with advanced telemetry capabilities for the instrumentation of weapon delivery tests. The high-technology infrastructure, location, and experience base at TTR make it ideal for a RSTAKA demonstration user facility.

R&D on these technologies can easily be advanced to demonstration projects in collaboration with industry partners and government users. Furthermore, demonstration at a higher, consolidated level will be required to test integrated RSTAKA systems for combat viability. Sandia has an extensive and sophisticated testing infrastructure that can make a unique contribution to the RSTAKA effort. In particular, the Tonopah Test Range in Nevada is superbly suited to large-scale, integrated RSTAKA demonstration with instrumentation and telemetry to support a variety of flight testing with high fidelity to combat conditions. Designating the Tonopah Test Range a user facility for RSTAKA demonstration would be a cost-effective and technically astute application of this outstanding defense R&D asset.

The gross funding estimate for Sandia participation in a national RSTAKA initiative shown below is based on the expectation of intensive utilization of Sandia R&D and test capabilities. Costs will vary depending on the mix of activities conducted. We expect that the installed capital base of test facilities will be a cost advantage to U.S. government and participating industry users.

Anticipated Funding Requirements for National Center for RSTAKA
(Dollars in constant FY 1992 millions; personnel in FTEs)

	FY93	FY94	FY95	FY96	FY97
Operating	30.0	50.0	70.0	90.0	90.0
Capital Equipment	10.0	20.0	20.0	10.0	10.0
Total Cost	40.0	70.0	90.0	100.0	100.0
Direct Personnel	75	125	175	200	200

Space exploration technology

In 1989 the President announced the Space Exploration Initiative (SEI) with new goals for America: return to the moon to stay, and land an American astronaut on Mars by 2019. The President commissioned a blue ribbon panel, the Stafford Synthesis Group, to define architectures and technology requirements to achieve these goals. Subsequent national policy directives specified a role for DOE as a partner with NASA and DoD in the SEI.

The DOE Office of Space (OS) has identified eight technology thrusts where the DOE national laboratories can contribute to the SEI and other NASA and national security space efforts. These areas overlap the fourteen supporting technologies identified by the Stafford Group for SEI.

Sandia's nuclear weapons technology base is a rich foundation for contributions to space activities and is currently supporting space technology programs for NASA, DoD, and DOE. Sandia can make contributions in all of the space technology areas identified by OS and nearly all of the fourteen technologies specified in the Stafford report. Several of these are described below:

Space nuclear thermal propulsion (SNTP)—Nuclear thermal propulsion was recommended by the Stafford Committee as an enabling technology for human exploration of Mars. It is also viewed by the Air Force as an important technology for its missions. Sandia is a member of the Air Force Phillips Laboratory team investigating the feasibility of a particle bed reactor for space propulsion. We have a key role in modeling and testing the behavior of the reactor fuel particles and elements, as well as developing new ground test facilities for nuclear propulsion activities. Assurance of nuclear safety is also a major Sandia responsibility.

Space nuclear electric power and propulsion—Sandia has performed systems level evaluations of space nuclear power concepts for DOE, DoD, and NASA. We have developed computer codes to predict steady state and transient behavior of space nuclear power systems. These codes model all subsystems of a concept, including reactor, shield, radiator, power conversion and conditioning, instrumentation and control, and safety. Codes have also been developed to compare overall system masses and radiator areas, two important parameters affecting cost and survivability.

Artist's rendering of what a space nuclear thermal propulsion rocket might look like orbiting Mars. The nuclear fission reactor rests forward of the craft's nozzle, where very hot, expanding hydrogen gas provides thrust. (Artwork courtesy of NASA)

Sandia is a member of the Phillips Laboratory team studying the Russian space nuclear reactor TOPAZ. The objective is to understand the TOPAZ technology and combine it with U.S. technology to produce a more efficient thermionic system.

In a related program, SDIO is planning to purchase several TOPAZ reactors for test and analysis. It will attempt to modify one of the reactors to meet stringent U.S. space nuclear safety requirements. A subsequent space launch will serve as a flight test for performing experiments on U.S. electric thrusters and evaluating the thermionic system for delivering electric power for satellites. Sandia has been selected by SDIO for the lead lab role for most nuclear parts of the program, including flight safety.

Space nuclear safety—Sandia has a distinguished history of contributions to space nuclear safety dating from the inception of the U.S. space program. Our capabilities for analyzing and testing nuclear systems safety are unique. Our accident modeling capabilities cover launch aborts, explosions, impacts, fires, radioactive debris transport and dispersion, and atmospheric entry. We have extensive nuclear and nonnuclear test facilities for performing a wide variety of accident simulations.

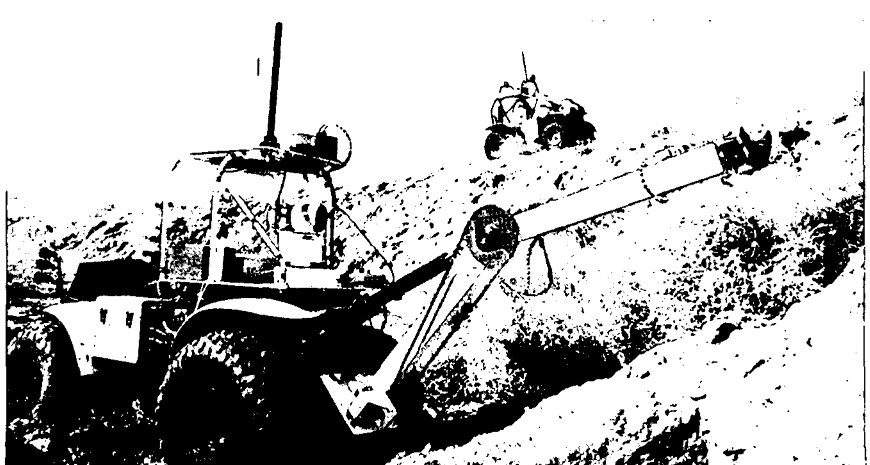
We used our systems analysis capabilities to calculate the atmospheric breakup and dispersal of two Soviet nuclear powered COSMOS satellites that reentered the atmosphere in 1978 and 1983. More recently Sandia has performed entry analyses of space nuclear propulsion systems. We have also made important technical contributions to establishing space nuclear safety policy. Ensuring the safety of U.S. space nuclear power and propulsion systems is a major challenge that Sandia is well qualified to perform.

Telerobotics—We have developed a fleet of robotic vehicles at our Robotic Vehicle Range (RVR) that demonstrate concepts applicable to SEI requirements. The robotic fleet ranges from simple teleoperated vehicles to autonomous navigation vehicles. Capabilities include multispectral sensor suites, elevated mast platforms, remote onboard manipulators, realtime multitasking software, and multiprocessor architectures, as well as multivehicle control from both fixed and portable control stations.

We are exploring collaboration with Oak Ridge National Laboratory to define a robotic precursor mission for a return to the lunar surface by the end of this decade. The mission would involve the NASA Johnson Spaceflight Center for flight and launch expertise as well as an aerospace industry team member for assembly and qualification of flight hardware. We are also developing software for autonomous robotic operations and investigating options for robotic construction of large structures in space.

Sensors—The sensor requirements for SEI include a variety of chemical and radiation sensors and equipment and life support monitors. As in the nuclear weapons program, small, light, highly reliable devices are design imperatives. Sandia is developing a variety of radiation-hardened and EMP-resistant microsensors. We have developed visible light and near-IR detectors suitable for space use and transferred them to industry. Infrared detectors based on Sandia's strained layer superlattice technology will be developed for manufacturable, long wavelength, IR focal plane arrays for space sensor needs.

We have developed a variety of microlasers that can be readily integrated with electrical components to provide optoelectronic integrated circuits suitable for



Sandia has developed a strong capability in designing tele-robotic rovers for hazardous environments in its work for DOE. This capability may be applicable to SEI requirements.

applications such as spacecraft and engine performance monitors. Our silicon microelectronic sensors have applications in propulsion systems, EVA suits, cryogenic transfer monitoring, automated rendezvous and docking, radiation effects and shielding, telerobotics, and closed-loop life-support systems. Sandia's strengths in microelectronics, microsensors, telemetry, software, and materials can contribute substantially to the design of remote health monitoring systems for spaceflight crews. Such systems might also be applicable to health care uses on earth.

Radiation effects—As a consequence of our long experience in nuclear effects testing, many of the issues concerned with the impact of radiation on crews and equipment from nuclear engines, nuclear electric power plants, and natural space radiation, are well understood at Sandia. Our sensors, shielding, and radiation transport modeling capabilities will be valuable assets for designers of nuclear powered spacecraft.

Materials, manufacturing, and structures—Sandia has a long history of materials and manufacturing technology development to support nuclear weapons programs. Consequently, we excel in the engineering of lightweight materials and miniature components, an expertise that is directly applicable to the SEI. A Sandia program in structural dynamics already supports Space Station Freedom. Current materials R&D includes spacecraft debris shield design and testing, as well as the use of electromechanical gels for robotic manipulators. In the future, designs for spacecraft, habitats, rovers, and EVA suits will benefit from these programs.

Nonnuclear space power systems—All space missions will require electric power. Sandia has a long history of accomplishments in power system technologies including both space and terrestrial power. Our solar programs include photovoltaic, solar thermal, and solar dynamic technologies. Photovoltaic work has emphasized development of concentrator cells and arrays, and we have achieved efficiencies in excess of 30 percent. High-temperature solar thermal systems have been developed that can be applied to space power requirements for either electrical or thermal energy.

Nuclear weapons employ long-life, high-reliability thermal batteries for short, high-energy power demands. Sandia has specialized in this technology for many years. Sandia is a participant in the newly created battery consortium made up of industry and government partners. This effort seeks to improve batteries for application in electric vehicles, a technology that could readily be applied to planetary rovers or space habitat emergency power systems.

Anticipated Funding Requirements for Civilian Space Technology (Does not include SNTP or Flight Topaz)
(Dollars in constant FY 1992 millions; personnel in FTEs)

	FY93	FY94	FY95	FY96	FY97
Operating	10.0	50.0	100.0	130.0	150.0
Capital Equipment	2.5	15.0	20.0	10.0	10.0
Total Cost	12.5	65.0	120.0	140.0	160.0
Direct Personnel	50	100	200	250	300

Transportation technology

The transportation infrastructure of the United States is aging and has not been fundamentally modernized in three decades. The last major upgrade was the construction of the interstate highway system, and there is little doubt that the interstates have had a desirable impact on economic growth. Nevertheless, the nation now faces a new set of transportation challenges that will persist into the twenty-first century.

Our national energy security is tightly linked to the availability of petroleum fuels. Unfortunately, the supply of foreign oil is subject to the political whims of producer countries. Weaning our transportation system from petroleum fuels would reduce the nation's vulnerability to oil supply and price shocks.

Major reductions in vehicle emissions have been achieved in the last twenty years through federally mandated improvements in vehicle fuel efficiency. However, the Department of Transportation (DOT) forecasts that total emissions will begin to increase again after 1996, even though more stringent fuel efficiency standards will be in place. The reason for the reversal is that total vehicle miles traveled is increasing faster than improvements in fuel efficiency. Federal air quality standards cannot be achieved or maintained in the long term unless significant changes occur in urban transportation systems.

In 1988 the average speed on California freeways was 35 miles per hour. By 1998 the average speed is forecast to be 15 miles per hour. Americans now lose over two billion work hours per year due to traffic congestion. Transportation systems play a vital role in economic and national security and in the general well-being of the public. Technological innovation is needed to modernize the systems in order to ensure a secure, prosperous future.

Data indicate that the economic competitiveness of a nation is significantly affected by the availability and cost of transportation. If transportation systems impose a relatively higher burden on U.S. producers, then they will face an institutionalized impediment to their competitiveness. Other countries realize this fact and are moving aggressively to modernize transportation infrastructures. High-speed rail systems are now in service in Japan and Europe. Prototype intelligent vehicles and highway systems are now in operation in Japan. Research on high-speed, magnetically levitated trains has continued in both Europe and Japan, while U.S. efforts have languished.

DOT is embarking on a new program to improve the safety and efficiency of the U.S. surface transportation system by applying the latest technology in sensors, data fusion, and information and control technology. This effort, the Intelligent Vehicle and Highway System (IVHS) program, envisions "smart" highways and vehicles that will improve safety and reduce congestion, energy consumption and pollution. The technology involves vehicle tracking systems, collision avoidance sensors, traffic control centers, automatic vehicle control systems, and roadside sensors. The enabling legislation for this effort is the Intermodal Surface Transportation Efficiency Act of 1991. In this act, DOT is directed to work with DOE to access and utilize competencies available at the DOE national laboratories.

This initiative proposes to direct Sandia's core competencies toward practical solutions to transportation problems. R&D will be conducted in conjunction with the private sector and universities to ensure rapid development and commercialization. Sandia can help in several areas of the national transportation initiative:

1. **High-Speed Computation and Systems Analysis.** Decisions on future transportation systems will need to balance the interrelated issues of energy security, environmental quality, cost, and efficacy. It is essential that computer simulations and systems analyses be performed before making major commitments to technology development and commercialization. Sandia's expertise in modeling and analysis will be drawn upon to perform analyses at all levels of system design from component and system performance to national impact studies.

2. **Management and Control of Advanced Transportation Systems.** The ultimate utility and safety of high-speed or magnetically levitated trains depends on the distance between vehicles. Precise position monitoring and real-time control of vehicles is necessary to provide fail-safe operation for passengers and cargo. Sandia's strengths in failure and risk analysis, remote monitoring of trucks, and real-time control systems will be employed to determine the control and monitoring requirements for such vehicles and develop appropriate control and traffic management mechanisms.

3. **Alternative Fuels and Vehicles.** Sandia has considerable expertise in combustion chemistry, catalysis, and batteries that can be applied to improved vehicle design. Our existing program in conjunction with a DOE-led consortium of auto makers to develop batteries for electric vehicles will be a springboard and model for this program.

4. **National High-Speed Rail Test Bed.** Sandia is exploring with the State of New Mexico and DOT the possibility of acquiring existing rights-of-way for a National High-Speed Rail Test Bed. Due to the availability of the rights-of-way and other favorable costs, the system can be built in New Mexico at approximately half the cost of other sites. Furthermore, it would be close to world class research facilities.

5. **Intelligent Vehicle and Highway System.** Much of the technology for IVHS is a logical extension of work already underway at DOE laboratories. The Safe Secure Transport (SST) program has developed reliable, secure systems for transporting nuclear weapons and materials. DOE has developed a complete highway data base to control the SST fleet and provide emergency response capability. DOT has expressed interest in this system (STARBASE) for their responsibilities in tracking hazardous waste shipments.

   Sandia has developed many types of robust, unattended ground sensors. This technology may be important to the IVHS program in developing roadside sensors for monitoring traffic flow, "weighing" passing trucks, and automatically assessing tolls. We have also developed many versions of teleoperated and autonomous vehicles. Consequently, we are leaders in advanced sensors, intelligent control systems, and communications as applied to vehicular control systems. DOT has expressed interest in using the DP laboratories to help develop technology specifically for use by the IVHS R&D community.

Anticipated Funding Requirements for Transportation Technology
(Dollars in constant FY 1992 millions; personnel in FTEs)

	FY93	FY94	FY95	FY96	FY97
Operating	45.0	50.0	60.0	60.0	60.0
Direct Personnel	90	120	150	150	150

Scientific and technical programs

DOE programs

Assistant Secretary for Defense Programs

The Assistant Secretary for Defense Programs (ASDP) is the cognizant secretarial officer for Sandia National Laboratories. The Weapon Activities program for the Deputy Assistant Secretary for Military Application employs 53 percent of Sandia's direct personnel and includes Research and Development, Testing, Inertial Confinement Fusion, and Production and Surveillance.

Effective with FY 1992, the Verification and Control Technology program and the Nuclear Materials Safeguards and Security program no longer reported to ASDP. The Defense Waste Management program was transferred to the Office of Environmental Restoration and Waste Management in FY 1991.

We expect our manpower level of effort in Weapon Activities to contract by about 13 percent between FY 1992 and 1994. The decrease reflects a marked reduction in new weapon development. The future level of effort required for Defense Programs is subject to determinations that are as yet still under consideration at policymaking levels and in Congress. In view of this ongoing discussion and planning, we project a flat manpower level of effort for Defense Programs from FY 1994 to the end of the planning period.

Dollars used in the funding summary tables for ASDP and other assistant secretarial offices in this chapter are not adjusted to compensate for inflation.

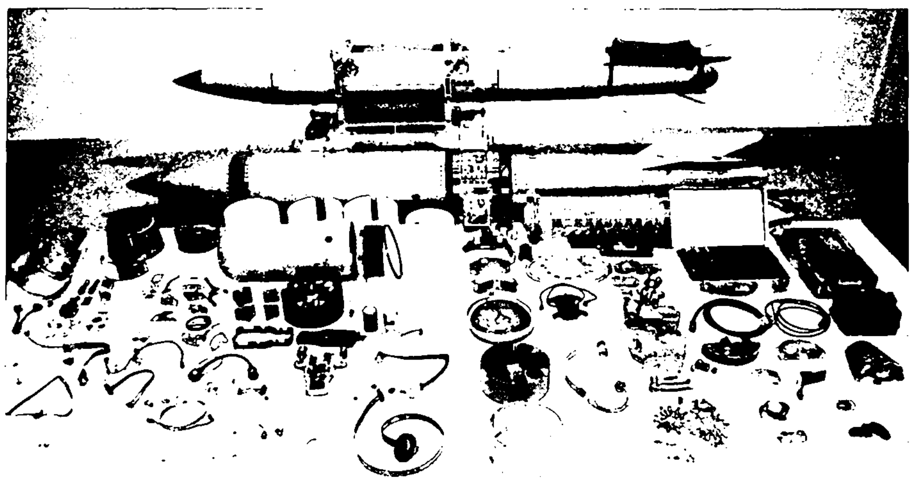
Summary of Programs for
Assistant Secretary for Defense Programs
(Operating BA in $ million)

B&R Code	Program Title	FY90	FY91	FY92	FY93
GB	Weapon Activities	582.8	583.0	660.2	625.9
GC	Verification and Control Technology	37.8	43.7		
GD	Nuclear Materials Safeguards & Security	9.9	10.9		
GF	Defense Waste Management	4.2			
	Total	634.7	637.6	660.2	625.9
	Percent	57%	56%	49%	45%

Weapon activities (GB)

Research and development

Nuclear weapon development—Nuclear weapons research and development is the largest single program at Sandia. It employs one-third of the population of direct personnel. Under this program, the Laboratories assesses advanced nuclear weapons technology, generates systems concepts, performs feasibility studies, and engineers the weaponization of nuclear explosive systems to meet Department of Defense requirements. In addition, we formulate weapon concepts that will meet new DoD mission requirements, and we pursue development of advanced components



The B61 nuclear bomb has proved to be a long-lived and adaptable design. Sandia has upgraded its nonnuclear components over the years with new, proven technologies, resulting in continuous improvements in safety, performance, and control.

that may be useful for enhancing the safety, reliability, and control of future nuclear weapon systems.

The varied and unique demands of nuclear weapon development require a strong research base, both to support the stockpile and to assure that there is little, if any, possibility of failing to anticipate significant technological advances that could challenge our national security. This critically important research base requires a threshold level of activity to challenge our staff and ensure continuity of capability.

Nuclear weapon development is carried out in close cooperation with Los Alamos and Lawrence Livermore national laboratories, which design the nuclear explosive subsystems. Sandia weaponizes the nuclear explosive; that is, we design the remainder of the warhead or bomb, integrating the nuclear explosive component with many Sandia-designed components to achieve the desired military capabilities. Sandia interfaces closely with DoD in the critical area of weapon surety: safety, command and control, and security. Component manufacture and weapon assembly are performed by other DOE contractors using designs furnished by Sandia, Los Alamos, and Lawrence Livermore.

Sandia's responsibilities principally include the safing, arming, fuzing, and firing systems; use control systems; gas transfer systems; delivery system interfaces; military liaison; stockpile surveillance; and related testing and instrumentation. Significant improvements in weapon safety, use control, size and weight, stockpile longevity, and capability have been made in all these systems during the more than forty years of Sandia's involvement.

Nuclear safety is of paramount importance in warhead development. The goal of safety design is to provide predictable, safe response at all times, even during exposure to unpredictable events such as accidents. This goal is achieved through a combination of design features. The nuclear explosive, detonators, and other critical components of a warhead's electrical system are contained in an exclusion region isolated from power sources by protective physical barriers. The transfer of energy through the barriers for normal operation is controlled by "strong link" components to ensure electrical isolation in abnormal environments. Other vital components are designed as "weak links" that become irreversibly inoperable in accident environments at levels well below the projected failure levels for strong links.

In the future, significant improvements in nuclear safety will be realized if electrical firing sets can be replaced with optical subsystems in which the high-power signals required to initiate detonators are transmitted by photonic energy carried by optical fibers. In this way, conductive penetrations through the safety exclusion region of the weapon are eliminated, reducing still further the unlikely potential that extraneous electrical energy might initiate a weapon during an accident. As part of Sandia's Direct Optical Initiation project, a prototype optical firing system has recently been developed and is being used to determine operability in various weapon environments.

In a related area, we have recently completed exploratory development of Laser Diode Ignition technology, which uses low-power optical signals for controlling and initiating various weapon pyrotechnic functions. Through the use of optical fibers to transmit the ignition stimulus from the laser diode to the energetic material, concerns over electrostatic discharge, electromagnetic susceptibility, and conductance after fire are eliminated.

Control over the use of nuclear weapons is of similar importance. Incorporating use control devices in weapons or weapon systems and implementing physical security measures contribute to meeting this surety requirement. It is also important to design use control devices and their ancillary equipment to support the command and control system that permits weapons to be used when (and only when) authorized by the President. Sandia is the principal laboratory supporting DOE in fulfilling its nuclear command and control system responsibilities.

Sandia pioneered the development of Permissive Action Links (PALs), which greatly enhance use control. A PAL is a coded device within a weapon that inhibits unauthorized use by terrorists or persons with access authority but without command authority. PALs were introduced in the early 1960s when U.S. nuclear weapons were deployed overseas in significant numbers. Sandia has continued to enhance use control designs for greater operational capability and flexibility.

A new PAL coded switch, the Code-Activated Processor, now in production, includes cryptographic features that substantially improve the security of PAL code information. In addition, Sandia is developing the ground-based ancillary equipment required to support worldwide peacetime and wartime PAL operations. These programs have led to involvement in code management systems to facilitate weapon systems utilization in support of U.S. response policy and to the development of systems that minimize support manpower required by the user services.

A number of programs are in place to support the command and control requirements of DoD and DOE as defined in a National Security Decision Directive signed by the President in 1987. The Air Force has a requirement for the capability to recode PALs on all weapons loaded on the rotary launcher of a strategic aircraft through a single connection, as opposed to dismounting each weapon for individual recoding. To meet this new requirement, Sandia is developing a Secure Recode System (SRS) that will provide for encrypted recode of the weapons' PAL devices. The SRS consists of a new recoder and associated headquarters equipment. This new system will be delivered to the Air Force in FY 1993.

An encrypted secure recode system is being developed to support tactical weapons recode operations. The design of this system, the Tactical Secure Recode System, will provide the military increased PAL code management flexibility and efficiency for the tactical nuclear weapons stockpile and associated deployments of the future. Verifiable control procedures have been developed and are being implemented worldwide in conjunction with NSA and DNA to improve the security of equipment supporting PAL operations.

Research and development on gas boosting systems for weapons and weapon concepts is being pursued. This activity centers around performance evaluation and component lifetime prediction in stockpiled and proposed weapons. Fundamental research and applied technology are being used to assure stockpile safety, design flexibility, long lifetimes, and component reliability.

Nuclear weapon systems are developed in response to changing military requirements. When a new weapon system is needed, DOE works with DoD to outline its military characteristics and environments, specify the number of units required, and identify an appropriate delivery system. The DOE laboratories and production plants are responsible for the design, development, testing and certification, production, maintenance, stockpile surveillance, and retirement of the warhead. These activities occur in seven phases:

- **Phase 1** evaluates new concepts and advances in technology for possible application to nuclear weapons.

- **Phase 2** involves a competitive technical feasibility study examining the military requirements and cost-effectiveness of a new weapon system. Phase 2A is a detailed design and cost study for a selected system.

- **Phase 3** commences when DoD decides to proceed with a weapon system acquisition. It involves the engineering development work for a warhead, including overall design definition and component development.

- **Phase 4** is production engineering. Design and manufacturing development are completed, and manufacturing processes are established.

- **Phase 5** begins with first production. These first units are rigorously checked in the laboratory and in the field. Ancillary equipment and manuals are completed during this phase.

- **Phase 6** is quantity production of the weapon and maintenance of the weapon in the stockpile. Upgrades or modifications may be performed during Phase 6 if required. Stockpile evaluation sampling and surveillance continue throughout stockpile life.

- **Phase 7** retires the weapon from stockpile and reclaims nuclear material and reusable parts.

Sandia is involved in all phases of the life cycle of nuclear weapons. Applied R&D is the principal activity in Phases 1 through 4 and continues to support the production and surveillance activities of Phases 5 through 7.

Phase 1 studies are currently in progress for three warheads: a High-Power Radio Frequency (HPRF) warhead, a Minuteman III replacement warhead, and a Precision, Low-Yield Warhead (PLYWD). The PLYWD study is just beginning. The HPRF study is nearly complete and continuation in a Phase II program is being considered.

In addition, Sandia is participating in several informal, joint DoD/DOE nuclear weapon studies for weapon options that will be examined in the FY 1992–97 time frame. Such studies include hypersonic delivery, ICBM precision delivery, nonstrategic nuclear forces, advanced technology warheads, and insertable components. Several pre-Phase 1 internal studies are also in progress.

Feasibility of a proposed nuclear weapon system is studied in Phase 2. A feasibility study must be formally requested by DoD and begins when accepted by DOE. Each study is a joint effort involving the military services, the DOE Albuquerque Field Office, and the three nuclear weapon laboratories. During the study period, two competing design teams—one Lawrence Livermore/Sandia and one Los Alamos/Sandia—consider a range of design options, including adaptation of an existing warhead. The teams must evaluate not only the tradeoffs among the physical, cost, and military characteristics of the proposed weapon, but also the manufacturing and assembly requirements that would be imposed.

A Phase 2 study has recently been completed for a Strategic Earth-Penetrating Weapon (SEPW) deployable on Air Force and Navy carriers. A Phase 2A-equivalent study (cost-effectiveness) has also been completed for possible application of the *W80* warhead (used on cruise missiles) to the Short-Range Attack Missile, SRAM-A.

Development engineering for new weapons or for improvements to weapons in stockpile occurs in Phase 3. Currently there are no Phase 3 projects in progress. During the FY 1992–97 time frame we are planning for Phase 3 starts for systems with greatly enhanced surety features. We are preserving our essential development engineering competencies through internal programs in technology maturation and systems engineering.

For example, over two years ago Sandia began to establish the Focal Point/STEP process for the maturation of components and subsystems for stockpile upgrades and for modular use in future weapon systems. The program was structured to respond to two predictions: (1) there will be fewer development programs for new weapon systems, and (2) future development budgets will be limited. In the face of these constraints, we needed a technology development process that could generate a variety of high-quality, state-of-the-art components that could be applied to specific weapon system programs with a minimum of development risk and cost.

The first level of this program, Focal Point, is advanced development in a system context. Focal Point evaluates new system architectures and components to meet long-term or emerging needs. It draws upon technologies with demonstrated feasibility and seeks to determine their suitability for weapon applications.

The second level, STEP (Stockpile Transition Enabling Program), selects from Focal Point outputs and advances them through full-scale engineering to production readiness. STEP demonstrates functionality and producibility with detailed designs and component testing. The development environment is not associated with a specific weapon system. Rather, it seeks to develop standardized, modular, advanced subsystems and components for multiple system applications.

The Focal Point/STEP program precisely defines the stages of component or subsystem development and imposes formal milestone reviews to ensure that all components in development offer significant improvements in surety, reliability, waste minimization, and cost. The reviews involve not only Sandia's own designers and technical management, but also representatives from production agencies and DOE. Advanced components and subsystems resulting from the Focal Point/STEP program are then available for system application if needed.

MAST (Multiple Application Surety Technologies), a current warhead prototype system, uses improved surety components and subsystems in a product realization process conducted with Phase 3 rigor. Product realization teams composed of laboratory design engineers and production plant manufacturing and process engineers exercise modern industrial techniques such as concurrent engineering, computer-aided design and process tools, and environmentally conscious manufacturing to emulate production within targeted cost, schedule, and waste minimization parameters. This activity assures that the laboratory/production agency interface remains intact and fully capable of supporting a quality weapon-system production program.

Sandia's work does not stop with completion of an engineering design (Phase 3) but continues throughout Phases 4, 5, 6, and 7. Phase 4 is initiated by the Production and Planning Directive, the official DOE order to produce warheads. This directive authorizes the DOE production plants to expend resources for tooling, capital equipment, and other production preparations. Similarly, it authorizes Sandia to prepare for warhead production, including the establishment of requirements for special tooling and production equipment and preparation of manuals and subsystem test plans. One program is now in Phase 4:

- *W89 Short-Range Attack Missile (SRAM) Warhead*—This warhead, originally designed for the cancelled SRAM II, is being considered for possible retrofit into the existing Air Force air-to-ground short-range attack missile (SRAM-A).

The First Production Unit (FPU) is a major program milestone that occurs during the relatively brief Phase 5. During this phase, the weapon and its production processes are evaluated and final problems resolved before quantity production commences with Phase 6.

The workload associated with weapon retirements is expected to increase. In the past, the volume of weapon retirements was low enough that the work was performed largely by hand. New, automated processes will have to be developed to safely and cost-effectively handle the increased traffic expected in the near future. Several weapons are in Phase 7 at the present time:

- *W33, W48, and W79* Artillery-Fired Atomic Projectiles (AFAPs)
- *B53* Strategic Bomb
- *B57* Tactical Strike/Depth Bomb
- *B61-0,4* Tactical Bombs
- *W56 Minuteman II and W62 Minuteman III* Intercontinental Ballistic Missile Warheads
- *W68 Poseidon Mark 3* Submarine Launched Ballistic Missile Warhead
- *W70 Lance* Short-Range Tactical Surface-to-Surface Missile Warhead
- *W71 Spartan* Anti-Ballistic Missile Warhead

Specific weapon dismantlement procedures are being defined in conjunction with DOE and DoD. Given the likelihood that the dismantlement process will be accelerated, we are placing special emphasis on certain activities, including surety concerns during disassembly, transportation, and staging. We will expand the computerized Pantex capacity utilization model to include methods for optimizing the utilization of staging assets. The feasibility of developing similar predictive models for the DOE transportation workload will be investigated, and software for integrating the various DOE/DoD stockpile data bases will be developed.

Sandia's robotics technologies are being used to develop systems to assist in weapon dismantlement, addressing disassembly, inspection, cleaning, and packaging functions, including the separation and removal of high explosives. There will be further utilization of Sandia's system engineering, surety, and systems integration capabilities in identifying near-term staging and long-term storage options.

Waste minimization plans for all weapons programs will be expanded to include the dismantlement process. Technologies for the treatment and disposal of classified wastes will also be developed with an emphasis on ensuring conformance with anticipated regulatory policy. Finally, the condition of all materials and components removed from the stockpile will be examined, assessed, and evaluated to expand the data base of weapon materials and components.

Sandia National Laboratories, by the nature of its nuclear weapons work, conducts numerous activities that may affect environment, safety, and health compliance at off-site locations such as military facilities and weapon production agencies as well as its own sites. Activities have expanded at all Sandia locations to assure that full compliance with federal, state, and local laws and regulations is maintained. In addition, a joint program with DOE's production agencies is being started to reduce manufacturing hazards for all weapon programs. The completion of this program will take several years. Changes to weapon designs will be verified to ensure that other requirements are not compromised.

Nuclear directed-energy weapons—Work on nuclear directed-energy weapons (NDEW) supports technology development to avoid technological surprise and to enable future, but as yet imperfectly defined, weapon options. The role of the NDEW program has been to assess the potential of a foreign NDEW system against a U.S. strategic defense system and offensive nuclear deterrent and to develop a technology base for development of U.S. NDEW systems if needed. The FALCON laser, x-ray lasers, and hypervelocity projectiles are currently being addressed.

FALCON (fission-activated laser concept) has been under development at Sandia for several years. The concept is for a device that uses fission fragments from nuclear reactions to directly pump a lasant gas. This type of laser is often called a reactor pumped laser. Key issues are addressed with analytical and computational theory, reactor experiments on Sandia's ACRR and SPR-III reactors, and laboratory experiments using electron beam devices. Technology demonstration and scaling to a weapon-sized laser will benefit from scaling tests at the Idaho National Engineering Laboratory TREAT reactor and the construction of a laser prototype to demonstrate capabilities for specific application. Practical applications for national security are being evaluated. The FALCON program will be phased out by FY 1995 unless a customer is identified for the next phase of development.

Lawrence Livermore National Laboratory is the lead laboratory for the x-ray laser program. In support of this program, we provide aboveground experiments in collaboration with LLNL scientists on photo-ionization and photo-pumping physics using the Saturn accelerator, new materials development, and materials for underground tests.

Los Alamos National Laboratory is the lead laboratory for the hypervelocity projectile (HVP) program. Sandia uses a combination of aboveground testing, analytical theory, and specially developed computer codes (with a detailed treatment of the strength of materials) to support LANL in the design of future experiments and the assessment of vulnerability and lethality of HVP weapons.

In FY 1993 the x-ray laser and hypervelocity projectile programs will become part of our multi-application technology base activities.

Technology base activities—To support exploratory weapon concepts and development of advanced components, Sandia conducts research and long-range development in solid-state physics, materials and processes, applied mechanics, and computer science and applied mathematics.

Microelectronics technology is critical to the development of components for modern nuclear weapons. Sandia is engaged in research to understand the fundamental electrical, mechanical, magnetic, and structural properties of electronic materials. We are exploring new techniques for fabricating and selectively altering thin film layers, surfaces, and new surface regions to aid in controlling the properties of microdevices. Recent advances in this technology suggest new applications to improve military effectiveness, survivability, use control, accountability, and safety.

Sandia has developed techniques for fabricating radiation-hardened microelectronic devices for use in nuclear weapon components. These components must be able to withstand the long-term intrinsic radiation from a weapon's own radioactive materials as well as the intense radiation that could occur during a nuclear conflict. Details of Sandia's jointly-sponsored microelectronics initiatives can be found in the section entitled, "Multiple Sponsors," (page 88).

Sandia is intensively pursuing R&D of compound semiconductors such as gallium arsenide and indium arsenide. Compound semiconductors will play a greater role in future weapon systems for improved safety and use control. This technology is already being incorporated in radars and secure data transmission systems. Future applications are envisioned to include microlasers, photodetectors, and optical computers.

Broad expertise in materials and processes is essential for the design, development, testing, and manufacture of weapon systems and components. Performance can be significantly degraded by problems resulting from inappropriate materials. Problems may arise as a result of conditions introduced during processing or because of incompatibilities between materials. A further concern arises from our desire to minimize the use of hazardous materials.

Sandia performs applied research in metals (including alloy development), inorganic materials (including glasses, ceramics, coatings, and pyrotechnics), and organic materials (including plastics, elastomers, polymer foams, adhesives, encapsulants, insulators, and organic matrix composites). We develop and characterize materials processes, including synthesis, forming, joining, modification, and cleaning. We also study the interactions of materials, particularly degradation processes such as corrosion, fatigue, crack growth, aging, and chemical incompatibilities.

Complex, thin-walled castings are essential components in many weapons. Sandia engineers and scientists have developed the capability to model metal casting processes as well as the experimental facility to cast high-performance alloys. We have developed an integrated program called Fast Cast to reduce the time needed to produce new investment castings.

Welding is a critical step in the manufacture of a nuclear weapon system and components. Weld defects may introduce serious problems, and weldments may interact with their environments in different ways than the base metal. Welding phenomena are not well understood and are difficult to study experimentally. However, by using advanced computer codes run on a supercomputer, researchers have been able to model the influences of weld parameters such as torch alignment, arc current, geometric irregularities, and the motion of liquid metal in the weld pool. This knowledge permits better control over the welding process.

Superconducting materials have the potential to greatly increase the speed of microelectronic devices for microwave communication and high-speed signal processing. Sandia materials scientists have succeeded in making device-quality thin films of the new thallium-based superconducting compounds on two-inch wafers. The new films have zero resistance at temperatures up to 110 Kelvin and can carry current densities in excess of 975,000 amperes per square centimeter at liquid nitrogen temperature without observable resistance. Based on these materials and new process technology, microelectronic circuits utilizing the superconducting flux

Rick Blum welds metal as diagnostic equipment checks the work. Sandia metallurgists and software specialists are devising computer codes to advance the basic understanding of welding and improve welding processes. Predictable, parameter-driven, welding process technology is important in weapon manufacturing operations and will benefit commercial manufacturing immensely.

flow transistor developed by Sandia have out-performed conventional electronics in a number of microwave and digital circuit applications. Current work is pursuing materials development and multi-layer structural and improved circuits.

One of Sandia's primary responsibilities is to understand the behavior of warhead systems during accidents. Crashes, drops, and fires must be understood and analyzed. Sandia conducts considerable research in applied mechanics with an emphasis on the deformation of inelastic structures under extreme conditions of shock and temperature. Research is conducted in several aspects of mechanics and thermodynamics, including the development of equations and computational methods for modeling such phenomena. The design of nuclear weapon structures for their intended functioning and for behavior in severe accidents is conducted using analysis and materials modeling tools developed at Sandia. The design of safing systems relies heavily on our thermal analysis capability. Shipping containers, fuzes, and components are also designed using these tools.

The aerodynamics and flight mechanics of the bombs, missiles, and reentry bodies that carry nuclear warheads must be understood. We have developed computer codes to predict the aerodynamics and behavior of these vehicles. Trisonic and hypersonic wind tunnels are used to measure flight characteristics of scaled vehicle models. Our work with high-performance parachute systems configured to some nuclear weapons is a comprehensive program of research, development, design, production, and stockpile maintenance.

Computation is an indispensable tool in many aspects of the nuclear weapon R&D program. It accelerates the scientific method by extending predictive capabilities and improves design engineering by permitting unlimited simulations of design adjustments. However, the vector processing supercomputers that have been the dominant architecture of the last decade are not adequate for many classes of problems in applied physics, materials science, and structural and fluid mechanics. Therefore, Sandia conducts an aggressive R&D effort in parallel processing.

In recent work Sandia scientists have developed massively parallel codes for three-dimensional solid dynamics that run an order of magnitude faster on the newest Hypercube parallel processing computer than on standard supercomputers. Another development is radar simulation for which the massively parallel version runs two orders of magnitude faster than the original supercomputer program. In addition, massively parallel codes show promise for permitting real-time solutions to battle management scenarios previously thought infeasible in real time. Current projects include three-dimensional wave propagation and radiation hydrodynamics codes for nuclear weapons applications. The goal is to produce a thousandfold increase in computational capability for nuclear weapons design and simulation. Other ongoing projects are aimed at developing the software infrastructure necessary to effectively perform parallel computing: new mathematical methods, algorithms, and computing utilities and environments.

Sandia is conducting research into advanced computer architectures for both embedded and scientific applications. A scalable multiprocessor computer architecture based upon the combination of dataflow and traditional von Neumann computational models is being developed that addresses the twin goals of performance and programmability. High-speed, memory-based, interconnect systems for combining multiple processors into a single, high-performance computing environment are also being developed. These architectures are designed to provide the extremely high computation rates required for the design, simulation, and operation of next generation weapons systems.

Sandia is also conducting R&D on the robotics technologies that will allow industrial robots to be used in the Department of Energy's batch manufacturing operations. Development activities are being carried out for Rocky Flats, Pantex, Y-12, Allied-Signal, and Savannah River.

Weapon disassembly will be greatly improved with application of a new intelligent machine designed by Sandia. During disassembly, the radioactive pit of a nuclear weapon must be removed, physically

Computer scientists John VanDyke and James Tomkins confer over data showing successful use of massively parallel computing to track many thousands of simulated warheads and decoys in mid-course trajectories in real time.

separated from the high explosive, locked into a handling fixture, and then placed inside a drum for transport. Workers now perform these tasks by hand. The new, automated disassembly system (soon to be tested at Pantex) will eliminate direct human handling of radioactive materials.

Other applied mathematics work pertains to data and communication security, message authentication, control of nuclear weapons, personnel identity verification for access control, and systems for authenticating data acquired to verify compliance with test ban treaties.

Testing

Hostile radiation environments for a nuclear weapon system are cited in its stockpile-to-target sequence (STS), and the resulting electrical and mechanical requirements are key design specifications. These specifications are developed jointly by DoD and DOE to balance mission requirements, cost, schedule, and available technology.

Sandia's radiation effects testing program certifies that components and subsystems will function reliably in the hostile nuclear burst environments that may be encountered in the specified STS. These threats include the nuclear radiation outputs of x-rays, gamma rays, and neutrons. We employ a combination of aboveground testing (AGT), analysis, and underground testing (UGT) for this development and certification process.

Congress has recently mandated that the DOE weapons laboratories take steps toward less reliance on underground testing. We are not yet in a position to certify future or reconfigured strategic systems without underground tests. It is important that we pursue AGT/UGT correlation programs that will demonstrate the extent to which system certification can be achieved by aboveground testing alone. Accomplishing this national mandate will require an accelerated program of AGT/UGT correlations and aboveground test protocol demonstrations, along with enhanced AGT capabilities.

In 1991 we began a program in cooperation with DNA to assess our ability to correlate aboveground and underground test results for electronic systems and extrapolate them to realistic hostile environments. The goal of this work is to develop a test protocol for certifying nuclear survivability with less or no reliance on underground testing.

It is important that the United States be able to continue radiation testing of weapon systems, subsystems, and components even if there should be a comprehensive test ban. Changes in stockpile size will dictate changes in weapon STSs. A smaller, reconfigured stockpile will present substantial certification challenges over the next decade. We must be able to test our systems to radiation-hostile environments and fratricide. Recent budget reductions have impaired our ability to field underground tests and are putting our aboveground x-ray, gamma-ray, and neutron testing capabilities at risk. The mandate to prepare for further test reductions requires additional investment now in these critical areas.

We have identified needed areas of improvement in our AGT capabilities, including rise time, pulse width, and fluence improvements in Saturn and Hermes III and construction of two new facilities to cover testing that now can only be conducted underground.

The first new facility is the Externally-Driven Nuclear Assembly (EDNA), which would employ a state-of-the-art linear induction accelerator and a fast-burst reactor. EDNA represents a world-class aboveground test capability based upon the proven Hermes III and SPR-III technologies. EDNA would make it possible to subject warhead components to extremely fast neutron pulses, high-fidelity source region EMP (SREMP), and realistic synergistic environments (gammas followed by neutrons). Currently these environments can only be created with underground testing.

The second new facility is a cold and warm x-ray facility that would permit testing of materials and structures currently possible only with underground testing. In consideration of cost-effectiveness, we will withdraw our request for this facility should the DECADE facility proposed by DNA meet our needs.

Our present underground testing program includes the following elements:

1. Understanding, predicting, and measuring the outputs of nuclear detonations

and their interactions with surrounding media.

2. Understanding the sources used in underground tests to produce outputs that meet technical requirements.

3. Interacting with groups providing the aboveground testing and analytical calculations to ensure that maximum benefit is derived from the expensive and time-consuming experiments undertaken at NTS.

4. Planning, preparing, fielding, conducting, and analyzing the results of these experiments to certify the radiation hardness of Sandia's components.

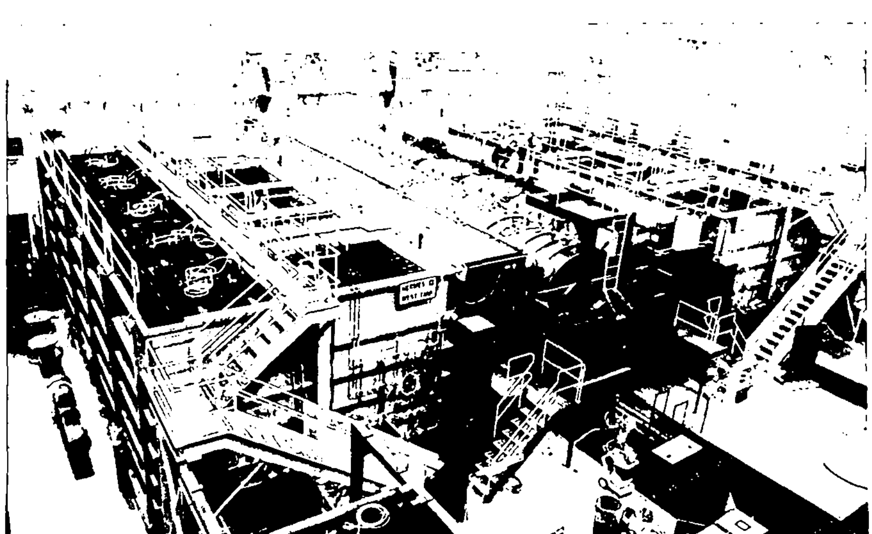
While some tests have been fired in vertical shafts, most are conducted in tunnels mined horizontally into the side of Rainier Mesa, a plateau at the north end of NTS. Typically, a network of tunnels extends from a common portal for several miles under the mesa and 1500 feet below its surface. A small nuclear device is exploded at one end of a tapered, evacuated line-of-sight pipe. Experiments arrayed down the pipe to its larger end, perhaps 1000 feet away, are exposed to the radiation output of the source device. For a desired STS exposure level, a component will be placed at the distance that will give that dose, while others will be positioned closer and farther to bracket that level.

We typically utilize between 15 and 20 percent of the space available on effects tests sponsored by the Defense Nuclear Agency (DNA) at a rate of about one test per year. We estimate that the new AGT/UGT correlation work required to meet our test ban readiness and "further limitations" needs will necessitate dedicated tests in FY 1995 and FY 1997. Details of this plan will be available in July 1992.

In order to document the test environment, Sandia, along with DNA contractors, develops and fields radiation output diagnostic experiments. We develop specialized instrumentation to measure sample and component responses. Pressure, stress, strain, impulse, temperature, acceleration, velocity, and displacement are measured in the severe radiation environment of the test chamber. We have also had to develop and field highly reliable and flexible recording systems capable of up to 1000 channels of information.

Sandia supports the DOE weapon development program at NTS by supplying arming and firing components and neutron generators for Lawrence Livermore and Los Alamos tests. We also work with Lawrence Livermore to arm and fire their tests. Working with integrated contractors such as General Electric Neutron Devices, we develop new arming and firing components and neutron generator designs. In addition, our UGT capabilities are available to other government agencies through reimbursable arrangements.

Our aboveground experimental (AGEX) facilities—the Saturn, Hermes III, and Proto



The Hermes III linear induction accelerator has proved to be a valuable resource for weapon effects testing. The gamma-ray accelerator takes advantage of short-pulse, low-inductance, pulsed-power technology to provide dose-rate area products not available elsewhere in AGT.

II accelerators and the SPR-III AND ACRR reactors—are primarily used to simulate x-ray, gamma-ray, and neutron environments. Saturn and Hermes III are pulsed power machines that generate low or high voltage *bremsstrahlung*, electron beams, and radiation from plasma sources (Saturn), and are used to simulate the x-ray and gamma-ray portion of conventional nuclear weapon threats. We typically test reentry vehicles, missile and satellite components, and subsystems in these simulated x-ray and gamma-ray environments.

Sandia's radiation facilities are unique national resources for high-fidelity simulation of nuclear weapon effects. The ACRR is a pool-type reactor with an annular-shaped core formed around the dry, central irradiation cavity. The spectrum and timing of the ACRR is representative of most endoatmospheric engagements. The reactor is also used to simulate high-level gamma environments. It is the only facility in the United States capable of properly simulating a fireball fly-through for total dose. The SPR-III fast pulse reactor is an unmoderated cylindrical assembly of fully enriched uranium alloyed with 10 percent molybdenum. These facilities are major AGEX capabilities.

As capable as these existing AGEX facilities are, they are still limited in comparison to UGT. Very high intensities over large areas cannot be achieved in the x-ray and gamma-ray simulators. Even with the improvements in our AGT capabilities described above and the addition of the two new AGT facilities, testing for thermonuclear effects in full structures could still only be accomplished with UGT. Nevertheless, by pursuing an accelerated program of AGT/UGT correlations, enhancing our present AGT capabilities, and constructing two new AGT facilities, we believe we can achieve the mandated state of less reliance on underground testing.

Inertial Confinement Fusion (ICF)

ICF has provided the principal pulsed power technology and facilities for our exploration of inertial fusion as a future x-ray source for nuclear weapon effects testing, weapon physics studies, and fusion power production. The low cost and high efficiency of the pulsed power approach have permitted unique megajoule-class facilities to be constructed and utilized for ICF research. Two of these facilities, the Particle Beam Fusion Accelerator I (PBFA I) and Proto II, have fulfilled their original research purposes and have been converted into new machines, Saturn and Proto II—major national facilities for nuclear weapon effects simulation, nuclear directed energy weapon x-ray laser research, radiation flow research, and survivability testing.

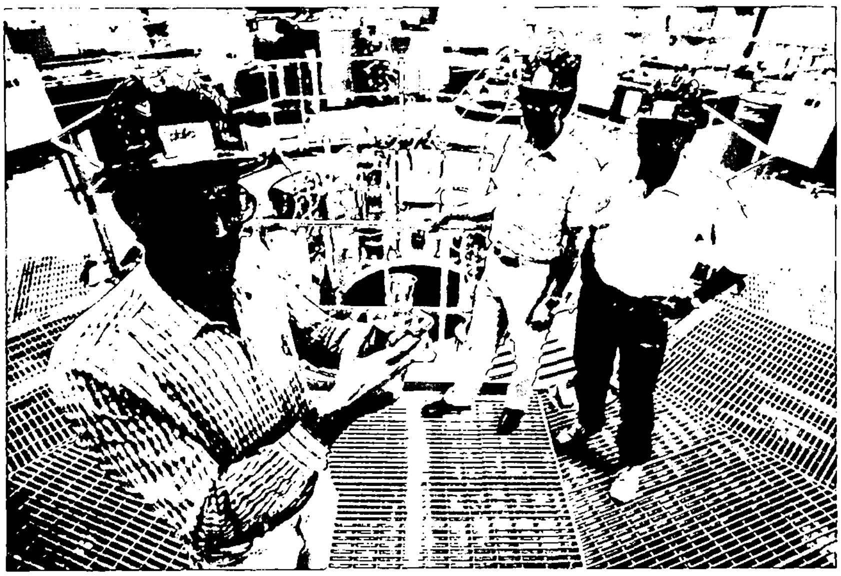
The pulsed power technology base developed primarily with ICF funding forms the core of our expertise in the DOE Center for Pulsed Power Research and contributes to national security today as we develop more challenging applications. The same low cost and high efficiency of pulsed power technology permit the light ion approach to ICF to enable cost-effective intermediate applications, such as accelerator production of tritium, fusion materials irradiation, and accelerator-based transmutation of nuclear waste in the longer term.

Our responsibilities include technical direction of all DOE-funded activities for the light ion ICF approach. Sandia directs light ion efforts in beam-target interactions, beam generation and transport, focusing, target implosion, and theory. Sandia's Particle Beam Fusion Accelerator II (PBFA II) is the world's most powerful particle accelerator, consisting of 36 pulsed power modules arranged around a central hub delivering power from all directions.

The success of an ICF experiment hinges on how effectively an intense beam of particles can be focused onto a small fuel pellet, causing its atoms to fuse, releasing energy. If fusion can be accomplished under the right circumstances, the fuel should ignite. With sufficient energy on the target, a break-even point should be reached where more energy will be produced than was used to start the process. It may then be possible to engineer fusion energy for applications.

Recent experiments give us confidence that a laboratory source of thermonuclear radiation may be obtainable through ICF if the four major technology milestones can be further developed and integrated on PBFA II:

1. Multi-modular synchronized pulsed power was developed in FY 1988.



Gordon Chandler holds a target chamber used in ICF experiments at Sandia's powerful PBFA II accelerator. Targets are inserted into the machine's central vacuum chamber located behind team members Paul Rockett and Mark Derzon. Experiments are concentrating on improving the focusing of the accelerator's lithium ion beam.

2. The physics of intense ion beam generation and focusing was adequately understood in FY 1989 with the completion of the 5 TW/cm^2 major milestone.

3. The plasma opening switch met its milestone in FY 1990.

4. The lithium ion source decision milestone was met in FY 1990.

Integration of these technologies by FY 1993 should open a new era in light ion ICF by enabling high-quality radiation-dominated experiments with ion-heated *hohlraums* after two decades of research and development for a low-cost, efficient, multi-megajoule technology for ICF applications for Defense Programs.

The near-term goal of the program is to establish the feasibility of ICF using ion beams produced directly from a pulsed power generator by meeting the milestones established with the Koonin Panel under the National Academy of Sciences review. The longer term, 10–15 year goal of the program is to provide the driver to ignite thermonuclear fuel on a PBFA II upgrade in the 1990s for a Laboratory Microfusion Facility for military applications in the 2000–2010 decade. Ultimately, the low cost and high efficiency of the pulsed power approach may provide fusion power generation for electricity.

Production and Surveillance

The authorization of production engineering (Phase 4) is the starting point for production and surveillance activities. The role of Sandia and the nuclear design laboratories during Phase 4 is to complete the development process and record a weapon's design in the form of drawings, manufacturing specifications, and process instructions that can be used by the DOE production plants to carry out component manufacturing and weapon assembly. It is a large and complex task. Thousands of engineering drawings and other design definition documentation are furnished to the production plants for the manufacture of a nuclear weapon.

Sandia is the lead laboratory for the Computer Integrated Manufacturing (CIM) Program within the DOE nuclear weapons complex. The objective of this program is to establish a unified approach to the management and communication of computer-based product definition data. Sandia provides technical leadership and direction for the CIM program in identifying and implementing cost-effective initiatives to promote the creation, exchange, utilization, and storage of product definition in electronic, computer-sensible form. Current efforts deal with the exchange and utilization of CAD-generated drawings and specifications containing both text and graphics.

Integration of new and existing CAD/CAE/CAM systems is an important goal for Sandia. Integration will provide project continuity from one phase of development to the next as well as flexibility in application of computer-aided tools to a broad spectrum of needs. NIRVANA, a project for electrical design and fabrication, was implemented in 1991. A second project that addresses mechanical design, ACCORD, was started in 1991 and will be implemented in 1992. The infrastructure needed to support the integration includes computer networks, design and test databases, and a configuration management system.

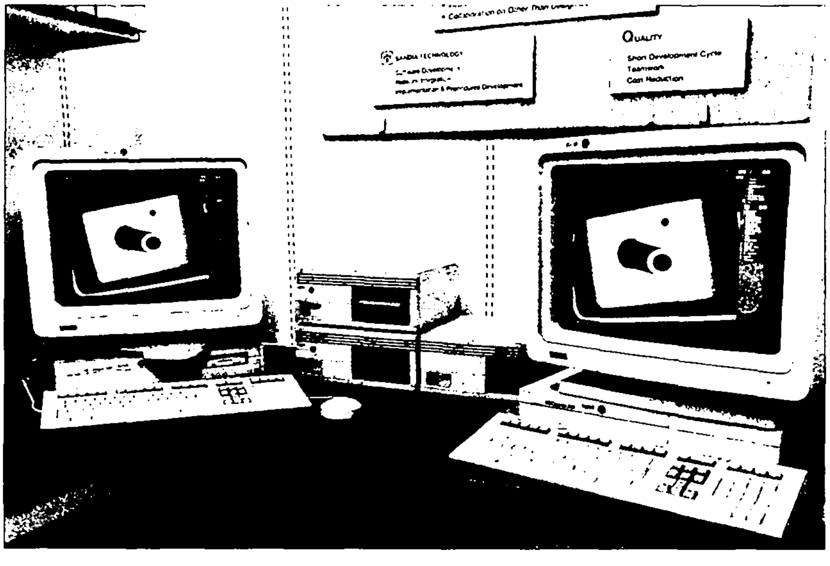
The integration effort reflects the need for concurrent engineering, the simultaneous participation of all contributors to a project—design, fabrication, test, analysis, and manufacturing. This need is addressed in an advanced network development project, Interactive Concurrent Engineering (ICE), that will allow real-time, shared use of computer-aided design tools by all project members, regardless of location. All integration activities are conducted in close concert with Allied Signal, Kansas City Division. The integrated environment and associated information systems will support DOE Reconfiguration and Dismantlement activities.

As part of its lead laboratory assignment, Sandia works closely with the DoD Computer-Aided Acquisition and Logistics Support (CALS) program, which has goals and objectives similar to those of the DOE CIM program. Working together with the CALS program will help promote standards across both DOE and DoD, eliminate duplication, and facilitate implementation of concurrent engineering practices for privatization of nonnuclear component manufacturing and rapid commercialization of DOE technologies.

The laboratories work closely with the DOE production plants during and after development to ensure that the design will be manufactured cost-effectively and that the end product will meet the design intent. Sandia provides technical advice and direct field assistance to resolve problems that arise during production and stockpile life. We also furnish engineering instructions associated with weapon retirement, support plant nuclear safety programs, evaluate tool-made sample assemblies and components, provide software quality assurance for test equipment control, and furnish technical input for joint DoD/DOE nuclear weapon safety studies and operational reviews.

Sandia and the production contractor Allied Signal, Kansas City Division, are jointly pursuing a manufacturing quality initiative. Engineers from both organizations have developed a certification, qualification, and monitoring (CQM) methodology they believe will measurably improve weapon component quality.

The CQM methodology incorporates the ideas of W. Edwards Deming, whose



Sandia has developed a capability to support concurrent engineering by sharing CAE programs among several participants in a design conference. Each of the participants—who might be separated by long distances—can simultaneously view and manipulate the design object.

theories on quality manufacturing have been widely adopted in Japan. The premise of Deming's work is that product quality is best improved by formalizing and improving the production processes themselves. CQM analyzes the constituent tasks from design through production, qualifies them by demonstrating that they contribute to a quality product, and provides for ongoing monitoring so that continuous improvements in the process can be measured. Definitions of CQM for specific component programs have been established and implementation is proceeding.

Sandia conducts an ongoing quality assurance program for all nuclear weapons in stockpile. This function is performed through a stockpile evaluation program that includes flight and laboratory testing of subsystems and components for each weapon system. We develop, fabricate, and modify system test equipment and help design instrumented assemblies of denuclearized weapons for joint testing with the military. We also collect and serve as the repository for all data associated with weapon production and related testing and keep it in retrievable form.

Sandia's responsibilities also include providing primary physical and electrical standards for equipment calibration for the entire nuclear weapons production complex. We provide classroom and field training in weapons handling for DOE, DoD, and laboratory personnel; conduct field engineering activities, such as providing spare parts and coordinating product change proposals; and prepare and maintain manuals and source data on all weapons and ancillary equipment.

Throughout all of these functions, it is imperative that high standards of quality be maintained. Our evolving quality ethic is placing increased emphasis on meeting the needs and expectations of our sponsors. During the formative stages of a weapon system, we are emphasizing the development of clear and reasonable requirements and the evolution of a design concept that meets those requirements. The design and development processes are pursued jointly with DOE manufacturing groups and vendors so that manufacturability, cost, ES&H, and other issues are incorporated in the development process from the beginning. After the weapon enters production, we continue to evaluate the manufacturing and stockpile history, making whatever manufacturing process, design, or retrofit changes are necessary to ensure a reliable, safe, and secure nuclear weapon.

Office of Arms Control

Sandia supports DOE with research, development, and analysis for arms control, verification, and nonproliferation technology and policy development. Sandia has one of the oldest and largest programs of such work in support of U.S. arms control and nonproliferation policies. This work has always been an important corollary to our nuclear weapon R&D responsibility, which is a requisite expertise for knowledgeable arms control development.

Effective with FY 1992 the DOE Office of Arms Control no longer reports to the Assistant Secretary for Defense Programs.

Summary of Programs for
Office of Arms Control
(Operating BA in $ million)

B&R Code	Program Title	FY90	FY91	FY92	FY93
GC	Verification and Control Technologies			46.7	52.0
	Percent of total operating funds			3%	4%

Note: Amounts for FY90 and FY91 are included in the table for Defense Programs.

Verification and control technology (GC)

The Verification and Control Technology program includes development and deployment of satellite-borne instrumentation to verify compliance with the Limited Test Ban Treaty; development and evaluation of seismic systems and technologies for verification of threshold or other limitations on underground nuclear testing; research and development of a variety of systems and technologies potentially applicable to the verification of agreements for arms limitations, nonproliferation of weapons of mass destruction, and Open Skies (reciprocal surveillance of defense installations from aircraft); technical support of verification and arms control activities; and assessment of foreign weapons technology and other intelligence issues.

Our satellite instrumentation is continually being improved. We continue to deploy new optical sensors that better detect and locate low-yield nuclear bursts in the atmosphere, even through clouds, and to work with Los Alamos National Laboratory to upgrade capabilities to detect bursts in space at greater distances from earth. Instrumentation for the Global Positioning System (GPS) provides almost continuous worldwide coverage for detection and two-dimensional location of atmospheric bursts now, and will provide full coverage and three-dimensional location when completed in 1993. The GPS data are also used by DoD (which shares system costs) for tactical warning and attack assessment. Enhancements in existing programs and DOE participation in a major new satellite program have required some increased effort since 1988.

Development and evaluation of seismic technology for detection, location, and yield estimation of underground nuclear explosions is continuing. The Regional Seismic Test Network, deployed from 1982 to 1987, comprised five National Seismic Stations in the U.S. and Canada. Information from the network was used to upgrade design of the stations and enhance regional seismic analysis techniques.

NORESS, a small aperture seismic array installed in Norway in 1985, was developed by DOE in conjunction with DARPA. It was augmented in 1987 with a second array installed in northern Norway called

ARCESS. These arrays incorporate a high-frequency capability for improved detection and discrimination, and the resulting data are now being used to design advanced seismic instrumentation.

A transition from the Regional Seismic Test Network to full-scale engineering development of a Deployable Seismic Verification System (DSVS) began in 1987. DSVS was designed to provide an integrated seismic monitoring capability to support verification requirements associated with a wide range of possible nuclear test monitoring scenarios. The system is fully autonomous and self-powered, and it furnishes high-quality, tamper-resistant seismic data suitable for regional and teleseismic analyses.

A working prototype DSVS first operated in June 1989. Five such seismic stations are now available. One began operation for long-term evaluation at the AFTAC test facility outside Pinedale, Wyoming, in 1990.

Elements of the DSVS were incorporated into the Designated Seismic Station (DSS) System, which will be used by DoD to monitor compliance with the recently ratified Threshold Test Ban Treaty (TTBT). Future efforts will build on the DSVS technology and knowledge base to provide solutions to meet the challenges of today's rapidly changing international climate. In particular, the breakup of the Soviet Union and recent, unsettling revelations about the maturity of Iraq's nuclear weapons program will likely result in a requirement for further improvements in our seismic verification capabilities.

Sandia has provided several of the technologies for verifying compliance with the INF and START Treaties. The INF Treaty requires that radiation sensors be used to distinguish single warhead SS-25s from triple warhead SS-20s during short-notice inspections. Neutron detectors were developed for this purpose and are being used by the On-Site Inspection Agency. Neutron and gamma radiation detectors are being investigated for monitoring cruise missiles and counting MIRVs as part of the START Treaty.

In START and other treaties it is necessary to distinguish between legal and illegal treaty-limited items (TLIs), such as missiles, during on-site inspections. The concept considered at Sandia is to attach unique, irreproducible tags to legal TLIs that can be examined for authenticity during inspections. We have broadened this work to establish the technological area of information integrity, which covers the general

A Deployable Seismic Verification System (DSVS) developed by Sandia has been installed in Wyoming for evaluation. The system is the latest generation of seismic monitoring devices for detecting underground nuclear explosions.

application of tags and seals to treaty monitoring problems. These problems range from the sealing of chemical weapon facilities to uniquely identifying unattended in-country sensors that are subject to counterfeit. An analogous technology for data protection is the authentication of data collected by incountry sensors. We are developing integrated circuits incorporating new authentication algorithms to meet the security requirements and the size constraints of authentication systems.

Studies are underway to investigate the impact on DOE facilities of nuclear weapon dismantlement that could be performed under a system of controls related to the START treaty. In a related effort, we are investigating ways of accounting for special nuclear materials from dismantled weapons. This work has provided the background necessary to support discussions with the Soviet Union and its successor federation on nuclear weapon dismantlement that are an outgrowth of President Bush's arms reduction initiative of September 1991. We are also preparing the technical information needed to support the nuclear surety discussions proposed in the President's initiative.

The proliferation of weapons of mass destruction, especially nuclear weapons, will be the central arms control issue of the upcoming decade. Sandia is the principal DOE laboratory for research and development of containment and surveillance technologies applied to international safeguards. We have developed and commercialized the Modular Integrated Video System, which will be the principal video surveillance standard for the IAEA for the next ten years. We have also developed and commercialized the Cobra Seal, a fiber optic seal used by both the IAEA and the United States On-Site Inspection Agency. In addition to these safeguards technologies, we are exploring new concepts for proliferation monitoring, such as all-open-source databases, new openness measures, and small satellite sensors.

Continuing efforts are devoted to analyzing foreign weapons and weapon development programs, to supporting arms reduction negotiations, and to assessing how our expertise can best be applied to verification issues of interest to DOE. These efforts include R&D for arms control, nonproliferation, treaty verification, and application of remote sensing technology to the detection of nuclear explosions. Experimental activities are included to develop a data base that can be used to support these analyses.

An important element of our work is the development of airborne synthetic aperture radar systems (SAR). We are planning test bed experiments to evaluate parameters such as radar resolution and target configuration that will influence SAR designs for Open Skies and monitoring of the Conventional Forces in Europe Treaty. We are also exploring the fusion of SAR with other imaging data and automated data analysis as methods for dealing with the deluge of data from such systems. Massively parallel processing has proven its value by reducing processing times over those achieved on sequential machines by an order of magnitude or more.

We are increasing our activities on the general problem of managing verification information. Our aim is to develop technologies to turn the vast quantity of data into useful information.

Office of Security Affairs

In view of the potential consequences of nuclear energy or materials being used for malevolent purposes, DOE's Office of Security Affairs supports a program to develop technology and systems for protecting nuclear facilities and materials. Sandia is a major contributor of systems for physical security of these assets.

Summary of Programs for Office of Security Affairs
(Operating BA in $ million)

B&R Code	Program Title	FY90	FY91	FY92	FY93
GD	Nuclear materials safeguards and security			11.6	12.0
	Percent of total operating funds			<1/2%	<1/2%

Note: Amounts for FY90 and FY91 are included in the table for Defense Programs.

Nuclear materials safeguards and security (GD)

Sandia is the principal laboratory for R&D on physical protection technology. Program objectives are to support the development and application of advanced technology to the protection of nuclear facilities to (1) prevent sabotage of nuclear facilities or components that could endanger the public health and safety, and (2) prevent theft and diversion of nuclear materials that could endanger the public. Technologies being investigated include those aimed at detection, delay, and response for outside adversaries, and those that deter and prevent insider attempts at sabotage, theft, or diversion. The protection of classified information and parts is another important program objective.

New concepts are developed and analyzed to identify the most promising approaches. Concepts with high potential performance are engineered, implemented, and operationally evaluated to provide balanced, effective, integrated safeguards/security systems. An important aspect of the program is the transfer of technology to DOE and its contractors, government agencies, and industry through handbooks, seminars, workshops, implementation assistance, and equipment performance specifications.

We also provide instructional support to the DOE Central Training Academy by developing and presenting vulnerability assessment training using ASSESS, a software system developed by Sandia for evaluating safeguards and security.

Office of New Production Reactors

To accomplish the relatively rapid design and construction schedule for the New Production Reactors program, DOE has asked the national laboratories to lend their expertise to developing and demonstrating essential technologies for assuring a high degree of reliability and safety. Sandia has been selected by the DOE Office of New Production Reactors (NP) to provide support for the heavy water reactor program. Our work for NP is primarily focused on severe accident phenomenology and containment integrity. This is an area in which Sandia has developed expertise from programs for the Nuclear Regulatory Commission.

Summary of Programs for Office of New Production Reactors
(Operating BA in $ million)

B&R Code	Program Title	FY90	FY91	FY92	FY93
NP	New Production Reactors	4.7	3.6	4.5	4.0
	Percent of total operating funds	<1/2%	<1/2%	<1/2%	<1/2%

New production reactors (NP)

The DOE Office of New Production Reactors has selected Ebasco Services, Inc. as the integrating design contractor for the heavy-water new production reactor. Sandia has been asked by DOE/NP to support the design work for this reactor by assessing the ability of proposed designs to cope with severe accidents and other challenges to containment.

Sandia is the lead laboratory for severe accident phenomenology, and is supported by other national laboratories as needed. The work involves characterizing phenomena which may contribute to severe accidents and assisting the designer in developing design options to minimize the consequences of such accidents on containment. An important tool in this work is Sandia's Annular Core Research Reactor, which is used to expose fuel to rapid heating in order to study the mechanisms of fuel melting and disassembly.

Sandia is also the lead laboratory for developing design criteria for containment integrity, known as Deterministic Severe Accident Criteria. This task requires an extensive evaluation of containment loading under accident conditions.

In the safeguards and security area, we are supporting NP in developing criteria and design guidance to assure a high level of security for the plant, as well as exploring how to provide such security with minimal impact on operations.

These activities are expected to have a duration of three to five years, after which Sandia's role will be to monitor and support the design process.

Office of Environmental Restoration and Waste Management

Work performed for the Office of Environmental Restoration and Waste Management includes environmental restoration, corrective actions, waste management (including the Waste Isolation Pilot Plant), technology development, and transportation.

Summary of Programs for Office of Environmental Restoration and Waste Management
(Operating BA in $ million)

B&R Code	Program Title	FY90	FY91	FY92	FY93
EW	Environmental Restoration and Waste Management	39.3	58.3	112.9	145.9
	Percent of total operating funds	4%	5%	8%	10%

Defense waste and environmental restoration (EW)

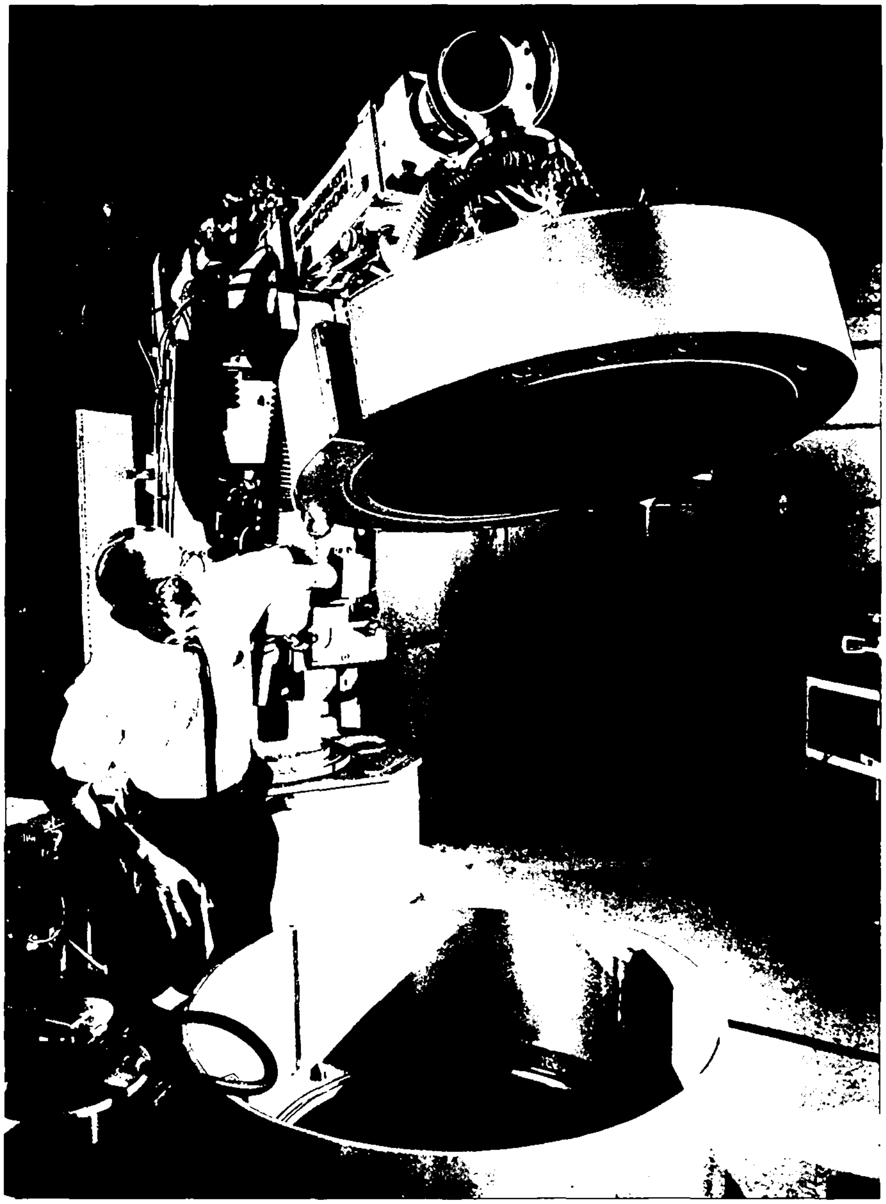
Environmental restoration—The goals of the Environmental Restoration program are to address environmental problems resulting from past practices, assess the extent and the nature of these problems, and remediate the affected sites, if needed, using the most effective and cost-efficient methods possible. Activities include identifying inactive hazardous waste release sites, developing an environmental restoration investigation and remediation program, coordinating NEPA documentation, obtaining necessary permits, evaluating surface and groundwater contamination potential, reviewing site underground storage tank practices, evaluating current waste management practices, and ensuring compliance with federal, state, and local environmental regulations. Projects involve the investigation and remediation of inactive waste handling, disposal, and spill sites in accordance with the provisions of the Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and relevant DOE Orders.

Corrective actions—Work under this category will design and implement actions to correct confirmed and potential environmental protection problems at Sandia sites at Albuquerque, Livermore, Tonopah Test Range, and Kauai Test Facility. It will cover groundwater, air quality, and sewer conditions.

Waste management—The goals of the Waste Management program are to reduce risk to the environment, workers, and the public from the generation and handling of hazardous and radiological waste and to reduce the long-term liability associated with disposal of such waste.

For a number of years Sandia has provided scientific support to the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. Three principal tasks are being conducted as part of the WIPP project. The first continues the experimental field and laboratory studies addressing technical issues associated with disposal of defense transuranic wastes in bedded salt. Major experiments address the thermal and structural behavior of salt; the interactions of salt creep, brine inflow, gas generation from waste organics and metals; the consolidation of backfill and waste packages in the waste rooms; and validation of seal systems designs. A selected number of new experiments will be implemented to support the data base requirements of the performance assessment studies.

The second task examines geotechnical phenomena important to understanding field test results and issues associated with



Researchers in Sandia's robotics lab are developing a system that automates the inspection of lids on transport casks for high-level radioactive waste. Ben Petterson checks the underside of a full-scale model of such a cask lid. We are developing several "smart" robots to help automate a variety of DOE waste operations.

the potential for migration of radioisotopes from the repository to the adjacent environment. Prediction of future geologic and hydrologic behavior and the development of hydrologic transport models are two of the main objectives of this task.

The third task is a performance assessment in support of the compliance determination requirement of the Environmental Protection Agency. The performance assessment will perform calculations of consequences for potential breach scenarios.

Sandia was recently selected by the Nevada Operations Office as lead laboratory for conducting the assessment of compliance for the Greater Confinement Disposal (GCD) site. The GCD site, located in the southeastern corner of the Nevada Test Site, is being considered by DOE for the permanent disposal of uncertifiable defense transuranic waste, greater-than-Class C low-level waste, performance-limited waste, nondefense-generated transuranic waste, and other DOE sealed-source wastes.

Sandia's role in the GCD project is expected to include (1) technical program management, (2) development of overall project strategy, (3) development and implementation of compliance assessment strategy, (4) model development and application, and (5) systems configuration.

Other waste management activities include handling, packaging, storage, and shipment of radioactive, mixed, and chemical wastes. In addition, waste management personnel provide emergency response, containment, identification, and clean-up of hazardous materials spills. Persons whose activities generate wastes are trained on their hazards and the appropriate handling procedures.

Technology development—Sandia is performing a variety of research and development in support of DOE's requirements for technology to facilitate environmental restoration and environmentally benign production processes.

Sandia has a key role in developing environmentally conscious manufacturing technologies for nonnuclear components and reducing the use of hazardous or environmentally injurious materials during weapons production. A program has been implemented to develop a systems approach to replacing such technologies in the manufacture of electronic assemblies and electromechanical components.

In addition to directed research at Sandia, this program also involves coordinating complementary development efforts at the production agencies and supporting research at U.S. universities. The goal of this program is to develop and demonstrate environmentally conscious manufacturing technologies, transferable to U.S. industry, that offer the same degree of materials compatibility and long-term stockpile reliability as those in current use.

We are implementing partnerships with industry that will focus on environmentally conscious manufacturing. The work will concentrate on environmental issues in manufacturing, especially replacements and substitutes for hazardous solvents. The primary emphasis will be on processes related to the fabrication and cleaning of electronic and electromechanical components, addressing concerns relating to the development of a total systems approach to cleaning and characterization. Partnerships are being developed through collaboration with the National Center for Manufacturing Sciences and their member companies. Work will be cost-shared with industry, and formal programs will be established by means of Cooperative Research and Development Agreements.

This work will be driven by industry's needs. Sandia's special capabilities will be matched with these needs to solve problems that could lead to substantial improvement in the economic competitiveness of U.S. companies. It is hoped that these partnerships will benefit industry by enhancing the rate at which the new technologies reach manufacturing floors.

In the first program with Ford Motor Company, we will evaluate the relative efficiency of selected cleaning processes, including an analysis of the reliability of samples prepared by different techniques. Also, we will develop imaging techniques to characterize the device quality as it relates to reliability under different environmental conditions.

Development of intelligent machines for environmental restoration and waste management will be carried out in three areas: (l) development of the Crosscutting and Advanced Robotics Technology Development Plan for DOE's Office of Technology Development (EM-SO); (2) implementation of critical features tests of subsystems for environmental restoration or waste management; and (3) research and development in component robotic technologies critical to improving safety and productivity and lowering capital costs of robotic systems.

There are several technology development programs for environmental restoration and waste management in process. An *in situ* permeable flow sensor will be a new type of instrument system that permits direct measurement of groundwater velocities at hazardous waste sites. The approach uses thermal boundary layer perturbation techniques to rapidly determine the three-dimensional vector velocity of groundwater flow in soils or permeable geologic media. This instrument and associated techniques will provide a vitally needed alternative to pumping and tracer tests for site assessment, cleanup, and post-closure monitoring of waste sites.

The Integrated Demonstration Protocol Project is concerned with field monitoring of an air stripping cleanup demonstration process being conducted at Savannah River Laboratory. Specifically, this project will use shear wave tomography and thermal perturbation groundwater flow techniques to monitor the efficiency and effectiveness of an air stripping cleanup sweep of an underground hazardous spill. Geophysical measurements will be made prior to, during, and after the air stripping sweep.

Sandia's programs in the application of solar energy to the destruction of toxic wastes involve both low-temperature and high-temperature destruction of organic compounds in waste streams and groundwater. Both processes employ catalytic reactions that can completely destroy organics, yielding innocuous reaction products such as water, carbon dioxide, and dilute acids. A large-scale solar detoxification field experiment is now underway at Lawrence Livermore National Laboratory involving LLNL, Sandia, and the National Renewable Energy Laboratory.

Concepts for the high-temperature process have been developed, and studies of possible field applications are underway. Field experiments have been conducted for high-temperature detoxification using a high-flux solar furnace at Sandia's National Solar Thermal Test Facility. Cooperative field installations in industrial environments, as well as in government applications, are envisioned as these concepts are further proven.

Sandia is supporting the DOE Office of Technology Development with a field demonstration of technologies for cleanup of chemical and mixed waste landfills representative of many sites occurring throughout the DOE complex and the nation. Program goals include the demonstration of technologies that provide better, faster, cheaper, and safer methods for remediating chemical and mixed waste landfills. The demonstration will include the characterization and remediation of the chemical and mixed waste landfills at Sandia Albuquerque. The Sandia Integrated Demonstration will draw upon technologies from other DOE sites, industry, EPA, and university contributors. It will coordinate all aspects of site remediation, including planning, permitting, quality assurance, reporting, technology transfer, and performance assessment.

Sandia's Weapon Component Waste Disposal Integrated Demonstration addresses the end-to-end process of the disposal of weapon dismantlement waste. The process includes waste identification, minimization, treatment, transportation, and ultimate disposal. This demonstration will focus on Sandia-designed weapon components, balancing available technologies for waste characterization, treatment, and disposal. In addition, it will explore the acceptability of these technologies, as well as that of security declassification technologies, in the context of current and expected regulations for hazardous and radioactive waste disposal. In performing

Sandia has developed an ingenious catalytic method for removing organic contaminants from water using solar energy. The low-temperature process is now undergoing field trials.

this integrated demonstration, waste treatment technologies under development in other programs will be analyzed and, if necessary, tested for their applicability to dismantlement wastes. It is envisioned that many of the technologies investigated for disposing hazardous materials found in Sandia-designed components can be applied to the critical waste problems now faced by U.S. and foreign electronics manufacturers.

Transportation—The objective of the Defense Nuclear Waste Transportation program is to assure that base technology is available to support DOE in the design, testing, and certification of radioactive materials packagings and to further assure that risk and economic assessment, logistic and routing methods, and environmental evaluation techniques are also available.

The Transportation Technology Center (TTC) is a multifaceted activity that supports the nuclear waste management functions of DOE through specific transport systems development and through generic technology development, information dissemination, and analysis of institutional issues. The project supports generic work that applies not only to defense waste activities but also to issues relevant to all kinds of radioactive, hazardous, and mixed materials transportation.

Sandia interacts extensively with the Federal Republic of Germany under a bilateral agreement in both WIPP and defense-generated waste transportation. This interaction is expected to peak in the next five years after analyses and documentation of WIPP's suitability for transuranic waste disposal have been completed.

Office of Energy Research

Sandia's Basic Energy Sciences activities contribute to the research foundation for many energy-related technologies. These research projects include a national responsibility in combustion sciences. We expect to expand the effort in basic energy research over the planning period. In addition, our magnetic fusion energy projects will continue to support a long-term, nationally coordinated program.

Summary of Programs for Office of Energy Research
(Operating BA in $ million)

B&R Code	Program Title	FY90	FY91	FY92	FY93
AT	Magnetic Fusion	5.0	5.1	5.5	6.0
KC	Basic Energy Sciences	17.9	25.1	22.2	21.7
KP03	Biological and Environmental Research		0.9		
KP05	Carbon Dioxide Research		0.9	2.3	14.3
KS	Superconducting Super Collider	0.2	0.2		
KT01	Laboratory Cooperative Science	0.8	1.3	2.5	2.7
	Total	23.9	33.5	32.5	44.7
	Percent of total operating funds	2%	3%	2%	3%

Magnetic fusion (AT)

The goal of Sandia's Magnetic Fusion program is to develop a technology base to support the design of components that will perform satisfactorily in fusion plasma environments. To achieve this goal, we study the interactions of plasmas and materials, the behavior of materials exposed to high heat fluxes, and the interfaces of plasmas and fusion reactor walls.

Extensive analysis of prototypes is required before components can be evaluated in fusion machines. This activity involves selecting, specifying, and developing materials for plasma-facing components exposed to high heat and particle fluxes. Prototype configurations and samples are tested in Sandia's Plasma Materials Test Facility (PMTF). The PMTF is a high heat flux component test facility with electron beam and ion beam sources and other test systems.

In addition to the plasma/materials interaction studies, we also provide direct support to U.S. and international fusion machine design efforts. This support includes diagnostics, tritium inventory, and materials studies for the Princeton Tokamak Fusion Test Reactor (TFTR); material analysis, diagnostic development, and operation for General Atomics' DIII-D Advanced Divertor Project; and an extensive R&D and design role for the International Thermonuclear Experimental Reactor (ITER).

A Sandia-designed advanced limiter has been installed in the TEXTOR tokamak in Jülich, Germany, an International Energy Agency effort. We participate in experiments with the operation of the advanced limiter, and we assist with diagnostics of its performance. Sandia has also designed and installed the first of three limiter systems for the TORE SUPRA tokamak in Cadarache, France. We will continue to be strongly involved with the Joint European Torus (JET). We also have an ongoing personnel exchange program with the Japanese fusion community, and we are in the process of establishing collaborations between DOE and agencies in Russia in the area of fusion reactor materials.

Basic energy sciences (KC)

Sandia's activities for the Office of Basic Energy Sciences comprise several leading research efforts. Larger projects include combustion research and scientifically tailored materials. Smaller or growing programs include gases in metals (computational metallurgy), massively parallel computation, and geoscience research.

Combustion research

Sandia's largest project for the Office of Basic Energy Sciences is the Combustion Research Facility (CRF) in Livermore, California. In this facility, we develop advanced research methods, particularly laser diagnostics, and apply them to the study of fundamental combustion processes. In addition, DOE's Office of Energy Conversion and Utilization Technologies and Fossil Energy's Office of Technical Coordination sponsor industry-oriented research at the CRF on automotive and continuous combustion, including coal combustion processes.

These continuing research programs help maintain U.S. expertise in the science and technology of combustion. They provide direction and challenge for diagnostics development. DOE sponsorship and policies make it possible and desirable for combustion scientists from other locations to participate through the visiting scientist program in ongoing research projects, and facilitate the transfer of fundamental combustion technology to industry and universities.

The long-range objective of the CRF is to accelerate the development of combustion technology in order to maximize its impact on conservation, fuel utilization, industrial productivity, and equipment design. Principal research activities conducted for Basic Energy Sciences include combustion diagnostics, combustion chemistry, reacting flows, combustion modeling, and high-temperature materials.

The staff at the CRF also represent the United States in the International Energy Agency programs on Energy Conservation in Combustion. International Energy Agency activities involve collaboration with foreign scientists in engine studies and coal research through an informal exchange program.

Combustion diagnostics—One of the primary thrusts of the combustion research program at Sandia is the development of advanced diagnostic techniques. Because of their nonintrusive nature and great versatility, laser-based optical techniques receive the strongest emphasis. Laser-induced fluorescence, Raman spectroscopy, laser Doppler velocimetry, and multi-photon optogalvanic spectroscopy are but a few of the diagnostic methods that are being developed. These techniques are used to measure temperatures, species concentrations, velocity flow fields, and other parameters of importance to the understanding of combustion phenomena. Sandia's work in combustion diagnostics is supported primarily by the Chemical Sciences Division of the Office of Basic Energy Sciences.

Combustion chemistry—The CRF work in combustion chemistry improves our understanding of the complex chemical processes involved when fuels are burned. The program emphasizes determining the rates of elementary processes, and it stresses the close coupling of experiment, theory, and modeling. Using mass spectrometry and laser-induced fluorescence for experiments conducted in low-pressure flames, researchers study the kinetic mechanisms involved in typical combustion systems. Related theoretical efforts and other experiments address fundamental questions of molecular dynamics, questions that must be answered to develop models of kinetic processes. Computer modeling of complete kinetics for combusting systems is used to define the dominant reaction pathways.

These experimental, theoretical, and modeling programs are focused on topics of importance to energy-producing technologies. Themes of current emphasis include the formation and destruction of nitrogen-containing pollutants and the oxidation of hydrocarbons.

Reacting flows—A multidisciplinary program in reacting flows establishes an important link between fundamental studies of combustion chemistry and the "real world" of practical combustion. The objective of the program, sponsored by the Division of Chemical Sciences, is to increase our understanding of the fundamental interactions between chemistry and fluid dynamics in chemically reacting flows. Research results will be used to improve predictive capabilities for turbulent combustion of hydrocarbon fuels. Experimental studies include flows involving complex fluid mechanics but simplified chemistry. These flows are used to probe primary turbulent transport mechanisms. Studies of flows with complex chemistry but simplified fluid mechanics help identify combustion mechanisms responsible for the formation and growth of soot.

Combustion modeling—Sandia's combustion modeling program emphasizes the development of numerical methods to predict the mutual influences of reactions and fluid transport mechanisms. Most combustion applications involve complex fluid dynamics. Our current modeling research attempts to provide a fundamental understanding of the subprocesses so that future simulations will contain more realistic chemical and physical descriptions of combustion phenomena.

High-temperature materials—Research in high-temperature materials is sponsored primarily by the Materials Sciences Division of the Office of Basic Energy Sciences. This effort focuses on the interface between the material surface and its gaseous environment and includes research on the formation of thin films or particles, adsorption and segregation, and flame-generated species. The work is interdisciplinary, involving the chemistry, physics, and fluid mechanics of the systems studied using nonperturbing probes and modern computational techniques.

Scientifically tailored materials

Our program in scientifically tailored materials (STM) is a growing part of the effort in Basic Energy Sciences. It combines Sandia's expertise and capabilities in solid-state sciences, atomic level diagnostics, and materials processing to produce new classes of materials tailorable for specific properties.

An important goal of the STM project is to explore how capabilities developed in the various programs can be used to enhance the competitiveness of U.S. industry. Towards this goal, we meet frequently with representatives from the semiconductor industry, universities, and the national laboratories to define critical needs and to plan collaborative efforts.

Current STM research includes the physics and chemistry of ceramics, the physics and chemistry of novel superconductors, energetic particle synthesis and science of materials, strained-layer semiconductors, chemical vapor deposition sciences, and atomic level science of interfacial adhesion. Many of these programs share common themes. The three major themes are high-temperature superconductivity, epitaxial materials growth, and energetic particle beams.

Physics and chemistry of ceramics—The objective of the physics and chemistry of ceramics program is to develop a funda-

Glenda Gentry and Michael Mills use a high-resolution transmission electron microscope to explore the atomic structure of an ultra thin crystalline sample.

mental understanding of the atomic and molecular processes that govern the formation of ceramics. Our ultimate goal is to improve ceramic processing by gaining a better understanding of the underlying chemical and physical principles.

Physics and chemistry of novel superconductors—The novel superconductors program investigates the electronic, structural, and chemical properties of inorganic high-temperature superconductors and organic superconductors. The goal of our experimental and theoretical studies is to develop a fundamental understanding of the physics of superconductivity in these materials. These studies are closely integrated with an extensive synthesis and processing program designed to produce materials with tailored properties.

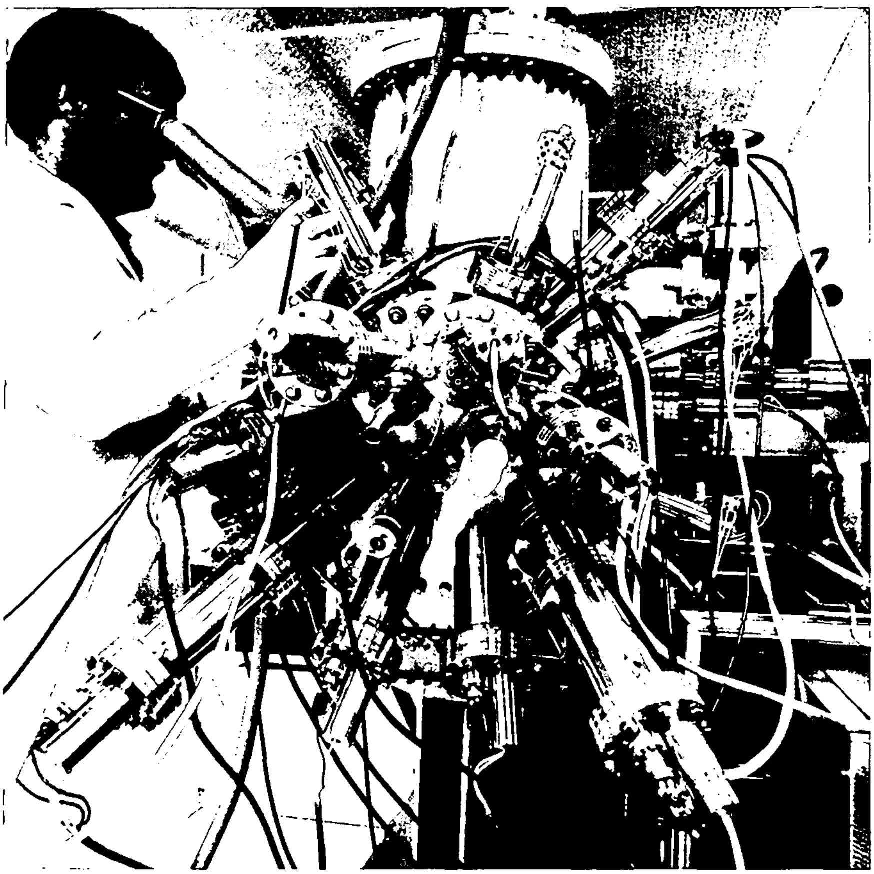
Energetic particle synthesis and science of materials—Basic research in the energetic particle synthesis and science of materials program is conducted on the interactions of ion, electron, laser, and plasma beams with metals, semiconductors, and dielectrics. The objectives of the program are to explore materials synthesis and modification with energetic particles, to create new materials and determine their properties, and to advance materials processing by elucidating relevant fundamental processes using the unique capabilities of energetic beams.

Strained-layer semiconductors—Our research on compound semiconductor strained-layer superlattice structures on semiconductor substrates and strained-metal overlayers on metal substrates represents the pioneering work in these areas. A strained-layer superlattice consists of many thin layers, each a few tens of angstroms thick, of alternating single crystal semiconductor materials. They are typically made from the more common periodic table class III–V semiconductors, such as GaAlAs, GaAsP, InGaAs, or InAsSb. The multiple thin layers behave macroscopically like a new semiconductor material. The structure may exhibit electronic, optical, and catalytic properties entirely different from those of its constituent materials. The combination of the thin layers and lattice strain allows flexibility in tailoring the properties of this "new" material. Sandia has applied these new semiconductors to the development of high-speed field-effect transistors (with world record transconductance), optoelectronic emitters, detectors, and novel optoelectronic mirror devices. Newly discovered properties of strained-metal overlayers have shown very exciting potentials as tailored base metal catalysts.

Chemical vapor deposition sciences—The objective of the CVD sciences program is to explore the basic physics and chemistry of chemical vapor deposition (CVD) as it is used in the synthesis of materials, particularly thin films. Our CVD research has thus far concentrated on semiconductors and other materials used to make semiconductor devices. But the understanding gained in this research is applicable to other classes of materials, such as coatings resistant to corrosion and wear, high-temperature superconductors, optical materials, and reduced-friction coatings. The work will be extended to these materials.

Atomic level science of interfacial adhesion—A new STM initiative deals with the atomic level science of interfacial adhesion. Despite the pervasive nature of adhesion problems in materials science and engineering, solutions are almost always the result of trial and error. Great technological and economic gains can be realized by placing the field of interfacial adhesion on a scientific basis, which will allow the selection of materials combinations to provide specific interfacial characteristics. Motivated by this need, the purpose of this initiative is to understand, in atomic detail, the nature of the physical and chemical interactions that bind solid surfaces together.

In other STM research, we are exploring the use of ion, laser, and electron beam excitation of surfaces during epitaxial growth of semiconductors to control the kinetic energy of surface atoms in order to extend the range of tailorable epitaxial materials. We are also exploring the potential of boron-rich solids, which have unique bonding, electronic, and transport properties as very high-temperature semiconductors. These materials appear promising for use in high-efficiency thermoelectric energy generators and as neutron detectors.



Raymond Hibray observes a sample inside a dual-chamber, molecular beam epitaxy crystal-growing machine used in Sandia's compound semiconductor research program.

Gases in metals (computational metallurgy)

Sandia's work in computational metallurgy has developed unique tools that permit researchers to apply atomistic calculations with great confidence. Foremost of these tools is the embedded atom method (EAM) for large-scale atomistic computer simulations, originally developed to understand the behavior of gas molecules in metals. The applicability of EAM is being broadened to nonmetallic materials and the effects of hydrogen and helium isotopes as they relate to energy applications ranging from fusion to coal liquefaction. Our visiting scientist program in computational materials science provides the opportunity for materials scientists, primarily from universities, to enhance their theoretical capabilities by collaborating with our staff—and for our staff to learn from them.

A new project in computational materials science takes advantage of exciting progress in quantum chemistry, local density, and embedded atom studies. Researchers are beginning to predict the mechanical behavior of complex alloys, such as Ni_3Al, by looking at the atomistic details of deformation. They are also studying the effects of segregation on the catalytic properties of transition metal alloys. Progress in applying the embedded atom method to semiconducting materials is encouraging.

Massively parallel computation

Sandia's computational sciences research is aimed at developing massively parallel computing methods and a software infrastructure for parallel computing. Research in parallel computing focuses on the development of parallel algorithms for solving the partial differential equations of physics and engineering. Research in software infrastructure for parallel computing covers such areas as graphics methods and visualization, static and dynamic load balance methods, parallel operating system issues, performance evaluation methods, and hybrid programming models and languages. This research program is designed to unleash the performance and cost performance advantages of massive parallelism on important DOE problems.

Advanced computing technologies are very important to national and economic security. Sandia has made a commitment to play a leading role in the national High Performance Computing and Communications Program (HPCCP). In particular, we are the DOE's lead laboratory for the HPCCP computational Grand Challenge in Computer Design of Materials and Molecules, which will create new computational structures for the design of materials. Our work on massively parallel computing has been recognized by several national and international awards, including the Gordon Bell Award, the Karp Prize, and two R&D 100 awards.

The Massively Parallel Computing Research Laboratory (MPCRL) at Sandia Albuquerque will provide prototypes of advanced, high-performance computing technology, including advances in scalable MP algorithms, MP graphics and visualization, and MP systems software (see page 29). Part of its strategy will be to form interdisciplinary partnerships with Sandia's DOE Defence Programs applications to create new, breakthrough simulation capabilities. It will also move such advances in computing technology into industry through technology transfer.

The Center for Computational Engineering (CCE) at Sandia Livermore is chartered to help scientists and engineers in industry make use of massively parallel processing to solve problems that are impracticable on conventional machines. The center focuses primarily on software engineering for applications. Applications currently being pursued include pharmaceutical design (*e.g.*, drug/organism interactions, "designer chemotherapy"), and global climate change. Research at the CCE will include methodologies for problem specification, code generation, data management, and theorems for performing proofs of software correctness.

Geoscience research

BES funding supports research on dynamic processes in the earth's crust to provide a predictive base for engineering issues such as waste storage, energy characterization and extraction, containment, treaty verification, and weapon effects. The program includes development of field instrumentation; geological and geochemical definitions of geological areas; understanding of fractures and processes occurring in them; the behavior of geologic materials; and the engineering support in research drilling related to the Continental Scientific Drilling Program.

The fundamental understandings are being continuously applied to DOE projects and industry interactions. Basic mechanisms of salt creep phenomena are valuable for the engineering design of nuclear waste facilities (WIPP), petroleum storage (SPR), gas storage (private industry), and other waste storage. Unique instrumentation is now being applied to seismic tomography by industry and to groundwater motion by municipalities and DOE waste sites. Understanding of heat and mass transport in the earth's crust has been significantly enhanced by the direct sampling and analyses of volcanic systems in the Continental Scientific Drilling Program.

Laboratory cooperative science (KT); and Biological and environmental research—health effects (KP03)

Sandia is a participant, along with Oak Ridge and Los Alamos national laboratories, in the Science and Technology Alliance sponsored by DOE. The Alliance was established in 1987 for the purpose of increasing the representation of blacks, American Indians, and Hispanics in the scientific and engineering programs of DOE, other government agencies, and industry. The Alliance is a collaborative program in science education and research between these national laboratories and the participating educational institutions. The laboratories make available instructors, support services, equipment, and faculty exchange appointments to the extent possible and as allowed under corporate policies. The participating educational institutions include: Fundación Educativa Ana G. Mendez in Puerto Rico, New Mexico Highlands University, and North Carolina A&T State University.

Sandia's Science Advisors Program places technical staff in public elementary and middle schools and Bureau of Indian Affairs schools one day a week. Their purpose is to support science teachers by enhancing science curricula and developing science demonstrations and experiments for the classroom.

Sandia and Los Alamos national laboratories have entered into a joint project to establish a pool of competent middle school science teachers for rural communities in New Mexico. Teachers will improve their skills through participation in a three-week summer institute. The institute will include content on specific topics in science and mathematics, skills for teaching science, hands-on science demonstration activities, and instructional materials.

Carbon dioxide research (KP05)

Sandia is performing research to assist DOE in understanding the impact of carbon dioxide and other energy-related emissions on global climate. DOE's goal is to use both measurements and modeling to substantially improve the climate forecasts on which future policy decisions are likely to be based. Sandia's contributions to that goal include remote sensing for mapping key climatic feedback effects (e.g., clouds and water vapor), data management to support a key measurement initiative, and a major computational speed-up to enable higher fidelity modeling.

The Atmospheric Radiation Measurements (ARM) program will improve our understanding of radiative and cloud processes critical to predicting Earth's climate and its changes. This project provides scientific and management infrastructure support to that program in the areas of air and satellite-based measurements, operation of field sites, data management, and development of remote sensing instruments for water vapor and cloud measurements.

A principal objective of the ARM program is to improve the understanding of radiation transport in the atmosphere. Such understanding will in turn improve the predictive accuracy and capability of the general circulation models (GCMs) that are used to predict climate change.

Clouds play a dominant role in global climate. Unfortunately, the dynamics of clouds are not well enough understood to be accurately reflected in GCM parameters, and so are one of the greatest sources of uncertainty in these models. The ARM program will establish ground stations that will continuously measure various dynamic and macroscopic properties of clouds. One particularly important parameter is the bottom altitudes of clouds.

Sandia researchers have conceived of a novel approach to the passive measurement of cloud bottom altitudes, geometries, and dynamic parameters with Whole Sky Imager (WSI) cameras, based on exploiting the characteristics of optical flow fields. The project will develop, implement, and determine the accuracy of this flow field technique. Successful implementation of the technique will permit cloud bottom altitudes and other properties to be acquired passively by WSI cameras. Resolutions of 50 to 100 meters, depending on the number of WSI cameras deployed, over a 30 kilometer diameter region could be achieved. An effective passive acquisition technique will permit unattended operation and provide timely information complementary to that of active modalities at modest cost.

Superconducting super collider (KS)

Radiation-induced degradation of optical fibers is a potentially serious problem for high-energy physics experiments. The Superconducting Super Collider program requested Sandia's help, based on our work on radiation degradation of polymers. We will describe the nature of radiation-induced color centers and evaluate the role of impurities in the degradation processes. We are developing an accelerated aging methodology for predicting materials lifetimes. We will also establish structure/property correlations for optical polymers and scintillating dyes with respect to radiation tolerance. We will investigate the use of radiation-stabilizing additives and recommend optimal materials for scintillating fibers resistant to radiation.

Assistant Secretary for Conservation and Renewable Energy

Sandia's Conservation and Renewable Energy programs are concerned with the identification and development of technologies that have potential for significant energy, economic, and environmental payoffs in utility applications. Current programs include the solar electric technologies (photovoltaics and solar thermal), wind energy, geothermal energy, and high-temperature superconductor technology for electric power systems. Two important objectives of these programs are to establish technology bases that will support private sector efforts and to work actively with industry and users to accelerate development and acceptance of these emerging technologies. Engineering studies to identify preferred system applications and configurations, along with fielding and evaluating prototype systems, are major activities.

Sandia will play a partnership role with Los Alamos National Laboratory, industry, and universities in DOE's Industrial Waste Reduction Program (IWRP) sponsored by the Office of Industrial Technology. IWRP will focus its combined resources on the specific problem of waste produced in the manufacturing process. Waste reduction technologies developed by industry and government will be investigated and improved. In many cases, such technologies are being developed for energy efficiency and waste minimization within the nuclear weapons complex, and they provide an excellent opportunity for benefit to U.S. manufacturing industry.

We believe that R&D efforts in conservation and renewable energy programs will increase over the next five years and that developed technologies will begin to play a significant role as clean energy resources and export products.

Summary of Programs for
Assistant Secretary for Conservation and Renewable Energy
(Operating BA in $ million)

B&R Code	Program Title	FY90	FY91	FY92	FY93
AK	Electric Energy Systems	0.8	0.9	1.1	1.0
AL	Energy Storage Systems	4.8	4.2	5.6	4.3
AM	Geothermal	3.4	4.4	4.5	4.0
EB	Solar Energy	20.4	23.7	26.8	30.0
ED	Industrial Sector	3.4	3.4	4.5	4.6
EE	Transportation	0.5	2.5	2.5	3.0
	Total	33.3	39.1	45.0	46.9
	Percent of total operating funds	3%	3%	3%	3%

Electric energy systems (AK)

Sandia is conducting a multidisciplinary program designed to apply the rapidly occurring results of high-temperature superconductor research to the development of improved materials and conductors with properties suitable for use in electric power systems. The goals of this program are to develop materials and processes to produce yttrium and thallium-based ceramic oxides, high-temperature superconductors with critical currents suitable for high-current power system applications; to improve the mechanical and electromechanical properties of these materials so that conductors can be fabricated; and to develop methods for evaluating these conductors for electric power applications. The results of this work are expected to lead to optimized high-temperature superconducting materials, development of conductor fabrication technology, and the eventual design and evaluation of prototype devices that can improve the economics and energy efficiency of electric power generation and distribution systems. Emphasis is placed on active involvement of academia and industry through cooperative R&D agreements.

Energy storage systems—battery development (AL); and Transportation—electric vehicle project (EE)

Sandia has served as lead laboratory for DOE-sponsored engineering development of rechargeable batteries for almost ten years. Advanced rechargeable battery technologies have been developed for the Office of Energy Management and the Office of Propulsion Systems. The goal of this activity is to conduct engineering development of cells, modules, and ultimately, battery systems, with the final result being products that private industry can commercialize. Two projects have resulted in commercial products to date.

This program is implemented by first selecting promising electrochemical technologies that are judged to be suitable for one of the applications described above. Sandia then places competitive contracts with private industry to perform engineering development work. This arrangement keeps the development activities closely tied to the organizations that must ultimately commercialize a marketable product. Furthermore, Sandia requires a meaningful level of cost sharing in these contracts to assure that the industry participation will be focused and effective.

To better manage these projects, Sandia evaluates the performance of prototype units and conducts specialized research on critical problems. These "hands-on" activities significantly impact projects by clearly identifying problem areas and directing the necessary research activities to work toward solutions.

Battery technologies presently under development include sodium-sulfur, by Chloride Silent Power, Ltd., of Runcorn, England. Partially through Sandia contracts, this technology is being transferred to Beta Power, a U.S. company. This transfer will improve the commercial position of U.S. manufacturers. Sodium-sulfur is likely to be the first advanced battery to be marketed for electric vehicles. Another technology under development is zinc-bromine, by Johnson Controls, Inc., the largest lead-acid battery manufacturer in the U.S. Finally, contracts are being initiated for the development of valve-regulated lead-acid and metal-air batteries. The battery development program is dynamic; new technologies such as lithium-polymer are now being considered for future work.

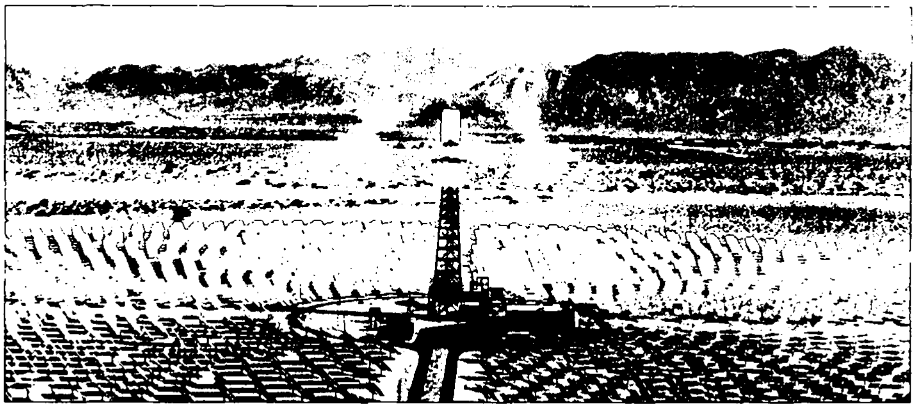
Geothermal (AM)

The primary objective of the Geothermal program is to develop new drilling and completion technologies that will make possible greater commercial use of U.S. geothermal resources. Technologies developed are also applicable to petroleum and mineral extraction. A second objective is to evaluate the geothermal potential of Long Valley Caldera, California, by drilling a deep exploratory well near the center of recent uplift within the caldera. A third objective is to develop joint industry/DOE projects in drilling and well completions.

In a new initiative, Sandia is collaborating with industry and the Bonneville Power Administration to expand commercial utilization of geothermal resources in the Pacific Northwest. Public utilities have forecasted a power shortage in that region during the 1990s of several hundred megawatts. There is considerable local public resistance to both coal-fired and nuclear power plants. Geothermal power is the only viable alternative energy resource that can meet the shortfall.

Sandia's contribution will be to help reduce the drilling costs associated with proving hydrothermal reservoirs. Slimhole drilling is a new technique that has the potential to reduce exploration reservoir assessment costs by fifty percent. Once demonstrated, slimhole drilling will have application to geothermal markets throughout the United States.

Areas of ongoing drilling technology development include lost circulation zone characterization and control; high-temperature logging tools based on downhole data collection, processing, and storage; acoustic telemetry of data through drill pipe; and core drilling for geothermal



This 10 megawatt central receiver power plant near Barstow, California, incorporates technologies that were demonstrated at the National Solar Thermal Test Facility located at Sandia Albuquerque.

exploration. The Long Valley exploratory well has been completed to a depth of 7,000 feet. Scientific measurements in this well will help define the evolution and current state of this major silicic caldera system.

Solar energy (EB)

Sandia has lead laboratory responsibility for the development of collection and conversion devices for generation of electricity by solar thermal processes.

The National Solar Thermal Test Facility located on Kirtland Air Force Base, New Mexico, is operated by Sandia as a test facility for solar thermal prototype hardware. The facility is maintained as the primary national center for the development of components and systems for solar central receiver and parabolic trough and dish power plants. The facility includes a 200-foot high solar receiver tower and a computer-controlled array of over 200 heliostats capable of focusing up to five megawatts of thermal power. Other hardware include two solar furnaces and several point-focus and line-focus solar concentrators.

Several industrial firms have used the facility to test designs of high-temperature solar receivers, large sun-tracking mirrors (heliostats), and trough and dish collectors for use in solar power plants. The capability to generate high-intensity solar beams has also been used by industry to test ceramic and ablative materials; to simulate aerodynamic heating and nuclear thermal flash; and to study combustion, solar chemistry, and other thermal effects. In research currently underway, the ability to destroy hazardous wastes using concentrated solar energy has been demonstrated. In addition to thermal effects, universities have used the facility's large-scale optical capabilities for astronomy. These optical capabilities also have application to lidar, a light-based remote sensing technique analogous to radar.

Over the years, Sandia, working with industry, has been improving the performance efficiency and cost-effectiveness of solar thermal systems. The industry is now at the point where commercial solar thermal power generation is economical in certain markets. Luz International, a private company, has constructed a modularized solar energy generating network using solar thermal designs developed by Sandia and collaborating companies. Luz is profitably selling electric power to supplement peak afternoon demand in southern California. The company has been successful in reducing its generating costs per kilowatt hour by two-thirds since its first module was brought on-line in 1985. Total generating capacity exceeds 350 megawatts, which is a little less than half the size of an average fossil fueled power generating station.

Improvements in the performance of the current commercial system design can be foreseen based on concepts now under development. "Power-tower" generating stations using molten nitrate salts for heat collection and storage will further lower energy costs and provide dispatchable power. Membrane concentrators of stretched aluminum or steel about 0.007 of an inch thick look promising as alternatives to plate designs. They will be more cost-effective to manufacture and will be dynamically controllable by manipulating the vacuum behind the membrane. Reflux receivers, also currently under development, offer more efficient and trouble-free receiver performance in a closed-loop system decoupled from the energy conversion unit. Advances in water detoxification technology are bringing this application closer to reality.

To exploit new concepts such as these and to accelerate their commercialization, certain next development steps are being conducted with industrial participation in cost-shared commercial applications. These government/industry partnerships represent teams that are uniquely qualified to rapidly advance each technology. The partnerships combine the manufacturing, marketing, and management skills of industry with the solar experience base and analytical capabilities of the government laboratories.

Sandia has principal responsibility within the DOE's Photovoltaic Technology Program for crystalline solar cell research, photovoltaic concentrating collector development, systems and balance-of-system technology development, and user-oriented technology outreach. While these efforts vary greatly in scope, the emphasis in each is to work with industry and users to accelerate development and acceptance of photovoltaic technology.

Photovoltaic cell and collector technology research activities support new, promising concepts and provide valuable device fabrication, testing, and product evaluation services to industry. Sandia engineers have demonstrated a 20-percent-efficient prototype photovoltaic concentrator module and are defining new, manufacturable module design concepts. These efforts, combined with current concentrator module and cell manufacturing technology initiatives, are designed to help industry more rapidly develop a cost-effective commercial product. Sandia engineers are working with the U.S. solar cell industry by improving industry cell fabrication processes through collaborative research in the Photovoltaic Device Fabrication Laboratory. Industry is also supported through cell measurements and analyses performed in the Photovoltaic Device Measurements Laboratory and module and array testing and evaluation in the Photovoltaic Technology Evaluation Laboratory.

The photovoltaic systems work concentrates on applications engineering, systems performance testing, data base development, and technology transfer to overcome technical and institutional barriers to photovoltaic technology market development. Photovoltaic systems are ideal for small-power, remote applications and are widely installed in developing nations under programs sponsored by the World Health Organization, the World Bank, multilateral development banks, donor agencies, and the U.S. Agency for International Development. Sandia's Photovoltaic Design Assistance Center has helped U.S. manufacturers compete in this growing international market and will continue to identify and develop both domestic and international markets for the technology.

Tom Hund focuses sunlight on the CONCEPT-90 photovoltaic concentrator. The prototype module features thin, flat components and improved optical elements. Its unique assembly will make it easy to manufacture.

Sandia is also working with the industry to develop a strategy aimed at the electric utility sector. Efforts include fielding of prototype systems, energy value analysis, and utility-oriented technology assistance activities.

Sandia is lead laboratory for vertical axis wind turbine (VAWT) technology, unsteady flow aerodynamics, and materials fatigue research. Construction and performance testing of a next-generation, commercial size VAWT research test bed has demonstrated performance improvements of 30–50 percent over existing commercial units. A current program initiative is to provide assistance to U.S. industry through cooperative R&D agreements in commercializing advanced wind turbine technology. This initiative should result in significant reductions in the cost of electricity from wind turbines, reaching as low as five cents per kilowatt-hour in the best wind resource locations.

Industrial Sector (ED)

Combustion Technology—Sandia is the lead laboratory for the Office of Industrial Technology's Combustion Technology program. The long-term goal of the program is to understand combustion processes to accelerate the introduction of new engine and furnace concepts for minimizing pollution and fuel consumption, while maximizing flexibility with strategic fuels, thus enhancing the nation's energy security posture. Process productivity in many industries is also dependent on efficient and well controlled combustion processes.

Sandia has been on the forefront of developing laser diagnostic instrumentation for the study of combustion processes. Recently, a new laser diagnostic technique, degenerate four-wave mixing, was developed. This diagnostic tool has the potential to permit temporally-resolved planar measurements of minor species and temperatures to be made in practical combustion systems, revealing details of combustion processes not previously obtainable.

Sandia has also developed diagnostics for use in unmodified production engines. A spark plug fitted with fiber-optic sensors for studying flame kernel development and an ion-probe instrumented head gasket for studying the end of the combustion process in production engines were developed in response to direct inquiries from industry. We believe that production engine diagnostics can be used to help optimize engine designs, and we are cooperating with engine designers at Chrysler, Ford, and General Motors.

We continue to work cooperatively with universities, industry, and other national laboratories and serve as the United States' technical representative to the Executive Committee for the International Energy Agency's Energy Conservation in Combustion Implementing Agreement. This participation enables us to track progress in energy combustion technology in Europe and Japan.

Materials Processing—Sandia is the lead laboratory in the Materials Processing by Design project of the Office of Industrial Technology materials program. Work involves two tasks: (1) rapid deposition of ceramics from gas streams with entrained solids; and (2) rapidly solidified metals.

The first task aims at developing predictive computational models, mechanistic information, and *in situ* optical diagnostics for use in designing and operating new ceramics processing technologies such as the Chemical Vapor Composites (CVC) process. The research is being performed at Sandia's Combustion Research Facility in collaboration with industry, including Thermo-Electron Technologies Corporation. Laser diagnostics are applied to probe high-temperature flow reactors which simulate CVC processes. Data are interpreted to discern chemical and physical mechanisms of chemical precursor decomposition and particle nucleation and growth. This quantitative and mechanistic information is integrated through extensive computational modeling of both the gas phase and the heterogeneous surface growth processes.

The objective of the second task is to provide computational models, as well as mechanistic information, to optimize both the production of metal powders through rapid solidification processing and the processing of such powders in consolidation and heat treatments. The goal is to achieve a fine, high-temperature microstructure in metallic alloys and intermetallic compounds that will extend the high-temperature performance of these materials in energy-related applications. Physical models and computational codes are being developed to define the relationships between processing variables (droplet size, cooling rate, superheat, gas solubilities) and vacancy supersaturation, gas entrapment, and microstructure. Physical models and computational codes are also being developed for the solidification of liquid metal droplets in high-velocity gas streams.

Advanced Industrial Materials Research—This project supports research in advanced industrial materials in two major technical areas: (1) novel acoustic wave sensors and (2) novel porous silicon processing technology for electrochemical and chemical devices. The work in novel acoustic wave sensors will focus on the application of acoustic wave technology to characterizing and controlling thin films.

The goals of this research are to (a) develop novel acoustic wave sensors for monitoring materials processing and (b) develop chemically selective sensors which can be used in process and environmental monitoring and control. The work in porous silicon processing will focus on controlled electrochemical etch silicon micromachining of the development of sensor devices. These devices will be used as humidity and pressure sensors for environmental control applications (e.g., smart buildings with heating, ventilation, and air conditioning control) with subsequent large energy savings.

Catalysis By Design—This project supports research in two major areas: (1) computer-aided molecular design of carbon dioxide activation catalysts and (2) catalysis by design. Specific goals of the first area of research are: (1) computer-aided molecular design of catalysts that mimic carbon dioxide-activating enzymes, (2) development of improved molecular modeling techniques, (3) structural studies of carbon dioxide-activating enzymes, (4) synthesis, characterization, and testing of designed biomimetic catalysts, and (5) integration of successful catalysts into a solar-driven process. Specific goals of the catalysis by design research are: (1) modeling of methanol in zeolite ZSM-5 with currently available models, (2) comparison of experimental data with modeling results, (3) development of massively parallel versions of computer models, and (4) application of improved computer-aided molecular design models to ZSM-5/methanol catalyst systems.

Office of Civilian Radioactive Waste Management

Effort for the Director of Civilian Radioactive Waste Management (RW) is expected to peak between FY 1993 and 2001. Sandia's major activities address transportation and geologic disposal of spent fuel and high-level radioactive waste.

Summary of Programs for Office of Civilian Radioactive Waste Management (Operating BA in $ million)

B&R Code	Program Title	FY90	FY91	FY92	FY93
DB	Nuclear Waste Fund	23.8	28.5	18.1	29.1
	Percent of total operating funds	2%	2%	1%	2%

Nuclear waste fund (DB)

The dominant effort in this program is the Yucca Mountain Project, an investigation to determine the feasibility of siting a commercial nuclear waste repository in the volcanic tuffs of Yucca Mountain on the Nevada Test Site. Sandia's responsibilities in this multifaceted project are to:

- support, through assessments of performance, the development of the design of the repository;
- perform laboratory tests and develop theoretical understanding of properties of tuff for repository design and performance assessment;
- determine parameters that describe water migration in tuff and develop predictive models;
- perform field tests to measure some geohydrologic properties of the rock in the repository system;
- develop and evaluate conceptual designs for borehole, shaft, and drift seals for the repository; and
- assess performance capabilities of the repository by using the repository conceptual design and known site characteristics; and
- use the assessments to determine compliance with regulations and guide the collection of data at the site.

The repository design resulting from this effort will be capable of handling high-level commercial and defense wastes as well as spent fuel. Sandia published the conceptual design to support the Site Characterization Plan in FY 1989. Our current role is to use our performance assessment capabilities to help set design requirements and to examine the design for its ability to comply with regulations.

Our role in testing and performance assessment will be to help develop a license application that DOE expects to submit to the NRC in 2001. Test results and analyses of performance will be major contributors to the commission's examination of the repository system's ability to meet regulations.

Sandia's Transportation Technology Center continues to support the RW program mission to develop safe and efficient spent fuel transportation and package handling systems. Design and production of the actual systems for transporting commercial wastes to storage or repositories are being performed in the private sector. Sandia will continue to participate in technology base and technology transfer activities that will be needed to certify this new generation of waste packagings.

Assistant Secretary for Fossil Energy

The primary objective of Sandia's fossil energy research and development is to provide technology that expands the base of domestic energy reserves and improves the nation's ability to use these resources efficiently. To achieve this objective, Sandia conducts programs in the combustion of pulverized coal and coal/water slurries; coal solids to liquids conversion processes; methane conversion; catalyst design; high-energy fuels; and gas from low-permeability sands and deep heavy oils. This strategy makes extensive use of our expertise in developing and fielding instrumentation, systems engineering and analysis, component development, materials science, and combustion. This expertise also supports the DOE project management office of the Strategic Petroleum Reserve. Our coal combustion programs interact strongly with U.S. industry through our Combustion Research Facility users programs.

Sandia collaborates with a number of international cooperative programs in fossil energy R&D. Current activities include exchanges with the United Kingdom and Japan in coal liquefaction, with Australia and Denmark in coal combustion, and with Venezuela in enhanced oil recovery.

Emphases in future fossil programs will be coal science, geosciences, and oil and gas recovery technology. The effort in coal science will be to develop a technology foundation for understanding the chemical structure and reactivity of coal and to use this understanding to explore concepts and processes for converting coal to clean liquid fuels. The goal in geoscience will be to develop a fundamental understanding of the characteristics of reservoir heterogeneities and to combine that knowledge with advanced diagnostics for recovery processes. This work will provide the basis for improved recovery of oil and gas.

Summary of Programs for
Assistant Secretary for Fossil Energy
(Operating BA in $ million)

B&R Code	Program Title	FY90	FY91	FY92	FY93
A A	Coal	4.0	4.1	4.7	6.6
A B	Gas	0.3	0.2	0.4	0.5
A C	Petroleum	1.7	3.7	3.3	3.5
S A	Strategic Petroleum Reserve - Storage Facilities Development	1.9	2.3	2.7	2.3
	Total	7.9	10.3	11.1	12.9
	Percent of total operating funds	1%	1%	1%	1%

Coal (AA)

Coal conversion—Sandia's long-range objective in coal science is to understand how reactivity is related to the molecular and macroscopic structure of coal, and from that understanding develop new coal conversion process concepts to provide a basis for industry to implement new and expanded uses for coal. Research in liquefaction is focused on the chemistry involved in the conversion of coal to liquid fuels at more moderate temperatures and pressures with optimum hydrogen use and with effective removal of sulfur and nitrogen. A group of hydrous metal-oxide ion-exchange compounds has been identified that are extremely active catalysts for the conversion of coal to premium liquid fuels. We are currently involved in an advanced development program that will culminate in the evaluation of these novel catalysts in a large-scale coal liquefaction test facility. This work is closely coordinated with the Pittsburgh Energy Technology Center and with other DOE contractors and industrial participants.

Investigators use computer-aided molecular design techniques to guide the synthesis of tailor-made catalysts. The work is currently focused on novel concepts for the direct conversion of natural gas (methane) to methanol and other liquid hydrocarbon fuels. Based on these results, synthesized materials have been shown in preliminary laboratory tests to be catalytic for the conversion of alkanes to alcohols. Computer-aided molecular design techniques are also being used to develop three-dimensional macromolecular models for coal to study the chemistry of large coal-related molecules.

Coal combustion—Sandia has developed an integrated program of basic and applied research in coal combustion that investigates pulverized coal combustion and related coal science issues under controlled laboratory conditions. We measure chemical and physical mechanisms and rates of ignition, devolatilization, and oxidation of coals and chars. The work requires development and application of laser-based diagnostics for the study of coal-derived, particle-laden combustion flows. We have also developed new instrumentation for real-time measurements of mass loading in fossil energy process streams. In addition, projects are underway that emphasize computational modeling of coal-derived combustion flows to predict fouling and slagging in commercial furnaces and boilers.

Enhanced gas recovery (AB)

The long-range objectives of the natural gas program are: (1) to improve the production of natural gas from low permeability gas reservoirs by combining comprehensive geologic characterization with the development of new reservoir stimulation technology; and (2) to develop novel separation techniques for the clean-up of natural gas streams to promote increased, economic use of natural gas.

Toward the first objective, Sandia performs geotechnical studies in the areas of sedimentology and natural fractures, geomechanics and *in situ* stress, and reservoir stimulation. These capabilities result from Sandia's key role in the Multiwell Experiment (MWX), a field laboratory in western Colorado conducted during the 1980s. MWX resulted in new perspectives on production from tight, naturally fractured reservoirs. Currently, Sandia is applying this technology in several ways: (1) to DOE's Slant Hole Completion Test being conducted at the MWX site, which tests the applicability of horizontal drilling to increase production from tight, fractured reservoirs in the West; (2) to developing a methodology for understanding and exploiting natural fracture systems in western basins; and (3) to the Gas Research Institute's projects in the Green River Basin of Wyoming, and at the Hydraulic Fracture Test Site—a major new GRI initiative.

A new initiative is the development of novel inorganic polymer materials for the separation of methane from mixed gas streams as an alternative to current energy-intensive methods such as distillation. This work is based upon the use of sol-gel technology, which provides tailored inorganic microstructures. Here, sol-gels are being used to create an inorganic gas separation membrane specific for methane supported on a porous, permeable ceramic substrate. Some of the work is being conducted at the University of New Mexico with Gas Research Institute co-funding.

Petroleum (AC)

The petroleum program comprises three areas of research: oil shale, advanced extraction process technology (AEPT), and improved oil recovery (IOR). The current oil shale effort is focused on blasting, which has shown to be an essential part of recovery of energy from this national resource, whether by mining and surface retorting or by *in situ* processing. Sandia has developed state-of-the-art computational capabilities in rock fragmentation and blasting. Further DOE support in this area is problematical; however, Atlas Powder Company is providing continuing funds for us to address their needs in surface coal mining.

One goal for AEPT is to develop superior geophysical techniques for improved reservoir characterization and *in situ* process monitoring. The current focus is electrical/electromagnetic (E/EM) geodiagnostic techniques. A key effort is the development of advanced computational capabilities for (1) design and assessment of the many different source receiver E/EM variations that are possible, and (2) the interpretation of field data by both forward and inverse analyses. Selected methods are evaluated in field experiments conducted at various sites in conjunction with other national laboratories, industry, and universities.

Also for AEPT, we are exploring the development of novel catalysts for the direct conversion of natural gas to oxygenates and/or other valuable intermediates. This work makes extensive use of computer-aided molecular design techniques to evaluate possible molecular catalyst designs, which are then synthesized, characterized, and tested for catalytic activity and selectivity.

A sea floor earthquake measuring system (SEMS), originally funded by AEPT, is now being supported by the Department of Interior's Mineral Management Service and industry. Two units are emplaced offshore California, and measurements of seabed response to earthquakes are being correlated with the response of offshore platforms in this joint project.

For IOR, the long-range goal is to develop technologies that will improve production of both heavy and light oils. Currently, there are two aspects. First, studies are performed that provide an IOR perspective to the E/EM geodiagnostic work described above. The resistivity changes occurring during steamflooding or other IOR processes are determined from analyses of industry field data. A petrophysical model and a reservoir simulation capability have been developed and applied that describe and predict the resistivity changes caused by the process. Second, our measurement of *in situ* stresses and other long-term phenomena at the Ekofisk Field in the North Sea, in conjunction with Phillips Petroleum, has led to a concept of geomechanics for reservoir management, which views reservoirs as dynamic systems that must be studied with full awareness of their changing conditions over their lifetimes. This concept is now being applied to domestic U.S. reservoirs in collaboration with industry.

Under both IOR and AEPT funding, a joint Oil Recovery Technology Partnership with Los Alamos National Laboratory has been established with the objective of using the capabilities, facilities, and expertise of the DOE national laboratories to assist the nation's petroleum industry. Sandia projects under the Partnership are:

1. Application of tight gas reservoir technology to tight oil reservoirs in conjunction with the Harvey E. Yates Company, an independent producer;

2. Development of a truly advanced, multistation borehole seismic receiver with OYO Geospace, which is now marketing a single station version of the tool;

3. A study into the geomechanics of horizontal wells in cooperation with Oryx Energy Company, a leader in horizontal well technology;

4. A joint investigation with Petrolite Corporation of the chemical changes occurring during hot oiling, a procedure applied nationwide thousands of times a day to stripper (low production) wells by independent producers; and

5. Development of an advanced, three-component borehole seismic source together with Chevron and Los Alamos.

An additional partnership task permits response to inquiries from industry. An industry-based Partnership Steering Committee, a Review Panel, and a Crosswell Seismic Forum have been established to provide review, evaluation, and guidance for partnership activities.

A short-term effort under IOR support is a systems analysis to study the effect of the addition of new natural gas pipeline capacity on shut-in heavy-oil production or on new enhanced oil recovery projects. This analysis contributes to the action plan for implementation of Initiative 37 of the National Energy Strategy.

Bruce Engler and Gerard Sleefe hold a prototype of the borehole seismic receiver that was developed at Sandia and has been successfully licensed to industry. The receiver's high resolution and multiple connection capabilities are particularly suited for cross-well seismic imaging of oil and gas fields.

Strategic petroleum reserve (SA)

The DOE Strategic Petroleum Reserve (SPR) is planning and developing storage for the currently approved 750 million barrels of crude oil, primarily in salt mines and solution-mined caverns in salt domes in the Texas-Louisiana Gulf Coast region. Sandia is supporting the implementation of the geotechnical program. This program provides a comprehensive, site-specific, geotechnical data base for the planning, design, construction, and safe storage of SPR crude oil. These data will aid in assessing the long-term stability of SPR storage caverns and mines to minimize the potential for storage cavity failures that could result in significant environmental impacts, economic losses, or inability to withdraw oil when needed. The program involves site characterization, engineering design assistance, and evaluation, including numerical simulation studies, laboratory and bench-scale testing of salt cores from SPR sites, monitoring, interpreting field events, and evaluating and developing instrumentation. Issues related to the quality of stored crude oil are also addressed.

Sandia has provided geotechnical support for the planning, design, construction, and operation of the SPR crude oil storage facilities since 1980. Our role is to acquire technically comprehensive, site-specific data and combine them with analytical models to address site characterization, leaching, and drilling activities at different SPR sites. As the quantity of stored oil increases to well over two-thirds of the approved total, the emphasis of our efforts has turned from site characterization studies to monitoring long-term integrity and stability of the caverns and mines.

The program develops and fields instrumentation to provide long-term cavern monitoring, validate cavern creep closure models, assess the integrity of wells and casings penetrating the caverns, and certify the integrity of caverns. In addition, engineers address specific geotechnical problems, such as the potential impact of water leaks on withdrawal of oil from the Weeks Island mine, and conduct studies to determine optimum cavern drawdown scenarios based on geotechnical considerations.

The technology developed for cavern creation, testing, and operations is currently being applied to commercial cavern development for natural gas storage under a technology transfer program.

Sandia will additionally support expansion studies to increase the SPR capacity to one billion barrels. These studies will include geophysical studies of candidate salt domes and tradeoff analyses of costs associated with expansion into new salt domes.

Assistant Secretary for Nuclear Energy

Current efforts for the Assistant Secretary for Nuclear Energy focus principally on advanced military and civilian space nuclear power applications and terrestrial reactor development, the latter emphasizing improved nuclear power plant safety, reliability, and economics. Many aspects of these efforts are closely related. Specific activities emphasizing Sandia's strengths include studies of systems concepts and technology evaluation, safety and reliability analyses, electronic systems and devices for operation in severe environments, testing, engineering of high-reliability components, and knowledge of materials behavior and degradation. We plan to increase the effectiveness and size of our efforts by expanding our support of NASA's Space Exploration Initiative (see page 38) and by establishing technology alliances with industry, bringing our expertise to bear on significant problems facing nuclear power.

Summary of Programs for
Assistant Secretary for Nuclear Energy
(Operating BA in $ million)

B&R Code	Program Title	FY90	FY91	FY92	FY93
AF/GE	Nuclear Energy R&D / Materials Production	4.1	7.4	8.3	8.0
	Percent of total operating funds	<1/2%	1%	1%	1%

Civilian reactor development (AF); and Materials production (GE)

The objectives of this work are to improve the safety, reliability, and cost-effectiveness of commercial light water reactors and thereby increase their acceptability and to develop technology for space power applications.

Sandia operates the LWR Technology Management Center for DOE. Activities are focused on developing and implementing reactor safety features and concepts that offer significant safety improvements and longer operating lives, and on developing approaches for improving the reactor licensing process. Work areas include studying the technical, institutional, and economic aspects of extending the licensed lifetime of commercial nuclear power plants, conducting technical studies for DOE's nuclear regulatory reform legislation currently before Congress, and applying new techniques to the reactor licensing process.

We work with the nuclear power industry to resolve technical issues associated with extending the useful life of operating light water reactors. In addition, we will be investigating improved approaches to the licensing of nuclear plants and exploring technological developments in support of future nuclear plant designs. This work is closely coupled with industry efforts. Most of this work is contracted to industry, universities, and other national laboratories.

These programs form a basis for closer cooperation with industry. We are in the process of forming technology alliances with industry to couple Sandia's strengths with the nuclear power industry's experience and knowledge to address issues of importance to current and future nuclear power plants.

Nuclear power is an essential component of this nation's energy supply mix, and its environmental advantages are becoming appreciated in light of worldwide concern over the emission of greenhouse gases from fossil fuel power plants. The U.S. has invested over $200 billion in nuclear power facilities that generate 20 percent of its electricity. Nuclear power plants are licensed for 40 years, but studies indicate that plant life could be extended by an additional 20 or 30 years. If an average of ten years additional operation could be gained, $170 billion dollars would be saved. Sandia has devised a step-by-step methodology for evaluating plant equipment—focusing on systems, structures, and components that are subject to age-related degradation—that may pave the way for safe, extended operation of nuclear power plants. The methodology is endorsed by the nuclear power industry as its technical approach to license renewal and has been submitted to the Nuclear Regulatory Commission for consideration in formulating license renewal regulations.

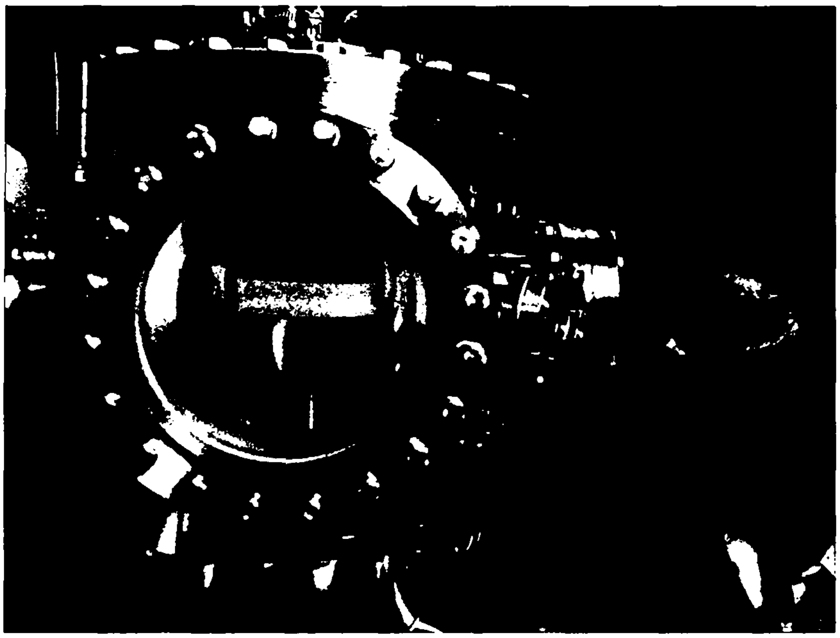
Within the DOE Space Nuclear Power Program, Sandia is responsible for independent safety, concept, and technology evaluation and instrumentation and control.

Sandia performs independent analyses of all safety issues related to space nuclear power. This activity includes recommending and developing new accident and response models as needed, conducting independent safety tests, and recommending design changes to meet safety criteria and specifications.

Sandia plays a major role in the area of instrumentation and control (I&C) for both space and terrestrial reactors. Our expertise in this area has been recognized by our selection as the lead laboratory in I&C for the SP-100 Space Power Technology program. Through this program, Sandia has become heavily involved in the development of advanced technology for reactor control systems, including digital and linear microelectronics. We are currently developing high-temperature, radiation-hardened electronic components for the SP-100 program.

Multiple Sponsors

This section describes programs that derive their support from more than one sponsor. The resource tables at the end of this document do not contain an entry for multiple sponsors; resource requirements are included in the resource tables for each sponsor.



Ben Aragon peers through the "portholes" in the GEC (Gaseous Electronic Conference) radio frequency reference cell. Sandia led a national effort to develop the standard plasma research reactor, which is already benefitting U.S. research in plasma etching, an essential step in modern microelectronics manufacturing.

Silicon semiconductor technology (ASDP, ER/BES, and SEMATECH)

A competitive domestic semiconductor industry is vital to U.S. national security in the broadest sense. Without a concerted, centralized effort to revitalize the microelectronics industry, there is concern that the United States will lose its microelectronics capability and become dependent upon foreign supplies for the next generation of microelectronics technology. A principal concern in the competitiveness of the U.S. semiconductor industry is the length of time required to effectively translate university research developments into manufacturing advantages. Sandia is involved in several initiatives to speed up this process.

Sandia participates with the University of New Mexico, Rensselaer Polytechnic Institute, and the University of Arizona in SEMATECH-sponsored Centers of Excellence in metrology (UNM), metallization (RPI), and ultra-clean process technology (U of A). In addition, SEMATECH has established the Semiconductor Equipment Technology Center (SETEC) at Sandia to apply research in reliability modeling and process technology to the development of new integrated circuit production equipment by U.S. manufacturers.

The SETEC approach is to assist the equipment manufacturers in utilizing the scientific and technological base that exists in the national laboratories and to support industry in areas of interdisciplinary, fundamental, and applied research. The goal of SETEC is to enable U.S. semiconductor equipment manufacturers to produce leading edge equipment for the semiconductor industry.

Sandia is also bridging the gap between universities and the semiconductor industry in reliability assessment and advanced fabrication techniques.

Semiconductor component development program (ASDP, DoD, and other federal agencies)

Nuclear weapon and space satellite applications call for custom integrated circuits with very high reliability and high tolerance to various forms of radiation. Therefore, special efforts must be made to design, fabricate, and qualify integrated circuits for military and space use.

Semiconductor component development activities include nonvolatile memory development; development of computer aids for integrated circuit design and testing; design of families of general purpose microprocessors; development of improved integrated circuit qualification methods; and development of a standard electronic parts list. Ensuring availability of high-reliability, radiation-hardened microelectronics through partnerships with U.S. industry for the production of qualified parts is an important element of the program.

Sandia's Microelectronics Development Laboratory (MDL) provides 12,500 square feet of nearly vibration-free, better than Class 1* clean room space. A 1.25 micron, radiation-hardened CMOS integrated circuit fabrication capability has now been installed in the MDL and is being used to fabricate test structures to support the development of improved qualification procedures. In addition, a flexible capability to process ferroelectric materials, perform micro-machining, and process compound semiconductors is being installed.

* A Class 1 clean room contains fewer than one particle per cubic foot of air.

Compound semiconductor technology (ASDP, ER/BES, ASCRE, and DARPA)

Current microelectronics in both the defense and civilian sectors is, for the most part, based on silicon integrated circuits. However, there is growing application in Sandia programs for compound semiconductors in electronic and photonic technology. As part of an effort to meet this demand, the Center for Compound Semiconductor Technology (CCST) has been established. The CCST focuses on research and development emphasizing materials growth, device design, modeling, and prototyping in compound semiconductors such as gallium arsenide, indium arsenide, and others. New device concepts, such as unlimited radiation hardness, optically triggered high current switches, and nonvolatile memories in compound semiconductors have been demonstrated in the CCST.

Work for other DOE locations, contractors, and offices

Sandia performs work for other DOE elements as requested to support programmatic and institutional requirements. These elements may include field operations and facilities of the nuclear weapons complex as well as special programs administered by DOE headquarters offices.

Summary of Programs for Other DOE Locations, Contractors, and Offices
(Operating BA in $ million)

		FY90	FY91	FY92	FY93
	Miscellaneous Locations	15.5	18.0	26.7	25.0
NT	Intelligence		2.1	2.1	2.1
WA50	Minority Economic Impact		0.7	2.5	2.6
	Total	15.5	20.8	31.3	29.7
	Percent of total operating funds	1%	2%	2%	2%

Sandia assists other DOE locations with facility safeguards and security matters. We have a broad base of experience in this field as it relates to the safety and security of nuclear materials and operations.

Sandia developed and delivered the Device Transport Vehicle (DTV) to DOE's Nevada Operations Office for use at the Nevada Test Site. This vehicle substantially upgrades the safety and security of nuclear explosive test devices from their point of assembly at NTS to their point of emplacement for detonation.

We also developed a software security system evaluation tool called ASSESS. This tool has been used at many DOE sites to help identify security needs and the adequacy of upgrades.

Sandia is involved with the Portsmouth Gaseous Diffusion Plant in the design and implementation of their alarm communications and display system. We are providing an integrated safeguards system with Los Alamos National Laboratory at the Argonne National Laboratory West that will provide physical security and materials accounting features. We are also consulting with a number of other sites, including Savannah River, Y-12, Pantex, Allied Signal, Mound Laboratories, Lawrence Livermore, and Bettis Naval Reactors.

Sandia performs work of a classified nature for the DOE Office of Intelligence.

We are playing a major role in the Waste Energy Conservation program sponsored by DOE's Office of Waste Reduction. This program is an alliance between the Department of Energy, including Sandia and Los Alamos national laboratories, and industry for the purpose of stimulating the development and transfer of waste reduction and energy saving technologies to industry.

Sandia conducts or participates in several minority education development and support programs under the sponsorship of DOE's Office of Minority Economic Impact. They include: DOE's Science and Technology Alliance; the University of New Mexico Minority Engineering Program Model; a joint Sandia/Los Alamos Mid-School Rural Teacher Training Program; Sandia's Science Advisors Program; and support of the solar detoxification program at the University of Turabo.

Work other than for DOE

Nearly 30 percent of Sandia's programmatic effort is work for agencies other than DOE; about 80 percent of that effort is for the Department of Defense. These "reimbursable projects" exercise and strengthen the capitalized resources we maintain for the nuclear weapons programs. They also make cost-effective use of existing federal investment for other technological needs in areas such as conventional defense, security, strategic defense, treaty verification, microelectronics, and space exploration. The technology base developed through our work for DOE provides us expertise and capabilities not always found in industry or in other government agencies; hence, opportunities to contribute technological solutions to agencies other than DOE not only help solve a national need, but also help us maintain our abilities to perform our DOE missions.

Before undertaking a reimbursable project, we ascertain that no interference with DOE weapon programs will result. Acceptable projects will involve problems of national importance that reasonably match our DOE missions and capabilities and are feasible in terms of program goals and availability of required assets. We are regulated to undertake only work in which we have special capabilities as a consequence of our technical expertise or facilities. Often this work is completed jointly with or transferred to private industry, requiring our involvement only so long as needed to meet the agency's objectives. Industrial bidders for DoD prime contracts will sometimes include Sandia technical assistance as part of a proposal, and unless constrained by service procurement regulations, we make our capabilities available to any legitimate bidder. If appropriate, Sandia capabilities may be communicated to all interested parties at bidders conferences hosted by the procuring service.

The discussions that follow outline important aspects of our programs for non-DOE agencies.

Summary of Work for Entities Other Than DOE (Operating BA in $ million)

Agency	FY90	FY91	FY92	FY93
Department of Defense	280.6	254.5	311.0	327.0
Nuclear Regulatory Commission	14.6	14.0	19.6	20.0
Other Federal Agencies	27.0	28.6	24.0	30.0
All Other	13.3	11.7	13.8	16.0
Total	335.5	308.8	368.4	393.0
Percent of total operating funds	30%	27%	27%	28%

Department of Defense

Army

Our parachute and control system technologies are being used to develop high-speed, low-level, airdrop resupply systems. We are exploring guidance concepts to defeat high-value battlefield targets and are studying the effects of low-observable materials on survivability in the battlefield of the future.

We have developed an improved, all-electronic, safing and arming system for the Patriot missile. The design is being transferred to industry for production, and we are currently qualifying a supplier for the Army.

Sandia evaluates enhanced security at NATO sites by providing technical support, operational tests, and methods to detect intruders and delay unauthorized access to weapons. To extend this work, the vice chief of staff of the Army requested Sandia to participate in a number of activities associated with low-intensity conflict. These activities included force protection evaluations in Honduras and the Sinai and other related studies and R&D tasks.

Sandia is developing packaging design requirements and a design concept for on-site transportation of obsolete chemical munitions that are scheduled for destruction at Army sites within the continental U.S. We will serve as technical advisor when the program includes private industry participation.

Navy

The Laboratories has long collaborated with the Navy on development of weapon subsystems. We were especially pleased, moreover, to have been able to contribute to the Navy's war-fighting effort during Desert Storm. Sandia's Tonopah Test Range was the site of night validation testing of the Tomahawk land attack cruise missile. (It may be recalled that a night-fired Tomahawk was the first shot opening the coalition attack on Baghdad on January 16, 1991.) Sandia provided camera coverage for documentation and measurement of target accuracy; telemetry reception, recording, and data reduction; and post-test missile recovery.

Continuing the successful relationship with the Navy that produced integrated arming, fuzing, and firing systems for the Mark 3 and Mark 4, Sandia developed an integrated AF&F system (one combining fuzing and firing functions) for the Trident II/Mark 5 weapon program that provides fuzing options to enhance effectiveness against hardened targets. The Trident II/Mark 5 development program was completed in 1991, and first production to support IOC is nearly complete.

Quality Assurance evaluation of Mark 3 and Mark 4 reentry body hardware is continuing while the systems are in stockpile. Similar activity for the Mark 5 is beginning. Production support activities for arming and firing components of the Mark 4 reentry body have continued over the past year, and production requirements for the Mark 4 have been completed.

Our experience in systems engineering, safing and arming systems, aircraft interfacing, parachutes, and aeroballistics permitted us to contribute to the development of two new conventional air-delivered gravity bombs. Sandia's role in the program, managed by the Naval Weapons Center, China Lake, was to develop a common bomb control unit and tail assembly.

Sandia has performed reimbursable work in support of Marine Corps expeditionary force capabilities. Drawing upon our expertise in sensor technology and rugged microelectronics, we developed a family of remote sensors for perimeter security, battlefield route surveillance, and support of amphibious assaults.

Our experience with deployable sensor systems has further led to the development of a Mini Intrusion Detection System for the armed services and other federal agencies. MIDS provides advanced, cost-effective patrol security for small installations. Sandia's competency and experience base in sensor-based security systems may have application to a variety of unique government requirements.

Our capabilities in providing physical security robotics for DOE site security have led to the development and demonstration of teleoperated battlefield vehicles. Sandia is also providing consultation as these concepts are pursued by the Marine Corps and private industry for further development and production.

During Operation Desert Storm, we developed a large fuel-air explosive device for the Marines, as well as remote control systems for Marine Corps landing craft to allow unmanned penetration of the formidable surf-zone mine fields deployed in Kuwait.

Air Force

We were pleased to make a contribution to the Air Force's war-fighting effort during Desert Storm. Sandia provided flight test support at its Tonopah Test Range (TTR) for rapid development of a 4,700-pound conventional penetrator bomb. The weapon was a long, penetrating glide bomb fitted with a laser guidance system from a smaller weapon. It was designed to destroy deep underground bunkers having urgent target priority.

A test at Tonopah Test Range in February 1991 was the only pre-combat drop test of the deep-penetrating bomb, which buried over 100 feet into the desert floor. Two days later two of the weapons were dropped on a bunker complex at the Al Taji air base near Baghdad. The target, a high command center, was destroyed. TTR has unique optical trajectory measurement capabilities (including the ability to measure penetration angles) that make it ideal for testing this type of munition.

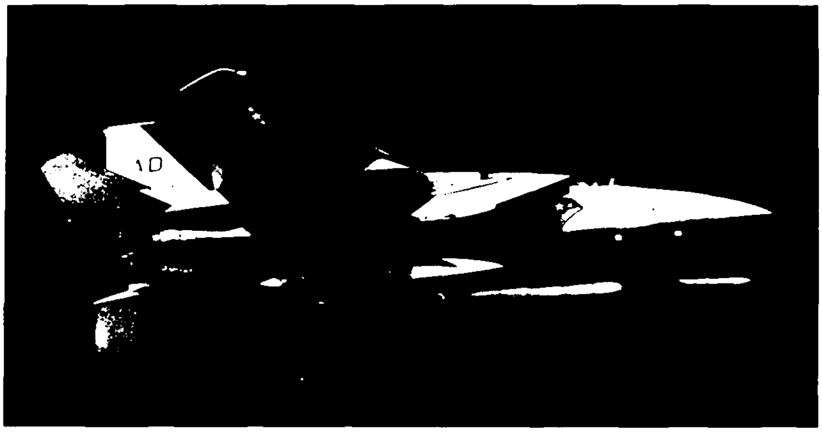
The 4,700-pound GBU-28 penetrator bomb was given a pre-combat test drop at Sandia's Tonopah Test Range on February 24, 1991.

The Laboratories has long collaborated with the Air Force on development of weapons subsystems, satellite instrumentation, and physical security systems. Currently, we are collaborating with Motorola under subcontract to develop an upgraded ordnance package for the AMRAAM (Advanced, Medium-Range, Air-to-Air Missile). Sandia's responsibilities in the program are (1) system analysis and support, (2) the design of an all-electronic safing and arming system, and (3) the design of the slapper detonator system. Sandia's expertise for these tasks comes directly from the nuclear weapons program and represents unique capabilities that supplement rather than compete with industry.

We are continuing to support Air Force satellite programs with special flight instrumentation systems, sensors, and ground processing capabilities to meet unique requirements for special applications. These activities include providing sensors and data processors for satellite tactical and surveillance missions and providing ground-based calibration and data processing systems to support Air Force users of data for these missions. We are continuing to support Air Force Ballistic Missile Office/Advanced Strategic Missile System reentry vehicle programs with work devoted to developing reentry vehicle technology.

Sandia is working closely with the Air Force Phillips Laboratory to support DoD's thermionic space reactor program. The TSET (Thermionic System Evaluation and Test) program involves nonnuclear testing of a Soviet TOPAZ II reactor. Sandia is developing the test schedule and providing the test director and technicians. In addition, we are developing computer software that can be used to predict TSET test results as well as the response of thermionic space reactor systems under various transient conditions. Finally, Sandia is providing technical expertise to assess the potential of various thermionic space reactor designs.

We and the Air Force Central Inertial Guidance Test Facility are continuing the



Sandia is working with Motorola to design a new ordnance package for the Advanced, Medium-Range Air-to-Air Missile. AMRAAMs are used on a variety of Air Force, Navy, and NATO fighter aircraft.

development of a small, high-accuracy, ring laser gyro inertial navigation system. This system is being developed for maneuvering reentry vehicle applications but will be used by the Air Force in a scoring system to evaluate other missile guidance systems.

Activities in support of U.S. Air Force physical security programs include systems design and development of weapon storage vaults, intrusion detection, communications, and assessment technology, as well as participation in evaluating the needs and appropriate application of these technologies to specific sites. Air Force organizations with whom these activities are undertaken include Electronic Systems Division of Systems Command, Electronic Security Command, Tactical Air Command, U.S. Air Force Europe, and other smaller organizations. These efforts draw directly upon and supplement our experience in providing security technologies for the DOE nuclear weapons complex. We are now soliciting proposals to transfer some of these technologies to private industry.

We are also working with the Air Force on RF sources for ultra-wideband radars.

Strategic Defense Initiative Organization (SDIO)

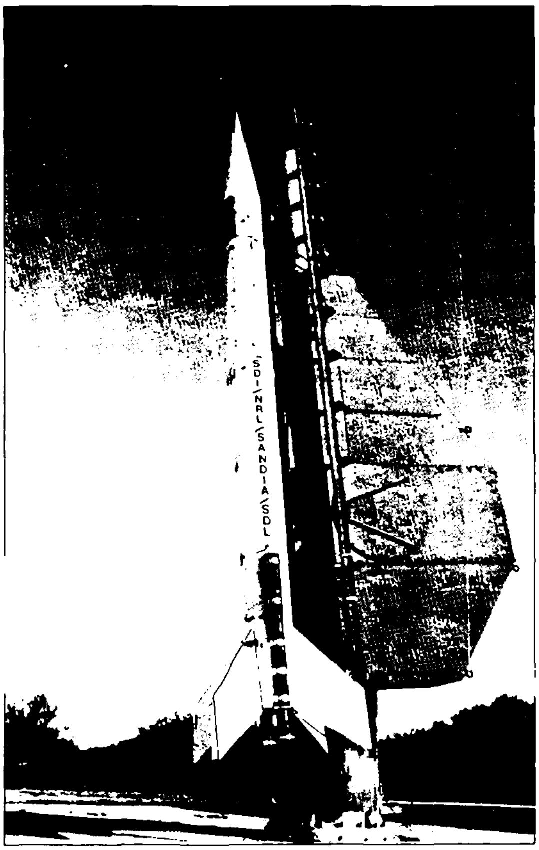
SDIO sponsors a broad range of research on technologies relevant to Sandia's prime mission as well as to its own programmatic goals. In this regard, Sandia is supporting SDIO in a number of areas where we have either special capabilities or unique facilities and where the work does not compete with our DOE mission responsibilities. We plan to continue working with SDIO in the areas of discrimination, countermeasures, space power, pulsed power, threat definition, space survivability, space experiments, and new concepts.

Discrimination activities include the definition of observables as well as the evaluation of the DELPHI concept, which uses an electron beam for interactive discrimination. These activities make use of our pulsed power and beam propagation expertise as well as our ability to provide advanced instrumentation for and to fly a variety of essential experiments.

The countermeasures evaluation activity at Sandia stems from our experience in nuclear weapon design, our previous activities in reentry vehicle technology, and the application and evaluation of concepts that could make strategic and theater nuclear weapons more robust against an SDI-type defense. This work will help provide a baseline from which SDIO can evaluate the cost-effectiveness and cost to the adversary of deploying countermeasures should any specific concept be fielded by the United States. Our activities in threat definition help provide a better understanding of both near-term and long-term strategic and theater ballistic missile threats.

Our rocket launching test facilities in Tonopah, Nevada, and Kauai, Hawaii, allow flight testing of instrumented vehicles in support of these activities. The Kauai facility is being upgraded under funding from SDIO and will be capable of launching STARS boosters later this year. We anticipate continuing to use this upgraded facility to support both SDIO-sponsored tests and needed flight activities for the DOE nuclear weapons program.

A three-stage Strypi XI rocket is poised on the launch pad at Sandia's Kauai Test Facility prior to an SDI-sponsored flight test coordinated with a Naval Research Laboratory satellite.



One of the technologies important to SDIO is that of space nuclear power. Sandia has continued to develop its capabilities to model space power systems for SDI applications and has produced comparative evaluations of the various systems for SDIO, DOE, the Air Force, and the Army. Our work also involves the development of instrumentation and control technology and independent analysis of safety features.

Sandia's capabilities in the area of radiation hardening serve as a foundation for evaluating methods and penalties for increasing the survivability of objects in space through hardening of the electronics and structure, as well as evaluating methods for maneuverability, shootback, and other features.

Capabilities developed primarily for the inertial confinement fusion program and for aboveground effects simulation are being applied for a future need to launch many satellites into low earth orbit. The Sandia coil gun has been developed through concept feasibility under SDIO sponsorship. In addition, new split-cavity oscillator microwave sources for high-power microwaves are being developed in the interest of more compact jammers, radars, and weapons.

Sandia builds unique, instrumented targets for experiments conducted for SDIO and the U.S. Army Strategic Defense Command. In order to provide more uniform assessment of proposed SDIO Strategic Defense System elements, a baseline target set has been defined consisting of target vehicles and potential penetration-aiding articles developed by Sandia. The experiments are launched from Vandenburg Air Force Base and from Kauai Test Facility. The Operational Deployment Experiment Simulator (ODES) is a target deployment platform being built for several SDIO experiments that will be flown on the STARS missile system.

Finally, Sandia, through its systems analysis organizations, is providing direct support to the SDIO Phase One Engineering Team (POET). In the past year, Sandia has chaired the threat specification group for this team, and we expect to continue to participate both in threat specification evaluation and command and communications issues.

Sandia is providing advanced computing capabilities to POET. In the past year we have developed massively parallel tracking and correlating programs that can handle scenarios thousands of times larger and more complex than previous efforts could. We expect to demonstrate the potential for real-time tracking and correlation for realistic SDI scenarios within the next year.

Other DoD

The Joint DoD/DOE Munitions Technology Development Program, enabled by the 1985 DoD/DOE Memorandum of Understanding, is a jointly funded effort of research and development to pursue innovative warhead, explosive, and fuze technologies and to improve nonnuclear munitions technology across all service mission areas. Projects pursued under this program include energetic materials, armor/

anti-armor, guidance and control, smart mines, countermines, and systems studies.

Each topical area under this program is overseen by a Technology Coordination Group (TCG) that acts as liaison between DoD and DOE and establishes a channel for technology exchange. Composed of technical experts from each agency, these groups work to ensure maximum benefit from the program. TCGs establish measurable deliverables and realistic schedules, coordinate multi-service requirements, establish classification guidance, monitor activity, and provide semiannual reports on project status and potential new projects. TCGs conduct technical reviews and provide written assessments to the Technical Advisory Committee. The Technical Advisory Committee administers the program and provides policy guidance. It reviews technical assessments from the TCGs, evaluates new proposals, and establishes the program plan.

Because much of the technology base developed in our nuclear weapons work is directly applicable to DoD needs in conventional munitions, this program has brought about major improvements in conventional munitions consistent with DoD's long-range planning and with DOE's mission and is an effective mechanism for leveraging available, already capitalized R&D resources. At the same time, the costs associated with maintaining many of the core competencies required for the nuclear weapons program are shared by DoD, and the resources are further exercised, challenged, and strengthened.

Sandia's Microelectronics Development Laboratory supports several DoD agencies with technology development, custom device design, and a limited amount of emergency parts supply through DOE or commercial vendors. Similarly, Sandia provides unique components, such as high-voltage switch tubes, and the consultation of various technology experts (*e.g.*, pyrotechnic device experts) as requested by DoD agencies.

DARPA is sponsoring experiments and analyses of high-frequency seismic wave propagation and detection to improve the verifiability of nuclear test bans. The agency is also sponsoring the continued development of hypersonic delivery and lethality for kinetic energy penetrator warheads for precision strike applications.

As an outgrowth of our research on novel warhead technologies, we are conducting R&D on methods for quieting future U.S. submarines. We are also using our extensive computer simulation facilities and expertise to demonstrate more lethal warheads for future torpedoes.

For the Defense Nuclear Agency (DNA), Sandia is developing improved security hardware, operational concepts, and tactics for the military security forces. With sponsorship from the Office of the Secretary of Defense and DNA/DOE funding, we are exploring means by which the survivability and security of nonstrategic nuclear forces can be ensured in the twenty-first century. We are also providing explosively actuated closures for use on DNA-sponsored tests at the Nevada Test

A strategic alliance between Sandia and DNA was formally established in August 1991 when Sandia President Al Narath and DNA Director Maj. Gen. Gerald Watson signed a memorandum of agreement. The alliance promotes cooperation in research, development, and testing related to national security missions.

Site and are making diagnostic measurements related to experiment protection and containment.

DNA is also sponsoring the research, development, and adversary analysis of new systems and technologies for portal and perimeter monitoring and the transition to private industry of Sandia's R&D in tagging for production of field systems.

On August 19, 1991, Sandia and DNA established a strategic alliance to strengthen their collaboration in nuclear weapon effects testing and in the design and evaluation of survivable systems. The memorandum of agreement encourages technology transfer and staff interaction between the two organizations, mutual access to complementary and unique facilities, teamwork in professional staff development, coordination of programmatic responsibilities, and efficient use of limited resources. We believe the alliance will strengthen both organizations and bolster the nation's core competency in weapon effects testing.

For the Defense Communication Agency, we have developed a broad range of technologies for survivable command and control centers. These technologies—including a broadband data bus with computer-aided remote control and monitoring—are being used for classified operational systems and proof-of-concept applications.

Extensive studies are continuing in the area of quick strike weapons in a regional conflict context. The Sandia concept of Quick, Precise, Attack System (QPAS) offers a highly integrated target acquisition, data fusion, retargeting, and warhead delivery system that is currently unavailable.

Nuclear Regulatory Commission

Sandia continues a broadly based research program for NRC in probabilistic safety analysis, reactor safety research, engineering technology, low-level waste management, and safeguards and security. We also provide NRC with technical assistance in the safety assessment and licensing of commercial nuclear power facilities.

We have performed many of the risk assessments sponsored by NRC, developed methods that now define the state of the art, participated in major technology transfer efforts, and addressed important regulatory issues amenable to solution by risk assessment. We have developed methods to analyze plant systems, operations, human performance, accident processes, transport of radioactive materials, and health and economic impacts. Major emphasis has been given to the treatment of uncertainties.

Our severe accident research program funded by NRC involves participation of the international reactor safety research community. Several unique experimental facilities have been developed at Sandia to investigate the diverse physical phenomena that may be important in postulated severe accidents. In-pile experiments to study accident progression effects are performed in the Annular Core Research Reactor. The theoretical work centers on the development and validation of mechanistic codes (*e.g.*, MELCOR, CONTAIN), which integrate severe accident knowledge. Results of the severe accident research are used for developing data bases and models for probabilistic risk assessment, improving hardware and procedures to decrease plant risk, and providing the basis for accident management and emergency response procedures.

Sandia has conducted an extensive analytical and experimental containment integrity program, including major tests on a 1/8-scale model steel building and a 1/6-scale reinforced concrete building. Testing has been performed to evaluate the hazards of turbine and external missile impact. Evaluations of seismic and fire risks are carried out in conjunction with testing where needed. Test facilities have been developed for performing quantitative measurements of fire burning characteristics and the associated smoke and combustion products. We have performed extensive testing of nuclear power plant electrical equipment and components under simulated accident conditions. These tests support equipment qualification and plant life extension activities.

Sandia is the lead laboratory for the development and application of performance assessment methodologies for the evaluation of the suitability of nondefense, low-level waste disposal facilities for NRC. We are also evaluating methods for classifying waste streams as "below regulatory concerns" for use in setting *de minimis* standards for radioactive and mixed wastes.

Sandia continues to support NRC in transferring technology developed by DOE-sponsored safeguards programs to NRC staff, inspectors, and the nuclear utilities. Other technologies transferred to industry or other entities include advanced computer codes and techniques for materials and component design and evaluation.

Other federal agencies

Sandia provides support and certain space-qualified hardware for NASA and the European Space Agency. We are providing a number of radiation-hardened, large-scale, integrated circuit devices for the Venus Radar Mapping Mission. We also provide support to NASA for the development of recovery systems for instrumentation sent into orbit. Sandia advised on the design of the high-speed parachutes used to decelerate the space shuttle's solid-fuel rocket boosters as they fall to earth.

Sandia continues to support the National Security Agency (NSA) in adversary analysis. This work involves evaluation of NSA-designated communications security (COMSEC) equipment, components, and design proposals to determine and identify vulnerabilities having a potential for exploitation by an adversary.

Sandia has developed a new, safe, diversionary grenade for use by many federal agencies. Ultimately, this new device will be commercially available to law enforcement agencies.

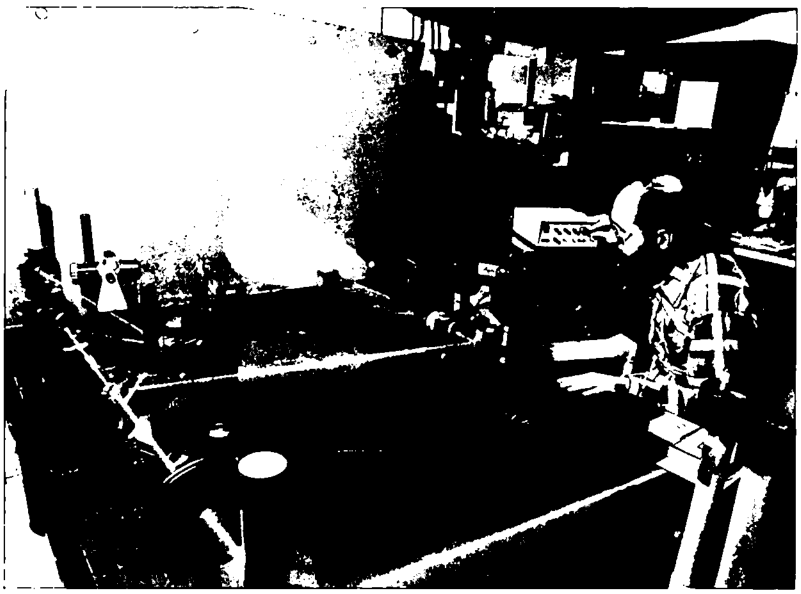
Sandia's experience in safeguards and security for nuclear materials and facilities has been applied to other federal security needs. We are developing force protection systems for use by military and nonmilitary personnel in special operation, low-intensity conflict environments. We helped develop and install an automated entry control system for the White House, and we have been tasked to participate in a security upgrade of the Hoover Building of the FBI. In addition, we are assisting the Federal Aviation Administration Technical Center in developing and investigating technologies for explosives vapor detection and in demonstrating airport security system concepts at Baltimore-Washington International Airport.

Sandia is further assisting FAA by bringing its expertise in nondestructive testing to bear on the problem of aging aircraft. There is insufficient knowledge about the effects of age on the performance and safety of aircraft to accurately forecast when components should be repaired or replaced. The program will develop procedures for commercial utilization of advanced inspection equipment already in use at DoD facilities. It will also advance laboratory techniques to operational readiness and develop new instrumentation. The program is designed for rapid technology transfer, and Sandia is collaborating closely with industry and academia.

Sandia National Laboratories is responding to requirements being brought forward by federal, state, and local law enforcement agencies involved in the war against illegal drug trafficking. The Secretary of Energy has pledged to the Director of the Office of National Drug Control Policy that the DOE laboratories will assist in helping to solve this significant national problem. In particular, Sandia was explicitly named a national technical resource in the Drug Abuse Act of 1989. Our response has been sharpened by extensive interactions with interested agencies at all levels, from individual agents patrolling the border to headquarters units involved in enforcement and R&D.

This Sandia effort has three foci: attempting to match available technologies with requirements in order to provide immediate solutions; defining and proposing long-term development efforts in areas where Sandia has expertise; and offering systems analysis support to better define and prioritize drug interdiction approaches. Immediate support is available in such areas as ground sensors, communications, and active RF beacons. Developmental areas include laser-induced fluorescence, compressed video communications, and passive beacons.

The results of these efforts are contractual arrangements with several agencies, and it is expected that these programs will expand as agency R&D budgets grow and the drug war becomes better organized.



Bruce Hansche uses laser interferometry to inspect a section of an aluminum aircraft wing. When the wing surface is stressed with vibration, heat, or pressure, flaws manifest themselves in larger displacements of the laser beam. Sandia is working to apply this and other techniques to the inspection of aging aircraft for the FAA.

All other reimbursables

When appropriate, Sandia also enters into projects involving state governments, private industry, universities, or other nonfederal entities. Criteria for these arrangements are the same as for other work-for-others endeavors. Current projects comprise a variety of activities and Sandia resources, including development of numerical models for rock blasting, computer modeling to predict chemical behavior in methane-air jet flames, microelectronics development, and studies to improve nuclear reactor safety.

Laboratory directed research and development program

Laboratory Directed Research and Development (LDRD) became a permanent program at Sandia in FY 1983 as permitted by federal law (PL 95-39, Section 303) and DOE Order 5000.4. The LDRD program provides support for technology base activities related to DOE's missions. Emphasis is given to early exploration of forefront science and technology projects that enhance Sandia's R&D capabilities and core competencies.

LDRD projects must be relatively small, well-specified, short-term (one to three years) projects that look forward in terms of technology and application (*i.e.*, projects that establish new capabilities, test new concepts, or investigate innovative approaches). LDRD funds are not used to substitute or increase funding for tasks otherwise funded by DOE or other agencies or to carry projects beyond the exploratory stage.

In previous years, funding for the LDRD program was generated by a tax on non-DOE reimbursable projects. Beginning in FY 1992 funds for the LDRD project are derived from a tax on funds from all sources, including DOE programs. The tax on DOE funds will be introduced gradually. In FY 1992, the program is funded at $34.1 million, which supports 121 projects selected from over seven hundred proposals submitted by employees.

The LDRD program permits Sandia staff to explore innovative scientific and technological opportunities that hold high potential for payoff in future applications. Some of these projects have led to tangible new DOE tasks and projects; others have enhanced the Laboratories' core capabilities.

For example, in 1989 an LDRD project led to the development of the radiation-hardened thyristor, a device with potential to enhance both the safety and survivability of nuclear weapons. Because of the high risk involved in the early stages of development, this project would probably not have been funded through a DOE weapons program. The device will permit the elimination of metal wires from the exclusion region of a nuclear weapon, thus removing any conduction paths for lightning or stray voltage that could be generated in accidents or by nuclear explosions. The device was engineered to meet design and safety goals and now replaces a complex firing circuit, thereby reducing system complexity and cost.

An FY 1991 LDRD project has led to the development of a mobile robotic manipulation and retrieval system. The project advances the state of the art for machine intelligence in mobile systems. This technology should find early application in hazardous waste removal operations at DOE facilities. In addition, the work has implications for U.S. economic competitiveness, and we are examining potential industrial applications. This project was outside the area of interest for funded robotics projects and thus could not have been pursued without LDRD funding.

Selection of LDRD projects is a formal process. Each spring a call for proposals is issued that describes the intent of the program and requirements for submittals for the forthcoming fiscal year. Projects that extend beyond one year must submit a request for continuation of funding, showing progress achieved to date toward the objectives and describing the tasks to be performed in the next year.

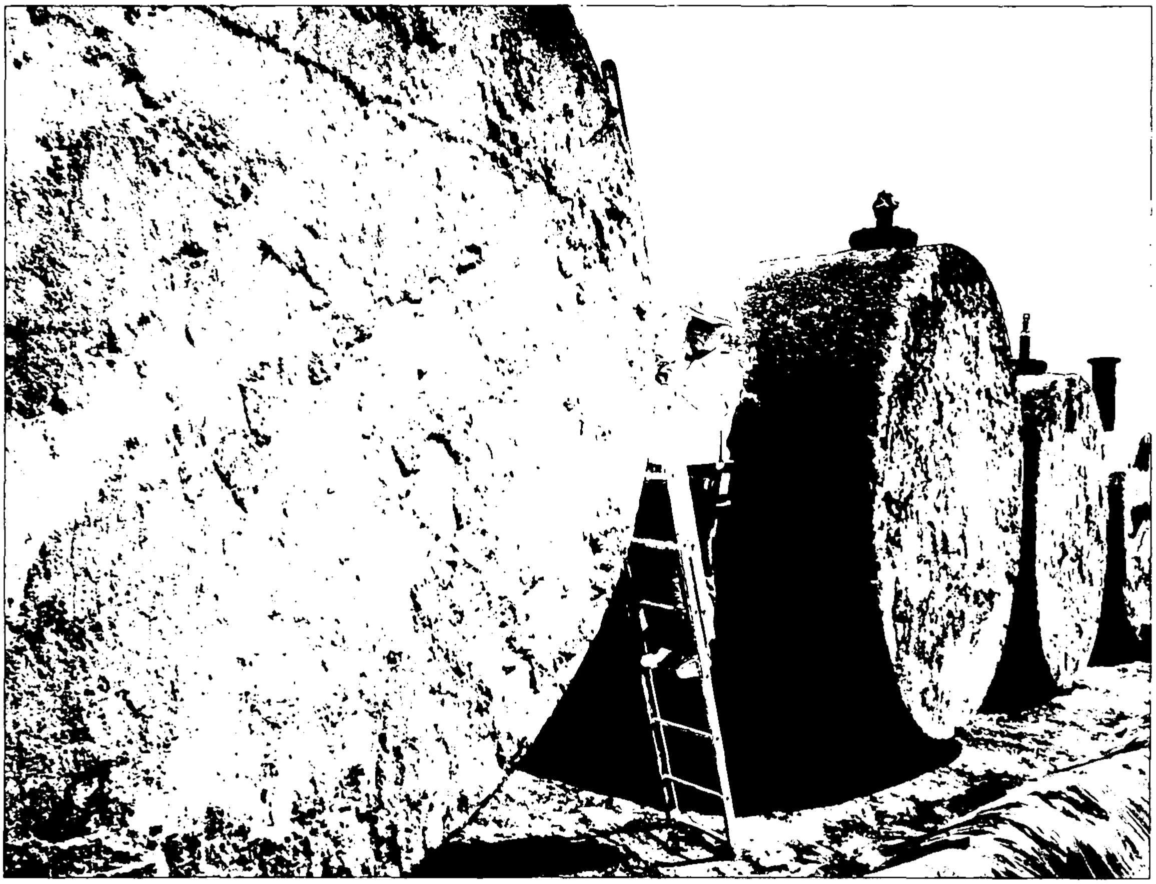
Proposals are subjected to two independent evaluations. A technical review by at least two reviewers evaluates the technical content of the proposed work, the technical approach proposed, and the technical potential of the project. Proposals that score well in the technical review submit to a programmatic evaluation by one of several review boards. In this evaluation, a proposal is reviewed with regard to its growth potential, its impact on future laboratory activities, and how the work supports Sandia's strategic intent.

With these reviews in hand, the responsible Sandia division manager ranks and selects the successful proposals based on the expected available funding. Beginning in FY 1992, selected proposals will be submitted to DOE headquarters for approval. Annual reports are also submitted to DOE.

Summary of Projected Investment in Laboratory Directed R&D Program
(Operating BA in $ million)

	FY91	FY92	FY93	FY94	FY95	FY96	FY97
Total funding	15.5	34.1	45.9	53.8	64.5	64.5	64.5

Art Rodriguez inspects a row of underground storage tanks removed from their locations at Sandia Albuquerque. The locations from which the tanks were removed are on Sandia's list of sites to be assessed and dealt with as part of the environmental restoration program.



Environmental, safety, and health management

Sandia is committed to protecting the environment and preserving the health and safety of individuals and the community. We have no higher priority. In the past year we initiated a comprehensive program to assure that laboratory operations are in full compliance with all applicable laws and regulations on environment, safety, and health (ES&H). Our program has been structured to address environmental problems in a timely fashion and thereby maintain public confidence in Sandia's ability to conduct its operations without harming the environment. It is our goal to provide leadership within the DOE complex by setting the example for a safe and healthful workplace and by pioneering industrial practices that protect the environment.

ES&H goals and objectives

There are three general goals for the ES&H activities at Sandia:

1. Make Sandia a safe, healthful, and environmentally sensitive workplace;

2. Comply with all applicable laws, orders, and regulations; and

3. Demonstrate this capability to DOE and the public.

A set of seven objectives supports achievement of these goals. These objectives employ both long-term and short-term strategies for their accomplishment.

Objective: *Use our quality process to achieve excellence in our ES&H programs and to fully satisfy our customers' requirements.*

Sandia will implement the AT&T Process Quality Management and Improvement (PQMI) methodology for all ES&H activities. PQMI stresses examining and continuously improving the processes involved in meeting requirements. It will be used to identify root causes of ES&H problems and enhance prevention as opposed to mere correction. Sandia has launched a Quality Improvement Initiative that will establish an overarching quality implementation strategy for all Laboratories activities, including ES&H compliance and improvement (see page 130).

Objective: *Enhance credibility through exemplary operations and through the development of innovative applications and solutions to critical internal, local, and national ES&H issues.*

Sandia will be active in identifying and helping to find solutions for ES&H problems in the community and the DOE nuclear weapons complex. Management will establish target values of internal research and development resources to be committed to ES&H. In addition, we will aggressively seek to transfer ES&H technologies to industry through hosting conferences and workshops and entering into cooperative research and development agreements with individual firms where appropriate. We will offer consultants to other DOE sites or facilities in areas where Sandia has a particular expertise, such as waste minimization in manufacturing processes.

Objective: *Require open, timely communication of ES&H problems, lessons learned, plans, and status to achieve appropriate and uniform actions throughout Sandia.*

We will develop an integrated plan for communicating ES&H issues at Sandia and for providing periodic communication to employees. Feedback mechanisms will be established for employees to identify ES&H concerns and suggest ideas for improvement.

Objective: *Team Sandia employees, customers, suppliers, and community representatives to assure protection of the environment and the safety and health of all.*

It is our goal to maximize involvement in ES&H throughout the Laboratories and to encourage cross-organizational efforts to draw upon the variety and creativity of our technical staff. We hope to involve universities in research and development for ES&H through visiting professorships, sponsored assistantships, cooperative assignments in the ES&H arena, and joint endeavors with university research centers. In addition, we can serve our communities and various entities of government by providing Sandia experts to serve in positions of responsibility at the national, state, and local levels.

Objective: *Create ES&H excellence through formal, established processes coupled with the mindful action of every Sandian.*

A Line Managers' ES&H Action Team (LMEAT) was tasked with developing a process for converting ES&H programs into procedures. Numerous generic procedures have been developed as a part of this process development. Representatives from affected organizations will be involved in generating facility-specific operating procedures. ES&H considerations will be incorporated into all project planning. Members of management will demonstrate their commitment and ownership of ES&H through direct involvement.

Objective: *Support our employees in personalizing Sandia's vision both at work and at home.*

The Laboratories will continue disseminating ES&H information helpful to the families of Sandia employees, such as the periodicals *TLC Newsletter, Family Safety,* and *Harvard Medical School Newsletter.* A recycling committee will be established to coordinate a recycling program for the Laboratories. We will define a process for recognizing and rewarding outstanding ES&H contributions.

Objective: *Ensure that every Sandian has necessary and sufficient ES&H training, and require that visitors and contractors comply with our ES&H requirements.*

We will maintain a record keeping system for tracking ES&H training requirements and the training status of employees. A basic ES&H awareness module will be included as part of the orientation process for newly hired employees. Experts from Sandia line organizations will be involved in developing the curricula for these modules. Trainers will train additional trainers where possible to allow staff to instruct their own organizations in good ES&H practices. We will select some staff out of every organization each year to receive extensive training in the fine details of compliance and then allow these people to practice and use their knowledge in self-appraisals.

Regulatory environment

Laws and regulations—There are many federal environmental laws and implementing regulations to which Sandia must adhere. These laws include the Clean Air and Clean Water acts; the Resource Conservation and Recovery Act; the Federal Insecticide, Fungicide, and Rodenticide Act; the Toxic Substance Control Act; the Comprehensive Environmental Response, Compensation, and Liability Act; the Safe Drinking Water Act; the Oil Pollution Control Act; the Marine Protection, Research, and Sanctuaries Act; the Noise Control Act of 1973; and others.

DOE implements several other federal laws affecting Sandia, including the National Environmental Policy Act, the Occupational Safety and Health Act of 1970, the National Historic Preservation Act, the Coastal Zone Management Act of 1972, and the Mine Safety and Health Act. Finally, the contract for the operation of Sandia National Laboratories by Sandia Corporation requires that Sandia's environmental, safety, and health operations be conducted in accordance with all applicable DOE orders and directives communicated to Sandia by the DOE contracting officer.

Sandia must also comply with state and local legislation applying to laboratory sites in New Mexico, California, Nevada, and Hawaii. Examples of such legislation in New Mexico include the New Mexico Air Quality Control Act, the Environmental Compliance Act, the Water Quality Act, the Hazardous Waste Act, and the Solid Waste Act. In addition, local regulations for air quality and sewage pre-treatment apply to Sandia activities. Examples of legislation in California include the California Clean Air Act, the Air Toxics "Hot Spots" Information and Assessment Act, and the Tanner Act. In addition, Sandia's Livermore site must comply with local regulations, such as the Bay Area Air Quality Management District rules. Similar laws in Nevada and Hawaii affect Tonopah Test Range and the Kauai Test Facility.

An example of cooperation between Sandia and environmental regulatory agencies is the October 1990 agreement between New Mexico and DOE to monitor cleanup and ongoing environmental activities. This agreement is the result of an initiative called for in April 1989 by several state governors with DOE nuclear facilities in or adjacent to their states. The agreement gives state environmental officials access to DOE facilities to monitor cleanup activities, as promised by Secretary Watkins. Under the agreement, New Mexico's Environment Department will hire 15 full-time employees to handle on-site monitoring. DOE will provide about $3 million per year for hiring and training staff and for purchasing equipment.

Internal regulations—Sandia receives orders and procedures regarding ES&H from DOE's Albuquerque Operations Office. These requirements, together with applicable laws and regulations, form the foundation of the laboratories' ES&H policy. This policy is implemented through written ES&H programs that define program objectives, organizational responsibilities, authorities and interfaces, and implementation requirements. Programs are implemented using detailed written procedures that are reviewed and approved for use according to the ES&H quality program.

All Sandia projects and facilities are to be operated according to the requirements of the ES&H programs. To facilitate integration of the operations with the ES&H programs, all facilities and project activities are categorized and analyzed for ES&H hazards. Actions are then specified to eliminate, mitigate, or otherwise control the hazards in accordance with the ES&H programs. These actions include the use of engineered systems as well as written procedures to control operations, specify training requirements, require the use of protective equipment, define responsibilities and organizational interfaces, and provide any other necessary requirements.

Sandia has 17 existing ES&H programs that are defined by functional categories that meet the requirements of the appropriate DOE orders and federal, state, and local regulations:

- Safety Engineering
- Construction Environment, Safety, and Health
- Fire Protection
- Industrial Hygiene
- Radiation Protection
- Emergency Preparedness
- Occupational Medicine
- ES&H Information Reporting
- Risk Management
- Human Resources
- Nuclear Facilities Safety and Criticality
- Self-Assessment
- Environmental Protection and Waste Management
- ES&H Quality
- Conduct of Operations
- Packaging and Transportation
- Stop Work and Restart

Anticipated future requirements—The legal and regulatory environment affecting Sandia's ES&H activities is likely to remain dynamic, with changes occurring as public concerns and government administrations evolve. For example, the Resource Conservation and Recovery Act currently is undergoing a reauthorization process in Congress. Information on its changes is not yet available, but any resulting changes will likely affect Sandia's procedures. We anticipate a general trend of laws and regulations requiring more attention to procedures, processes, and documentation to ensure a greater degree of auditability in environmental compliance.

ES&H policies, organization, and management

Sandia's policy with respect to ES&H is set forth in the following policy statement:

> Sandia National Laboratories considers the protection of the environment, as well as human life and health, to be its top priority. Conflicts between ES&H requirements and other programmatic needs will be resolved to fully meet the ES&H requirements. Accordingly, Sandia shall design products and conduct operations with the highest regard for the protection and

preservation of the environment and safety and health of its personnel, contractors, and the public.

Sandia National Laboratories shall ensure the occupational health and safety of Sandia personnel, as well as environmental protection and preservation throughout all operations, by complying with applicable federal, state, and local laws and regulations, DOE orders, permit agreements, orders, and consent decrees. Sandia shall make sure that contractors and site visitors are fully informed of this policy and of their obligation to comply with it.

In addition, Sandia National Laboratories shall continuously evaluate regulatory requirements, corporate policies, and customer needs and shall adjust its operations to meet these changing needs through the Sandia Quality Improvement Plan. This includes a goal of continuous improvement in ES&H processes.

Concern and conduct in matters pertaining to the environment, safety, and health are the responsibility of all Sandia employees, on-site contractors, and visitors.

No job is more important than your health, your safety, and the protection of our environment.

The president of Sandia National Laboratories has overall responsibility for environment, safety, and health at the Laboratories. He sets ES&H policy and tasks the line organization vice presidents to implement that policy. Further, the president has established a senior management group, the Sandia ES&H Council, to oversee the implementation of ES&H policy and serve as a forum for discussion of major corporate ES&H issues. This group, together with the Sandia Management Council, also works to promote, communicate, and establish a culture that recognizes ES&H as the Laboratories' top priority.

The vice president for ES&H and Facilities Management oversees implementation of ES&H improvement and compliance. Reporting to him, the director of ES&H provides leadership in ensuring that line organization implementation issues are adequately addressed in developing programs and procedures and implementing the ES&H programs and standard operating procedures. The ES&H Integration Department facilitates the implementation of the ES&H culture by coordinating activities of the Line Implementation Working Group (LIWG) and the ES&H coordinators for buildings and organizations. The director of ES&H also provides ES&H support capabilities required to meet applicable laws, regulations, compliance agreements, and DOE orders.

The director of ES&H is responsible for converting applicable ES&H requirements into programs that govern all ES&H practices at Sandia. In doing so, he must translate all applicable ES&H laws, regulations, and orders into specific requirements, policies, and programs that can then be implemented. He is also responsible for acquiring and applying all ES&H support capabilities required to meet applicable laws, regulations, compliance agreements, and DOE orders.

Responsibility for implementation of specific planned actions has been assigned by management to appropriate individuals and organizations for the technical or organizational actions being addressed. For example, the Medical center has the primary responsibility for developing and implementing occupational medical programs to support ES&H concerns across all organizations. The Human Resources center has responsibility for providing educational and training systems for ES&H that can be utilized by all.

The ES&H Project Management Office was established to ensure that formal oversight and control is provided by management to all ES&H activities. The project office is contained within the office of the vice president for ES&H and Facilities Management and is responsible for negotiating performance, schedule, and cost for all ES&H activities; prioritizing ES&H activities based on risk, benefit (risk reduction), and cost considerations; tracking performance, schedule, and cost for all ES&H activities; and maintaining liaison with Sandia budgeting organizations.

The ES&H Regulatory Assessment Department is responsible for providing an assessment that is internal to Sandia but independent of line organizations. Both functional appraisals and management appraisals are conducted. Internal appraisals are planned, scheduled, performed, and their results documented in accordance with written procedures. Root cause analyses for findings are performed by the appraised organizations. Corrective actions for all findings are developed and tracked to completion. Senior management receives regular summary reports on the results of internal appraisals and evaluates the effectiveness of the appraisal program through triennial reviews.

An audit structure advising the president consists of the ES&H Review Board and the Process Quality Department. The Review Board provides independent assessments of the effectiveness and compliance of the Laboratories' ES&H program. The Process Quality Department is responsible for providing quality assessments for all nonweapon activities (including ES&H) throughout the Laboratories. It also provides the management tools necessary for staff to prepare for independent appraisals and to strengthen compliance with DOE orders, federal and state laws, and implementing regulations.

A standard procedure has been implemented for reporting ES&H events (accidents, incidents, occurrences, releases, etc.). The procedure applies to all employees and on-site contractors. When an event occurs, involved individuals are required to ensure that all steps necessary to negate or minimize the situation are taken. An occurrence reporting hot line is staffed by knowledgeable personnel who log and route event reports to the proper organizations for corrective action. DOE immediately makes the required notifications to EPA and other appropriate federal and state agencies. Sandia management ensures that all necessary formal documentation regarding the event is prepared.

Laboratories ES&H Programs
Funding Requirements
(Dollars in millions)

	($ FY 1993)					
	FY92	FY93	FY94	FY95	FY96	FY97
Corrective Action Plan-Related						
Defense Programs	13.0	11.0	10.0	7.0	7.0	5.0
Environmental Restoration and Waste Management	16.3	12.0	11.1	13.2	18.6	34.1
Subtotal	29.3	23.0	21.1	20.2	25.6	39.1
Overhead	16.7	19.6	16.0	9.8	8.6	7.3
Total Action Plan	46.0	42.6	37.1	30.0	34.2	46.4
Baseline ES&H Activities						
Environmental Restoration and Waste Management	27.3	49.1	32.6	114.1	80.4	133.7
Overhead	24.0	25.2	26.5	27.8	29.2	30.7
Total Baseline	51.3	74.3	59.1	141.9	109.6	164.4
Total ES&H Programs	97.3	116.9	96.2	171.9	143.8	210.8

David McTigue and Carol Stein test soil conditions near a surrogate landfill cap at Sandia Albuquerque. Studies such as this one are necessary to design site-specific remediation strategies.

ES&H plans and initiatives

Sandia's ES&H operations comprise activities associated with its corrective action plans and those associated with ongoing ES&H functions. Site-specific plans describe how the Laboratories will implement programs to complete corrective activities, environmental restoration, waste management, and technology development projects within the DOE Five-Year Plan for Environmental Restoration and Waste Management.

Corrective activities—Corrective activities are those actions needed to bring active and standby facilities that are currently or potentially out of compliance with applicable local, state, federal, or internal DOE requirements into compliance. Also included as corrective activities are projects and activities needed to correct anticipated noncompliance conditions with known future regulatory requirements.

Sandia's corrective activities are found in three areas: (1) groundwater monitoring, (2) air pollution control and monitoring, and (3) sanitary sewer evaluation and monitoring. Key FY 1992 corrective activities at Albuquerque include the installation of five additional hydrogeologic wells, completion of the control system for the liquid effluent from Tech Area V, and completion of a study to locate any cross-connections in the sewer lines. The corrective activities at Sandia Livermore relate primarily to air emission control measures for the Tritium Research Laboratory.

Environmental restoration—The DOE Environmental Restoration (ER) Program was initiated in 1987 to consolidate and coordinate those regulatory compliance activities designed to identify and remediate inactive sites at DOE installations contaminated with hazardous, radioactive, or mixed waste. Environmental restoration projects address known, suspected, or potential contamination and involve both assessment and remediation.

Three primary regulatory drivers form the basis for environmental restoration program investigation and remediation. These include (1) the Section 3004(u) provisions of the Resource Conservation and Recovery Act (RCRA), which require corrective actions for releases from solid waste management units (SWMUs); (2) RCRA provisions that require closure and post-closure care for inactive treatment, storage and disposal (TSD) units; and (3) the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) that address remediation of releases of hazardous substances in accordance with the National Contingency Plan (NCP). Most of the ER sites fall under RCRA, while a lesser number will be addressed in a manner consistent with the NCP.

The majority of Sandia's environmental restoration program efforts are grouped in the following three categories:

1. RCRA Corrective Actions: Efforts required to address releases of RCRA hazardous waste or constituents from SWMUs, regardless of the date the waste was placed in the unit.

2. RCRA Closure Actions: Efforts pertaining to the closure of inactive RCRA TSD units that will not be permitted for continuing operation.

3. Other Actions: Efforts involving assessment and, as necessary, remediation of sites from which there has been a release or where there is the potential for a substantial threat of a release of a hazardous substance, regardless of the date of the release.

Sandia Albuquerque and Livermore currently operate under RCRA interim status and have filed Part B RCRA applications for hazardous wastes. Neither the U.S. Environmental Protection Agency (EPA) nor the State of New Mexico has yet issued corrective action orders regarding releases at Sandia's Albuquerque site. Consequently, environmental restoration corrective actions there within the RCRA framework being undertaken at this time are voluntary. Future corrective action requirements will be specified as part of the Hazardous and Solid Waste Amendments (HSWA) module to the RCRA Part B Permit.

Waste management—Waste management projects allocate the resources necessary to safely and efficiently manage the Laboratories' hazardous, radioactive, and mixed wastes. This effort includes projects in minimization, treatment, storage, disposal, and continuity of operations.

Radioactive, hazardous, and mixed wastes are generated at Sandia. All radioactive waste is either stored on-site or sent to DOE-authorized facilities for disposal. At Albuquerque, hazardous waste is temporarily stored in the Hazardous Waste Management Facility, then transported off-site for recycling, treatment, or disposal at commercial facilities with EPA permits. A draft Part B (final operating) permit application under RCRA for the Albuquerque hazardous waste units has been issued. It is likely that a public hearing will be held before the permit is finally issued. Mixed wastes are currently held on-site in storage areas that were included in the Part A permit application for mixed waste units submitted to the New Mexico Environment Department (NMED) in September 1990. Also included in the permit application was a facility, not yet operational, that will be used for repackaging and storage of low-level radioactive waste and mixed waste.

At Livermore, hazardous waste is incinerated, reclaimed, recycled, neutralized, encapsulated, landfilled, or otherwise treated at various commercial disposal facilities. Compatible waste streams are consolidated at Sandia's hazardous waste storage facility to decrease costs and liability. These consolidated streams are analyzed before disposal in accordance with the Waste Analysis Plan that has been approved by the EPA and the California Department of Health Services. Low-level mixed waste is disposed of at NTS in compliance with DOE Orders, EPA and State of California requirements, and NTS criteria (NV0-325). "Scintillation cocktails" (small vials of low-level radioactive liquids) from the Tritium Research Laboratory are placed in 55-gallon drums and transported to a commercial facility for incineration. Other low-level mixed waste streams will be stored at Sandia Livermore until off-site disposal options are developed.

The Reynolds Electrical and Engineering Company, a DOE contractor, arranges for shipment and disposal of hazardous wastes generated at Tonopah Test Range within 90 days of its generation.

The Kauai Test Facility generates extremely small quantities of potentially hazardous wastes. These wastes are handled through the Navy's Pacific Missile Range Facility waste management program.

In addition to the need for adequate funding to perform waste management operations, additional needed resources include the availability of approved off-site treatment and disposal facilities for hazardous, radioactive, and mixed wastes. In particular, such facilities are needed for

At Sandia Albuquerque's waste management facility, drums are filled with sorted wastes, inventoried, and then stored for shipment to approved, off-site disposal facilities.

mixed wastes. The lack of treatment and disposal facilities for mixed waste is currently a problem for the entire DOE complex.

Technology development—Technology development to benefit environmental programs is taking place at both Albuquerque and Livermore in several areas: site characterization, waste minimization, environmentally conscious manufacturing, waste treatment, risk-based standards, and robotics. This work is aimed at on-site needs, other DOE site needs, and support of technology development at other DOE sites for Sandia on-site needs.

Sandia is currently managing three Integrated Technology Demonstrations of environmental technology. The objective of the Mixed Waste Landfill Integrated Technology Demonstration is to assess, implement, and transfer technologies and systems leading to quicker, safer, and more efficient remediation of chemical and mixed waste landfills in arid environments. The Weapon Component Waste Disposal Integrated Technology Demonstration will address the end-to-end process of the disposal of Sandia-designed weapon dismantlement waste, including waste identification, minimization, treatment, transport, and ultimate disposal. The Environmentally Conscious Manufacturing (ECM) Integrated Technology Demonstration will implement a total systems approach to ECM that will lead to cost-effective elimination of waste in the manufacture of nuclear weapons electronic and electromechanical components.

Sandia is undergoing intensive efforts to ensure excellence in ES&H performance. During the spring of 1990 the DOE ES&H Tiger Team evaluated Sandia Livermore for compliance with ES&H-related orders, regulations, and best management practices. The Tiger Team listed 286 findings in four general categories: 41 in environmental, 119 in safety and health, 112 dealing with OSHA regulations, and 14 in management and organization. Fourteen out of the 286 were considered key findings, including three in environment, three in safety and health, two pertaining to OSHA, and six involving management.

Secretary Watkins has approved the Sandia Livermore Corrective Action Plan that responds to the Tiger Team findings. The 508-page document outlines proposed actions Sandia and DOE will take to correct deficiencies. Many of the corrective actions recommended by the Tiger Team have been completed.

In spring of 1991 a DOE ES&H Tiger Team evaluated ES&H efforts at Sandia Albuquerque, Tonopah Test Range, and the Kauai Test Facility. In all, the Tiger Team identified 242 individual findings in the worker safety and health category, 82 in environmental, and 18 in management.

Key areas of concern in the environmental area included inconsistent management of hazardous, radioactive, mixed, and solid wastes; lack of accurate, consistent, formal procedures to assure compliance; and a lack of necessary programs to monitor and control potential air emission sources. Management findings concerned the integration of ES&H strategic planning into subordinate plans and the resource allocation process; ES&H human resources and training programs; and various means of improving oversight.

In addition to these findings and concerns, the Tiger Team cited five "noteworthy practices" and two "commendable practices." Noteworthy practices must be unique and have potential for application at other DOE sites.

A preliminary Final Action Plan detailing how Sandia Albuquerque will correct the deficiencies identified by the Tiger Team inspection has been submitted to DOE for approval. We intend to vigorously prosecute all corrective actions as part of our effort to re-establish full awareness and accountability for our responsibilities in health, safety, and the environment. In addition, Sandia has developed a formal Project Plan to institutionalize and manage the Laboratories' ES&H activities systematically, with emphasis on the process quality methodology elements of cost, performance, and schedule. This plan, while not a DOE requirement, allows the Laboratories to apply its concepts of quality processes and management to a critical laboratory activity.

Environmental Restoration and Waste Management Activities

Work performed for the Office of Environmental Restoration and Waste Management includes environmental restoration, corrective actions, waste management (including the Waste Isolation Pilot Plant), technology development, and transportation. These activities are described in detail in the section on programs for the Office of Environmental Restoration and Waste Management beginning on page 63. The table on the following page is an estimate of anticipated costs for EM work by major category through the planning period.

EM Anticipated Costs
(Dollars in millions)

	($ FY 1993)					
	FY92	FY93	FY94	FY95	FY96	FY97
Environmental Restoration						
Operating	26.5	39.7	24.9	69.0	39.8	92.5
EM Corrective Actions						
Operating	1.5	1.2				
Capital equipment	1.1	0.5				
GPP	1.5	0.5				
Total	4.1	2.2				
Waste Management*						
Operating	46.8	63.4	61.8	57.4	50.4	51.5
Capital equipment	2.1	1.6	1.1	0.4	0.5	0.5
GPP	1.3	1.0	0.2	0.2	0.2	0.2
Line items				4.3	11.1	26.2
Total	50.2	66.0	63.1	62.3	62.2	78.4
Technology Development						
Operating	23.6	30.0	40.0	50.0	60.0	70.0
Capital equipment	1.1					
Total	24.7	30.0	40.0	50.0	60.0	70.0
Transportation						
Operating	7.0	7.6	8.3	9.2	10.0	11.0
Capital equipment	0.4	0.4	0.5	0.5	0.6	0.7
Total	7.4	8.0	8.8	9.7	10.6	11.7
Total EM Funding						
Operating	105.4	141.9	135.0	185.6	160.2	225.0
Capital equipment	4.7	2.5	1.6	0.9	1.1	1.2
GPP	2.8	1.5	0.2	0.2	0.2	0.2
Line items				4.3	11.1	26.2
Total	112.9	145.9	136.8	191.0	172.6	252.6

*Includes WIPP

Contributions to economic competitiveness

Technology transfer plan

Sandia's technology transfer program promotes and facilitates the transfer of Sandia-developed technologies, processes, and special technical know-how to the private sector as a means for helping to strengthen the nation's competitive position in world markets. We consider the use of Sandia's core competencies to help improve the U.S. economy a natural extension of our defense and energy missions. Effective collaboration between government and industry—the mutual exchange of expertise and knowledge—makes it possible for the private sector to leverage its R&D resources by taking advantage of existing federal defense R&D investment and enables the national laboratories to sustain the core competencies that are essential to their DOE missions.

As we pursue this important new mission, we are committed to protecting national security interests, providing fairness of opportunity to industry, creating lasting value to the taxpayer, and following the highest ethical standards to avoid even the appearance of conflicts of interest.

Our efforts to refine technology transfer processes and shape them into a flexible, responsive program were boosted by the signing of agreements with AT&T and DOE in January 1991. The agreements, provided for by the National Competitiveness Technology Transfer Act of 1989, recognize technology transfer as an official mission of Sandia and permit Sandia for the first time in its history to negotiate Cooperative Research and Development Agreements (CRADAs) directly with companies in the private sector.

Anticipating these agreements, we worked throughout 1990 with various DOE field task force committees to develop technology transfer policies and streamlined procedures. We continue to work closely with DOE to further refine the approval process for CRADAs—especially as it concerns those areas in which potential partners wish to depart from standard terms and conditions—and to shape a mutually agreeable CRADA model that will be a flexible, efficient mechanism for accomplishing technology transfer.

We are currently fine-tuning the organizational structure of our Technology Transfer Applications department and our Partnership Agreements department to ensure that they are effective, integral elements of the newly created Technology Transfer Center. The Technology Transfer Center will continue to further simplify and streamline technology transfer processes and mechanisms (CRADAs and the CRADA approval processes, in particular) and continue shaping Sandia's technology transfer program into a flexible, responsive effort capable of assuring that the wealth of new knowledge generated at Sandia and our unique capabilities are shared with industry on a continuing and timely basis. We have also developed a data base for tracking information associated with CRADAs and licenses, put into place internal operating procedures for preparing and processing CRADAs that require the coordinated efforts of many Sandia organizations, and expanded our licensing program. We continue to work with the local business community and agencies of the state of New Mexico to develop a regional technology transfer plan to promote and facilitate greater local participation in Sandia's technology transfer program.

Complementing our CRADA and licensing activities is our Technology Maturation Program (TMP) begun in 1990. Through this program, we fund additional development of technologies judged to have commercial potential but which need further development before industry will invest in them. These are technologies that have been developed sufficiently for the purposes of our weapons or other mission programs but are not developed to the level needed for industry to undertake the remaining risks and cost of developing marketable products. The program acts as a sort of bridge to enable technologies developed by Sandia for highly specialized purposes to move to the private sector where they may be put to different or broader uses. All technologies selected for development in the program have been or will be made available for transfer to the private sector through CRADAs or licenses.

In addition to CRADAs and licenses, we continue to use an array of formal technology transfer mechanisms, including work-for-others agreements, some types of technical assistance, user facilities, personnel exchanges, and collaborative agreements with consortia.

To inform the scientific and technical communities in the private sector of technology transfer opportunities at the Laboratories, Sandia publishes the results of unclassified research in professional and technical journals and regularly disseminates information about available technologies through *Commerce Business Daily,* special publications, brochures, news releases, workshops, seminars, and one-on-one interactions.

To help ensure that Sandia's talents and facilities are directed effectively toward meeting national needs, we have identified a number of thrust areas in which special strengths and capabilities developed by Sandia in the pursuit of its defense and energy missions can be applied to solving problems in private sector areas as diverse as manufacturing equipment and processes, industrial waste management and pollution control, energy security, technologies to reduce health care costs, and in the development of security systems that could enhance law enforcement and drug interdiction. In this effort, we are attempting to respond to "market pull"—to become sensitive to the technological demands exerted on industry through the marketplace and to focus the transfer of Sandia technologies and capabilities to meet those needs.

Special efforts are underway to promote the dual use of technologies and capabilities developed through Sandia's federally funded research and development. Dual-use technologies are technologies that have been developed for specific defense needs but which can also serve critical private sector needs, leveraging both federal and industrial R&D investments and giving taxpayers the highest possible return on their investment in the nation's defense program laboratories. Several initiatives are already in place, and other strategies are being devised for cost effectively exploiting dual-use technologies to forge strategic alliances between Sandia and industry to achieve shared national goals.

The Technology Commercialization Initiative established by DOE Defense Programs in 1990, for example, is being reorganized to make more funding available to DP laboratories for cost-shared collaborative projects with the private sector. The goal is to improve and speed up the selection and execution of cooperative research and development projects.

Technology Transfer Effort
(Dollars in millions; staffing in FTEs)

	FY91	FY92	FY93	FY94	FY95	FY96	FY97
Funding:							
ORTA activity	4.7	4.8	5.0	5.0	5.0	5.0	5.0
Patent/licensing activity	0.1	0.1	0.1	0.1	0.1	0.1	0.1
CRADA funding—federal	3.0	40.0	40.0	40.0	40.0	40.0	40.0
CRADA funding—industry	3.0	60.0	60.0	60.0	60.0	60.0	60.0
Total funding	10.8	104.9	105.1	105.1	105.1	105.1	105.1
Staffing:							
ORTA activity	13	25	25	25	25	25	25
Patent/licensing activity	5	9	9	9	9	9	9
CRADA activity	4	10	10	10	10	10	10
Total staffing	22	44	44	44	44	44	44

Cooperative research and development agreements (CRADAs)

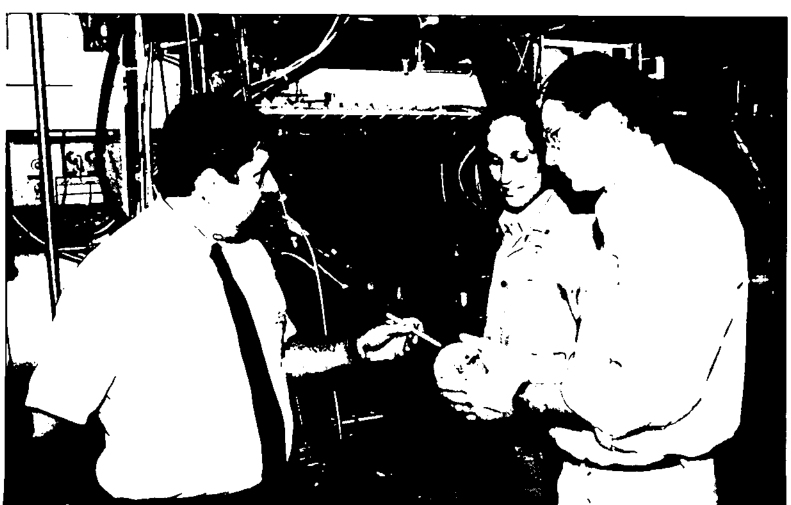
Cooperative Research and Development Agreements (CRADAs) are expected to become the preferred mechanism for structuring most collaborative research and development arrangements between Sandia and partners in the private sector. The primary purpose of CRADAs is the effective transfer of Sandia technologies, processes, R&D capabilities, and technical know-how to the private sector. This new mechanism is simpler than conventional government contracts, protects a company's confidential information, and permits wide latitude in the assignment of intellectual property. Under a CRADA, Sandia may contribute facilities, property (including intellectual property), and personnel to the cooperative effort. Sandia may also pay costs associated with the participation of its personnel or the contribution of property and facilities but may not provide cash funds to a participant. Sandia's partners in the private sector may provide funds to Sandia as well as personnel, services, facilities, equipment, or other resources needed to advance the proposed work. Implicit in a CRADA is the idea that the participants are equal partners who bring to the interaction complementary, identifiable capabilities that will lead to a new or improved product for the marketplace.

Since Sandia was granted CRADA authority in January 1991, 14 CRADAs have been approved, two of which are with small businesses. At the end of FY91, a total of 59 CRADAs had been initiated: Twenty were submitted to the DOE Albuquerque Operations Office for approval and an additional 39 are in various stages of preparation and negotiation and will be submitted in early FY 1992.

Industry-laboratory collaborative projects

Industry-laboratory collaborative projects offer Sandia the unique two-pronged opportunity of providing strong support to U.S. industry and, at the same time, using the strategic alliances formed with industry, universities, and other laboratories to maintain and enhance the core competencies that enable us to perform our DOE missions. In this respect, we are providing access to some of Sandia's unique facilities and special expertise through several mechanisms, including agreements with industrial consortia.

Semiconductor Equipment Technology Center—Under an agreement with SEMATECH (a consortium of 14 major U.S. semiconductor manufacturers), we established the Semiconductor Equipment Technology Center at Sandia to help improve the reliability of existing manufacturing equipment and develop



John Deere representative David Trees (left) and Sandians Tony DeSousa and Tony Bentley examine a welded part. Sandia is working with the farm equipment company to transfer welding feedback technology that monitors and then automatically adjusts welding processes while such parts are being manufactured.

advanced equipment and processing techniques. The program, which successfully combines Sandia's expertise and leading-edge research base in chemistry, materials, and process technology with industry's hands-on engineering experience with production equipment, is yielding significant improvements in a number of areas critical to ensuring that America's microelectronics industry will have the reliable, high-quality equipment needed to remain competitive in global markets. SETEC is more fully described in the chapter "Scientific and Technical Programs" on page 88.

Speciality Metals Processing Consortium Program—Similarly, in an agreement with the Speciality Metals Processing Consortium, we are working with the small but critically important U.S. specialty metals industry to improve the technology base for melting processes used in the manufacture of specialty metals. Specialty metals such as high-performance steel and titanium and nickel-based alloys are critical to American economic competitiveness in areas ranging from microelectronics to airplanes and are also vital to national security. Any country that must import the basic materials for such products is at a severe disadvantage. Sandia and SMPC personnel have already conducted several major experiments. Most of the research takes place within Sandia's Melting and Solidification Laboratory Complex, which features the only large-scale, fully instrumented research furnace in the country. Results of the industry-selected research projects are enabling or generic in nature so that each member company can use the results to develop its own proprietary processes and products. Sandia will make patents resulting from any of the work available to consortium members through a royalty-free licensing arrangement.

Combustion Research Facility—The Combustion Research Facility (CRF) is a designated DOE user facility. Researchers at the CRF have for many years worked with industry researchers to improve energy efficiency in engines, reduce environmental effects, and investigate combustion processes in flames, coal combustors, and internal combustion engines. Cooperative Working Groups facilitate collaboration among participants from industry, universities, and other national laboratories, ensuring that research is focused on key issues and results are made readily available to the private sector.

Jim Heilman of Carpenter Technology takes the temperature of metal inside Sandia's slag remelt furnace. Jim is an industrial intern assigned to Sandia to conduct research supported by the Specialty Metals Processing Consortium.

Microelectronics Quality/Reliability Center—We are also providing access to Sandia's special expertise through arrangements such as the newly formed affiliates program designed to make some of Sandia's skilled staff and unique facilities accessible to microelectronics manufacturers. Throughout the microelectronics industry, standards for quality and reliability of microelectronic products are intensifying, even as increasingly smaller-scale features make finding and analyzing failures more difficult. To ensure reliable microelectronic products for military and space applications, Sandia maintains a Microelectronics Quality/Reliability Center that includes a "SWAT" team for resolving production problems, a test bed for evaluating the impact of new materials and processes introduced into production, and an advanced R&D program to develop new quality tools and techniques. This affiliates program gives U.S. microelectronics manufacturers access to the center and its skilled staff, saving industry participants the cost of constructing their own test facilities and giving them access to capabilities that are not available elsewhere.

Patent and software licensing

Sandia averages about 35 patent applications per year. However, many invention disclosures filed by Sandia as a result of our work for DOE have not been patented or licensed for application by industry. To encourage a higher level of licensing, we intend to conduct periodic reviews of existing invention disclosures that would make good candidates for patenting and licensing. We will then broadly advertise these disclosures, hold workshops, select the best qualified contenders to compete for specific licenses, and ultimately, enter into licensing negotiations.

Sandia has also expanded its licensing program to facilitate the transfer of technologies through a variety of licensing options. Through commercial licenses (exclusive or nonexclusive, as appropriate) companies in the private sector can obtain the right to manufacture and sell technologies patented by Sandia in exchange for license fees and royalties.

To promote the effective use of our technologies in as many ways as possible, we try to license a given technology nonexclusively or exclusively to different users for specific fields of use. Nonexclusive licenses can sometimes ensure rapid and effective transfer of the technology into commercial or scientific uses, but we also recognize that a license may at times require various kinds of protection, including exclusivity, to protect a firm considering a large investment in a new technology. Our aim is to remain flexible and take into account the unique circumstances of each technology and licensee.

Licensing Income and Use
(Dollars in thousands)

	FY91	FY92	FY93	FY94
Licenses:				
Number of new licenses	3	40	80	100
License income	10	200	500	1000
Use of income:				
Invention & ORTA administration	3	60	150	300
Scientific or applied R&D	4	80	200	400
Awards & inventor payments	2	40	100	200
Education or training	1	20	50	100
Other				

Technology transfer initiatives

Defense Programs Technology Commercialization Initiative—The Defense Programs Technology Commercialization Initiative (TCI) was begun in 1990 to facilitate the transfer of technologies, skills, and know-how between the DOE Nuclear Weapons Complex and the private sector. While the laboratories and production plants that compose the nuclear weapons complex are well known for their work in nuclear weapons, it is less well known that many of these technologies, skills, and processes can also be applied in the private sector. The goal of TCI is to make DOE technical capabilities available to U.S. private industries in areas related to manufacturing in a manner that will help strengthen core competencies of DOE Defense Programs and enhance the competitiveness of U.S. industry. Continued increases in TCI funding provided by DOE/DP will enable defense program laboratories to significantly impact national competitiveness. The initiative is managed by DOE.

Biomedical Technology Initiative—The growing cost of health care, diagnosis, and treatment has become an issue of national concern. Sandia has identified health care technology costs as a crucial area into which the transfer of laboratory capabilities and technologies will be intensified. A number of technologies arising from our work in microelectronics, microsensors, telemetry, data processing, and software and materials engineering could be usefully applied with further development to improving the quality of the nation's health care and reducing costs. Current Sandia technologies appropriate for application in the medical field include a sensor for monitoring blood sugar levels in diabetics; software for the personal computer that incorporates a powerful new set of analytical tools for chemists; computer vision for automated screening of mammograms that would enable radiologists to focus on abnormal films and allow earlier screening of more women; a device for measuring the oxygen saturation of fetal blood that could safely reduce the number of Cesarian sections; and spectroscopy for rapidly and reliably screening suspect human tissue. All of these technologies will be made available for transfer through licenses or CRADAs to private companies to be developed into products that will directly benefit the nation's health care by improving the quality of life and reducing the costs of diagnosis and treatment.

Technology-Based Regional Economic Development (TRED) Program—We have developed a regional technology transfer plan to encourage greater local participation in Sandia's technology transfer program. The program is coordinated with New Mexico's Small Business Development Centers, Cooperative Extension Service Agents, and the Manufacturing Productivity Center. Many of New Mexico's technology companies are start-up enterprises that require manufacturing, management, and marketing counsel in addition to the technology know-how provided by Sandia. The program includes tours of Sandia to acquaint business people with Sandia's resources. Sandia will also offer periodic technical workshops and seminars to businesses and publish a state technology transfer resource directory listing the types of technological resources available statewide, including those at Sandia and Los Alamos National Laboratory. The program is meant to utilize Sandia's unique capabilities and provide advice or technical assistance not readily available elsewhere. It is not intended to provide services or assistance obtainable from commercial companies.

Science and mathematics education support programs

The Sandia Education Outreach Program consists of an extensive, interrelated set of projects supporting scientific and technical education. Each of these projects helps to improve scientific and technical education as Sandians interact with students, teachers, parents, and institutions toward enhancing public understanding of science and increasing the number of students choosing careers in science and technology. It is our intention to be active at all levels of educational attainment from kindergarten through post-baccalaureate, across a broad range of constituencies, locally, statewide, and nationally.

A few examples of Sandia's involvement in such programs include: the Summer Science Camp for high school students; the Hands On/Minds On Technology Program for fifth through twelfth grade minority students; DOE's minority universities Science and Technology Alliance and its Teacher Research Associates summer employment program; local sponsorship of the Math/Science Network's "Expanding Your Horizons" conferences, a program that encourages girls to pursue mathematics and science courses; project STRETCH (Students and Teachers Raising Expectations to Challenging Horizons), a program to encourage educational reform in the Oakland, California, Unified School District through parent, community, and industry involvement; and the Livermore, California, Unified School District Science Advisory Council, established at Sandia's urging to improve the quality of science education in the Livermore Valley elementary and secondary schools. BASTEC, the Bay Area Science and Technology Education Consortium, involves four San Francisco Bay Area national laboratories and the University of California in developing cooperative models for interacting and collaborating with schools and school districts to improve K–12 education.

Focusing primarily on support of teachers as the most efficient way to achieve our outreach goals, Sandia has developed two new projects with the direct support of the Department of Energy: the Science Advisors (SCIAD) project and the Teacher Opportunities to Promote Science (TOPS) project. The well received Science Advisors project places Sandia technical staff in public elementary and middle schools and Bureau of Indian Affairs schools one day a week. Their job is to support science teachers by enhancing teacher understanding of scientific principles, contributing to the science curriculum, and developing demonstrations and experiments for the classroom. The project is in its second year, serves more than 150 schools throughout the state, and is being emulated by other agencies. The TOPS project helps twenty-five rural middle school teachers enhance their knowledge and understanding of science in a three-year program conducted both at Sandia and at schools. Now entering its second year, the project is showing positive results.

Bubble wrap and a helmet protect Albuquerque middle school student Ian Bogost as he and his classmates are introduced to Newton's Second Law of Motion (force = mass times acceleration) by Sandian Ken Eckelmeyer.

Sandia interacts extensively with

universities for research services, technical expertise, campus recruiting, faculty development, facilities sharing, and technology transfer. It is also in our interests as an active corporate citizen to support local educational institutions. Universities provide continuing educational opportunities for on-roll employees and help shape the cultural climate of the communities in which we live.

Pre-college projects

Hands On/Minds On Technology—These projects are offered to middle school and high school black students, middle school American Indian students, and middle school Hispanic students to take classes during the evening for several weeks. Classes are taught principally by Sandia employees in subjects such as physics, electronics, mathematics, and computers. There exist three individual projects: Hands On/Minds on Technology for black students, Dream Catcher Science Program for American Indian students, and MANOS for Hispanic students.

Summer Science Academy—A project whereby high school juniors and seniors attend four weeks of half-day classes in physics, mathematics, computer science, electronics, materials science, and energy technology. This very successful program has been in existence for sixteen years.

Science Advisors Project—This project is designed to enhance the mathematics, science, and engineering education of large numbers of students by helping teachers become more knowledgeable and comfortable in teaching those subjects. The project pairs a scientist, engineer, or technician with the faculty at an elementary or middle school one day a week for the entire school year. Currently, there are approximately two hundred Sandians and 170 schools from New Mexico participating in the program. One unique benefit of the Science Advisors Project is that it does not target a particular group but rather maximizes the benefit for all children.

Rural/American Indian Science Education Project—Sandia scientists, engineers, and technicians serve as long distance consultants to science and mathematics teachers in rural and American Indian schools, providing teacher enhancement through guidance on the implementation of classroom experiments, development and use of new instructional materials, and access to state-of-the-art, practical, scientific applications. The Sandian assigned to a school will visit the school once each semester and thereafter interact with faculty from that school on a weekly basis via audio/video communications technology. The schools currently in the project are located in North Dakota, South Dakota, North Carolina, Arizona, and New Mexico.

Albuquerque Public Schools Career Exploration Program Half-Time—This program provides half-time employment positions at Sandia National Laboratories for senior high school students. Students work independently on projects with assistance and mentorship from engineers and scientists.

Summer Employment for Minority Youth—This program provides summer employment for minorities who are high school juniors and seniors or university freshmen and sophomores. The program is designed to provide real-world work experiences in technology fields. This program does not require applicants to meet any financial criteria and is strictly targeted to students with mathematics and science interests.

Youth Opportunity Training Program—This program is directed toward economically disadvantaged high school and post-secondary students. Program goals are for the student to understand principles learned in the classroom, determine occupational inclinations, identify career options, experience the disciplines and rewards of work, and earn income to continue her or his education.

Teacher Research Associates—This DOE-sponsored program provides outstanding high school science and mathematics teachers opportunities for scientific and engineering research experiences during the summer.

Educational Program Participation
(Number of individuals participating)

	FY90	FY91
Pre-College Programs:		
Hands On/Minds On Technology	100	125
Summer Science Academy	100	60
Albuquerque Public Schools Career Exploration Program Half-Time	5	25
Summer Employment for Minority Youth	44	23
Youth Opportunity Training Project	98	150
Work Study Trainee Project	61	103
Teacher Research Associates*	9	11
Summer Teacher Enrichment Program	11	9
Undergraduate Programs:		
Science and Technology Alliance*	27	32
Historically Black Colleges and Universities*	13	15
Summer Employment for Minority Youth	35	35
Co-op Education	9	12
Las Positas College Scientific Honors Program	2	2
Outstanding Student Summer Program	60	90
Graduate Programs:		
One-Year-on-Campus	13	10
National Consortium for Graduate Degrees for Minorities in Engineering	2	4
AT&T Cooperative Research Fellowship Program	1	1
Graduate Engineering Interns	4	4
National Physical Science Consortium	1	1
Postdoctoral and Faculty Programs:		
Postdoctoral Internship	16	38
University Faculty Summer Employment/Academic Year Sabbatical	21	21
Sandia/UNM Distinguished Professor Program	8	8

* Program sponsored by DOE Headquarters

Summer Teacher Enrichment Project—Provides an opportunity for middle school and high school teachers to upgrade their knowledge and skills through practical work experience in areas related to their educational specialities and through exposure to the Laboratories' programs and projects.

Work Study Trainee Project—This project is directed toward economically disadvantaged students enrolled in occupational education programs.

Undergraduate projects

Science and Technology Alliance—Sandia is a major participant in this DOE-sponsored program, a consortium of three national laboratories (Sandia, Los Alamos, and Oak Ridge) and three educational institutions (Fundación Educativa Ana G. Mendez, New Mexico Highlands University, and North Carolina A&T State University). AT&T has joined as the first industry participant. The Science and Technology Alliance was created in November 1987 for the purpose of increasing the representation of blacks, American Indians, and Hispanics in the scientific and engineering programs of DOE and other government agencies and private industry. It was established as a developmental effort to assist the participating universities in upgrading their infrastructures and increasing collaborative efforts with the national laboratories.

Historically Black Colleges and Universities—Sandia is an active participant in this DOE-sponsored summer program designed to offer summer employment for exceptional junior, senior, and graduate engineering and science students and faculty from the historically black colleges and universities. Students earn academic credit for participating in research and preparing technical papers.

Summer Employment for Minority Youth—Begun in 1990, this program provides summer employment for minorities who are high school juniors and seniors or university freshmen and sophomores. The program is designed to provide real-world work experiences in technology-related fields. Unlike some other summer employment programs in existence, it imposes no financial criteria and is strictly targeted to students with mathematics and science interests.

Co-op Education—Provides opportunities for undergraduate students to acquire meaningful laboratory experience by alternating work experience with college studies. Work assignments are carefully matched to the individuals' interests, and the technical challenge is raised as one's education advances.

Las Positas College Scientific Honors Program—Provides summer work experience at our Livermore, California, facility for academically outstanding and financially disadvantaged, first-generation college, or minority students.

Minority Engineering Program—The program provides advising, tutoring, and mentorship for Hispanic and American Indian engineering students at the University of New Mexico.

Outstanding Student Summer Program—Provides opportunities for summer work experience in a laboratory environment for students of engineering and science from the junior level through PhD.

Graduate projects

One-Year-on-Campus—To help meet Sandia's need for minority engineers and scientists, bachelor degreed candidates are hired and allowed to attend school full time in the One-Year-On-Campus program. In specific disciplines where Sandia has difficulty recruiting masters level people, bachelor level employees are hired and allowed to attend school half-time for two years to complete their masters degrees.

National Consortium for Graduate Degrees for Minorities in Engineering—Sandia is a participant with this consortium of university and industry members that provides opportunities for under-represented minority students to obtain masters degrees in engineering through a program of paid summer engineering internships and financial aid.

AT&T Cooperative Research Fellowship Program—Sandia participates in this AT&T program that originated in the research departments of Bell Laboratories. The program provides financial support and summer internships to minority engineering and science doctoral candidates.

Graduate Engineering Interns—Similar to a co-op program, this program provides opportunities for graduate students to acquire meaningful laboratory experience by alternating work and academic experience. Available during the academic year.

National Physical Science Consortium—Sandia is a member of this consortium of universities, federal research facilities, and corporate employers, which provides doctoral fellowships for minorities and women in the physical sciences.

Postdoctoral and faculty projects

Postdoctoral Internship—Sandia hosts postdoctoral students in areas of research where its expertise or facilities provide a good match for the student's interest.

University Faculty Summer Employment/Academic Year Sabbatical—These two programs are designed to attract outstanding professors from universities throughout the country who will make meaningful contributions to the Laboratories' technical expertise. At the same time, the participants have the opportunity to engage in interesting, mission-oriented work. These professors are brought on-roll as temporary employees to work on research and development projects specified by Sandia organizations.

Sandia/UNM Joint Appointments Program—This collaborative program seeks new faculty members for positions in fields important to both the University of New Mexico and Sandia. Appointees under this program devote half time to teaching at the university and half time to research at Sandia for a period of two years.

Sandia/UNM Distinguished Professor Program—Under this arrangement, outstanding professors join the University of New Mexico and are permitted to perform research at Sandia under contract.

Sandia University Research Program—This faculty development program provides research funds for faculty members at the three PhD-granting institutions in New Mexico. The program is limited to new faculty and is usually the first funding the investigator has received. This "seed money" is sufficient only to fund one graduate student, pay the summer salary of the faculty member, and reduce the teaching load during the academic year. Funding is limited to research that is of active interest to the sponsoring Sandia organization and is for a maximum of two years. The return on this seed money is frequently substantial. Participants have often attracted to their institutions many times more funding than the original Sandia outlay.

Improving communication laboratory-wide is one of several strategies Sandia is using to increase employee participation and achieve an empowered culture. In a program entitled, "Brown Bagging with Brass," Sandia managers hold informal, lunch-time discussions with employees.

Human resources management

Sandia's Vision Statement declares that people are Sandia's most important asset. Sandia's philosophy is to hire exceptional people, provide them with the support needed to meet individual and organizational objectives, and reward them appropriately for their achievements. The desired environment reflects openness, candor, innovation, and professional growth within a framework of compliance with all legal and contractual requirements.

The mission of Sandia's Human Resource (HR) management program is to provide leadership in HR management that acknowledges and supports the "people side" of doing business. In partnership with customers, the services and consulting that support the business strategy create an environment for living Sandia's values. HR plans are derived from Sandia's business strategies, quality goals, and program requirements, both short-term and strategic. The planning process is designed to ensure (1) the inclusion of HR considerations in implementation strategies of organizational plans and (2) the alignment of Sandia's HR policies, programs, and services with regulatory, legal, and internal requirements.

HR planning begins with an impact analysis of Sandia's strategic and near-term business challenges and the concomitant human resource implications. These are evaluated to produce a set of critical HR success factors, which include changes in legal and regulatory requirements, work force productivity, future work force demographics, forecasts of work force needs and supplies, training and retraining requirements, and so forth. Strategic and near-term objectives and policies are formulated from assessment of these factors against current operations. When implemented, these should result in the staffing profile, work force environment, and work force characteristics required for successfully meeting legal, regulatory, and internal customer requirements.

Manpower planning is a major responsibility of management. Sandia's HR management program oversees the planning activity, which involves four major processes:

1. Determining affordable staffing requirements by program
2. Utilizing existing Sandia staff
3. Acquiring new staff for Sandia
4. Supplementing the regular work force with nonregular and contract personnel

These processes are managed with appropriate regard for labor contracts and equal employment opportunity requirements. Manpower planning is initiated with an annual analysis of Sandia's manpower by HR management and Sandia's Management Council to determine the Laboratories' size for the upcoming three fiscal years and to formulate the overall hiring program to attain the desired size.

Sandia administers its compensation function in support of its vision and philosophy regarding the value of people. In addition, Sandia acknowledges that compensation must support the philosophy that work must be performed in a manner consistent with ES&H, quality, and other process values. Both the results and the process used to achieve results are key components for success.

Sandia's benefits are developed, maintained, and administered to provide cost-effective employee benefits and services that support Sandia's capability to recruit and retain a high quality work force. The HR management program is responsible for ensuring that equal employment opportunity and affirmative action are conducted in accordance with good business practices. Sandia is succeeding in increasing its utilization of women and minorities in all staffing classifications.

Laboratory personnel

Sandia Laboratories management is committed to preserving the vitality and quality of the Laboratories' technical and support staff. In general, Sandia follows the personnel practices at AT&T and Bell Laboratories, allowing for unique provisions to accommodate local conditions and precedent.

For many years we have conducted nationwide recruiting efforts at leading universities for the best qualified technical candidates. In parallel, extensive continuing education and retraining efforts are ongoing for all staff in order to respond to changing technical challenges and mission needs and encourage effective employee development. Staff recruiting requirements are updated and published annually for campus recruiters. The listing includes requirements by degree level and discipline, which are determined for all departments at Sandia. These requirements are supplemented by changes in requirements throughout the year.

Sandia's technical staff are recruited from all disciplines of engineering and the physical sciences. About 58 percent of the nearly 3,600 Members of Technical Staff (MTS) have engineering backgrounds, with the majority having degrees in electrical and mechanical engineering. The remaining 42 percent is comprised of various technical disciplines, including nearly 400 physicists and nearly 400 computer scientists or mathematicians. Approximately 36 percent of the Members of Technical Staff (MTS) have PhD degrees, while 43 percent have MS degrees.

In support of the professional technical staff are various categories of technicians. There are well over 1,000 Senior Technical Associates and approximately 500 Technical Associates included in this group. In addition, indirect and administrative support is provided by over 700 Members of Laboratory Staff (MLS) and nearly 600 Management Aides. Nearly 1,700 graded employees perform clerical, crafts, service, and maintenance functions.

For many years it had been the policy of Sandia that a master's degree was the minimum educational requirement for new hires for technical and administrative staff positions. Management altered this policy in FY 1990 to permit hiring of bachelor-degreed engineers and administrators. The change acknowledges that there are job needs of varying levels of sophistication that should be filled by appropriate candidates.

The internal Job Announcement System gives employees the opportunity to achieve career objectives and helps create good morale (Sandia's quit rate is 0.8 percent). At the same time, it gives management a mechanism to acquire staff internally.

Management is actively fostering a work culture that permits assumption of risk and responsibility by individuals in order that creativity, participation, and ownership may flourish. Sandia has adopted the Process Quality Management and Improvement guidelines used by AT&T. Our goal is to build a quality ethos into all of our operations and activities. We are moving toward an environment that emphasizes defect prevention while retaining the benefits of our historical focus on defect detection. Quality improvement processes involve employees working together in teams to search out the root causes of errors or defects and correcting the processes that give rise to such errors. Thus, the focus for improvement is on processes, not people. Formal training in quality process theory is being provided for all staff.

Upward feedback, a program to provide managers with insight into subordinates' perceptions of their effectiveness as supervisors is continuing. The Sandians' Perspective Survey, conducted in the summer of 1991, is a tool for strengthening communication throughout the laboratory community.

Sandia has implemented several initiatives to help employees balance the needs of work and family. They include child and elder care referral services; dependent care spending and health care reimbursement accounts; flexibility in establishing working hours; employee assistance programs; health and wellness programs, and others.

Sandia has instituted a no-smoking policy to foster a more healthful workplace. In view of the documented adverse health effects of secondary smoke on nonsmokers, we extended an existing partial smoking ban to a comprehensive smoke-free policy in all of Sandia's buildings in 1990.

The Laboratories implemented a pre-employment drug testing requirement in December 1990. It is our intent to send a clear message to those considering employment that we are firmly committed to a drug free work place. We reserve the right to require any employee to cooperate in testing for the use of drugs and controlled substances where there appears to be reasonable suspicion of drug use.

Laboratory Staff Composition

	PhD	MS/MA	BS/BA	Other
Professional Staff:				
Scientists	699	475	116	21
Engineers	637	1152	326	22
Other Technical			1	326
Management and Administrative	29	408	146	35
Support Staff:				
Technicians		21	193	1559
All Other		30	193	2218
Laboratory Total Staff	1365	2086	975	4181

Affirmative action and equal employment opportunity

'Respect for the individual' is one of the five corporate values articulated in Sandia's strategic plan. This value is at the foundation of Sandia's human resources policies, including affirmative action and equal employment opportunity. It is Sandia's policy to conduct all corporate activities in accordance with the letter and spirit of all applicable employment opportunity laws and regulations, including Title VII of the 1964 Civil Rights Act, Executive Order 11246, the Age Discrimination in Employment Act of 1967, the Rehabilitation Act of 1973, the Vietnam Era Veterans Readjustment Assistance Act of 1973, and the Americans with Disabilities Act of 1990.

Details of Sandia's workforce composition and progress toward meeting Affirmative Action objectives may be found in the Laboratories' Affirmative Action Plan. We ensure that our employment and promotional actions are in accord with the principles of equal employment opportunity and affirmative action by basing our decisions only on valid job-related requirements. We recruit, hire, train, and promote persons in all job titles without regard to race, religion, gender, age, or national origin. Other personnel actions and policies (such as compensation, benefits, transfers, layoffs, return from layoff, Sandia-sponsored training, education, tuition assistance, social and recreational programs) are also administered without regard to race, religion, gender, age, or national origin.

With respect to job applicants or employees with disabilities, Sandia's personnel process assures a thorough and systematic consideration of applicant qualifications and job requirements. We will review the physical or mental job requirements to ensure that such requirements are job-related and consistent with business necessity and safety. Accommodations to reconcile job requirements with a candidate's unique situation are routinely developed.

Ongoing EEO/AA initiatives are conducted on several levels, both within the organization and outwardly directed. During FY 1991, all levels of Sandia management attended "Valuing Diversity" training. The objective of this training is for members of management to acquire expanded sensitivity and awareness with respect to the potential of all employees regardless of racial, gender, or cultural considerations. During FY 1992 we will conduct two pilot sessions of "Insights for Success" for women and minorities. If these sessions are reviewed positively by those who attend them, more sessions will be scheduled later in the year. The Affirmative Action Council, a group of five members of Sandia's Management Council, plus one female and one minority director, brings executive focus to affirmative action issues, plans, and programs, and has been meeting quarterly since November 1988.

It is also Sandia's policy to prohibit sexual harassment of its employees in any form. Policies and practices conform to the Sex Discrimination Guidelines for Government Contractors (41 CFR 60-20). Both supervisors and employees are subject to complying with Sandia's policy on sexual harassment. Complaints of sexual harassment (or other forms of harassment or discrimination) are investigated immediately. Appropriate sanctions may range from warning to termination of employment.

We ensure that maximum opportunity is afforded to minority and women-owned business enterprises to participate as suppliers and contractors to Sandia. Sandia has had a very active small, disadvantaged, and woman-owned business program for over 15 years.

The small business liaison officer must approve all requests for quotation of $10,000 or more that are awarded on a competitive basis. In the event that a buyer has been unable to locate a small, disadvantaged, or woman-owned business, the liaison officer attempts to locate one.

Sandia has received several awards from the Small Business Administration, DOE, and other organizations. They include the SBA's Distinguished Prime Contractor of the Year Award for Region VI; SBA Category A Superior Program Performance Awards (the SBA's highest national award for federal prime contractors); the Department of Energy's Superior Achievement Award "in recognition of outstanding service to minority and women-owned business development"; and the Rio Grande Minority Purchasing Council's Outstanding Contributor Award.

Continuous professional education

Continuous employee improvement is essential if the Laboratories is to thrive as a world class research and development organization. In support of the corporate mission, values, and objectives of Sandia's strategic plan, Sandia's Education and Training function nurtures and supports individual and group development by providing a wide variety of high-quality opportunities for performance improvement throughout an employee's career at Sandia. The scope of performance improvement opportunities includes gaining and applying knowledge, skills, and abilities in the advancement of technology, quality human processes, protection of the environment, and ensuring the safety and health of Sandia's employees.

Training needs of the staff are determined through ongoing assessments, and curricula are developed to target specific job performance improvements. Current emphasis is on curricula in quality, design for manufacturability, and project management. Career development needs are addressed by a combination of classroom-based interventions and job assignments to improve both qualifications for jobs and the optimum match of people and positions.

Sandia offers ongoing training and skills enhancement in leadership and management development. Currently, we are accomplishing this through a combination of internal courses and university or institute seminars. Individual coaching of newly promoted supervisors at the time of their promotion, and at regular intervals during their first year, has recently been begun.

In keeping with national trends, Sandia has expanded its use of organizational effectiveness training, providing consultation in both organizational development and human performance improvement. Organizational development consulting consists of strategies and interventions based on behavioral science theory and

Perry Horse conducts a workshop in supervisory effectiveness for new managers.

practice that lead to planned change within an organization. Process consulting continues to be offered and used as a vehicle for corporate strategic planning, strategic management, problem solving, group facilitation, team building, and change management.

Human performance improvement focuses specifically on the performance of individuals within organizations. This expertise is currently being applied to corporate initiatives linked to our strategic plan, upward feedback, leadership effectiveness, and the total management of human resources at Sandia.

Sandia employees may begin or continue university academic studies by one or more of several programs. These include the Local University Education Off-Time Program, the University Part-Time Program (which allows for half-time work assignments while attending school half-time), and the Doctoral Study Program, where participants attend school full-time for two years while completing PhDs. The One Year On Campus program serves the Laboratories' affirmative action objectives by permitting bachelor-degreed new-hires to attend school full-time to earn a masters degree.

Sandia also designs, develops, and implements requirements-based training to develop the knowledge, skills, and abilities to enable employees to perform their jobs with proper regard for ES&H. During the last year we developed instructional design and technical standards, methods, and processes to endure consistency and quality across the Laboratories in the development, procurement, implementation, documentation, and evaluation of ES&H training.

Instructional television is used as an on-site delivery vehicle for university courses and professional seminars. Sandia maintains video links with the University of New Mexico, New Mexico Institute of Mining and Technology, and New Mexico State University to offer courses at our Albuquerque location. Three educational television networks were started in 1971 that link Sandia Livermore with several Bay Area universities, including Stanford University and the University of California at Davis.

Other delivery mechanisms include lecture style classroom instruction, individualized self-paced instruction, and home study.

The Sandia quality improvement initiative

Quality is one of the five corporate values articulated in Sandia's strategic plan. It is defined as conformance to customer requirements for performance, cost, and schedule. Exceeding the sponsor's "musts" and providing some of the "wants" will further increase customer satisfaction. Going even further and fulfilling customers' unanticipated needs will gain their loyalty and reflect world-class excellence. As a national laboratory, we cannot be satisfied with less than world-class performance.

Customer focus will be the single most important characteristic of the successful corporations of the future. Our definition of 'customer' comprises internal as well as external customers.

The general customer-supplier model, based on AT&T's Process Quality Management and Improvement (PQMI) methodology, provides a graphical depiction of Sandia's Quality Management System. The model is constructed on the premise that every individual has customers who use the outputs of his or her job. Similarly, every individual is dependent upon suppliers who provide inputs. Processes should initially be designed to satisfy the customer's requirements and should be continuously improved based on customer feedback and objective measures of the extent to which requirements are being satisfied. Process owners should likewise communicate their requirements and feedback to suppliers.

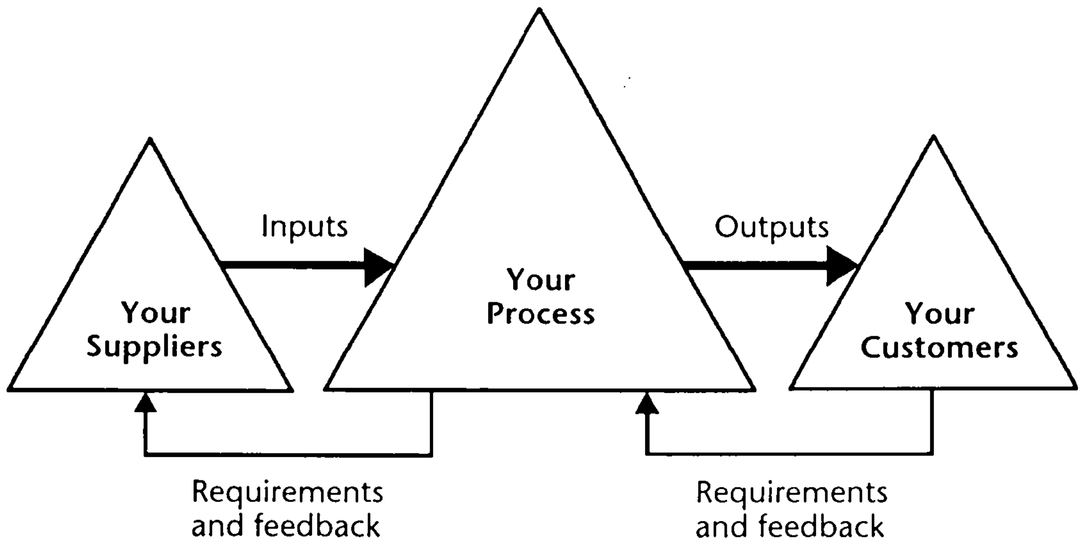
It is important to thoroughly understand the processes occurring within the center triangle of the customer-supplier model. Quality improvement involves employees working together in teams to search out root causes of engineering errors, defective software, late reports, unmanufacturable designs, ineffective or time-wasting systems, and other process problems. This team approach ensures that quality improvement becomes an integral part of the way we do our work.

Twenty percent of Sandia's employees have been trained in PQMI, which helps people focus their efforts for improvement on processes rather than on individuals. As a result of this training, Process Management Teams have been formed throughout the Laboratories to address critical issues related to quality processes.

Quality Function Deployment (QFD) has been recognized as an effective follow-on tool to PQMI. QFD is a discipline for product and service planning and development in which key customer desires can be matrixed with the task and process variables needed to satisfy them. Line personnel are being given the opportunity to be trained to teach PQMI, and many of these same people are receiving on-the-job training in how to facilitate the application of QFD to specific projects.

The processes that have resulted in safe, reliable, high-performance nuclear weapons can be used in other ways to improve services and products. We are sharing a limited amount of resources for teamwork activities with city and state government (such as the Albuquerque Quality Network) and educational institutions. This activity is in keeping with serving the national interest and is an expression of our desire to be a good neighbor in the community.

Senior management, through the Sandia Quality Council, has provided leadership by revising the Sandia Quality Policy, defining the Quality Management System, and developing corporate quality goals. This management commitment and implementation guidance is formalized in the Sandia Quality Improvement Plan, which presents a Quality Management System that integrates Sandia's quality policy and several independent improvement processes into a



The General Customer-Supplier Model

cohesive structure. The Plan is based on management practices generally accepted by high-technology industry and specifically adapted by AT&T.

Sandia management has established five corporate quality goals to provide a consistent direction for quality improvement throughout Sandia. These goals are supported by objectives, responsibilities, measures of performance, and a desired schedule. They are intended to accelerate progress toward ES&H excellence and build a bridge to the future application of quality methodologies to all Sandia programs.

Quality Goal: Demonstrate progress toward becoming a national leader in quality. Sandia's Strategic Plan 1990 stated a strategic objective that the Laboratories shall "become a national leader in quality and quality progress." Sandia has taken a very important step in the journey toward becoming a national leader in quality. Ownership for each of the seven categories of the AT&T Chairman's Quality Award has been accepted by Sandia senior managers. These categories are identical to those of the Malcolm Baldrige National Quality Award:

1. Leadership
2. Information and analysis
3. Strategic quality planning
4. Human resource utilization
5. Quality assurance
6. Quality results
7. Customer service

Milestones have been agreed upon that begin with a schedule for the first rough draft of the award application to the winning of the award. The set of scores for the seven categories will be used as a frame of reference from which we can measure our improvement over time. Our progress will be judged by looking at the approach, deployment, and results in each category. Success will require extraordinary dedication, teamwork, and training at all levels. The benefits of winning the Chairman's Award could include national recognition, enhanced sponsor confidence, and a firm funding base from which to serve the national interest.

Quality Goal: Vigorously and persistently solicit our sponsors' evaluations of work performed and work with our sponsors to make sure that such evaluations are as meaningful as possible. Measuring the quality of work performed can begin quickly using evaluations from our prime customer, DOE. The appraisal system currently being developed with DOE/AL-KAO has several elements that are important to DOE. These elements include compliance with DOE Orders, ES&H compliance and improvement, progress toward reaching strategic plan objectives, and performance on major projects.

We are developing feedback techniques to assure that we collect the necessary data to enable us to properly evaluate customer satisfaction. Several Sandia organizations are now using such data to create action plans directed at processes in need of improvement.

Quality Goal: Increase efforts at defining processes, establishing ownership of the processes, and vesting responsibility and authority for continuous improvement of these processes with individual employees where possible. Process improvement is essential to both quality improvement in programs and ES&H performance improvement.

Sandia is implementing a Quality Action Request (QAR) system to provide a mechanism for employee involvement in process improvement. QARs from employees are entered into a data base and assigned to the cognizant center directors or a corporate screening board for evaluation and possible action. Similar employee input programs have led to significant improvements at other companies, such as Florida Power and Light, the first U.S. company to win the Deming Prize for quality.

Quality Goal: Improve the job-related ability of all Sandians. One of the ways to accomplish this goal is to increase job-related education and training. The training required should be determined by employees and their supervisors. Initially, the focus should be on ES&H-related training. In the future, it might also include quality training, a university course, symposium attendance, a management training short course, or a training course in a specific skill. It is our objective that all employees will receive all ES&H training required to be certified to do their jobs by October 1, 1992. Additionally, it is our objective that all employees will obtain required ES&H-related, quality-related, or other job-related training by October 1, 1993.

Quality Goal: Improve project management by including project reporting, control planning, and requirements establishment (cost, performance, and schedule). We are adapting project management tools and methodologies that will fit with our existing support systems at the Laboratories. Project management information that is derived from generally accepted project management techniques used in industry is made available to Sandia managers in several forms, including written materials and course offerings. We will continue to evolve our project management guidelines as we gain experience and improve our support systems.

Sites and facilities

Laboratory description

Sandia is one of the nation's largest research and development facilities. Its executive management offices and larger laboratory location are on Kirtland Air Force Base on the southeastern edge of Albuquerque, New Mexico. Another Sandia laboratory complex in Livermore, California, adjoins Lawrence Livermore National Laboratory. Test ranges are operated near Tonopah, Nevada, and on the Navy Pacific Missile Range, Kauai, Hawaii.

Total Sandia facilities represent in excess of $1 billion of U.S. government assets at current replacement value, consisting of $360 million in buildings and structures, $10 million in improvements to land, $735 million of capital equipment, and $31 million in utilities. Sandia's 660 buildings provide total laboratory, shop, and office floor space of approximately four million square feet. They are located on land totaling approximately 562 square miles, most of which is at the Tonopah Test Range. About 7,250 employees work at the Albuquerque location and about 1,050 at Livermore. Slightly more than 100 Sandians are located at Tonopah, the Nevada Test Site, and elsewhere.

Sandia operates a broad range of facilities, many of which are unique. These facilities are used for a wide variety of projects ranging from basic materials research to the flight testing of components. They include state-of-the-art equipment for environmental testing, radiation research, combustion research, computing, and microelectronics research and production.

Extensive environmental test facilities are located at the Albuquerque laboratory location and within a 60 square mile hazardous test area further south on Kirtland Air Force Base. In addition to standard environmental test capabilities for component and system development, Sandia has a variety of special purpose test facilities. Examples include two of the world's largest centrifuges; blast tubes operating from 1 to 2,000 psi; a facility for impulse testing using sprayed, light-initiated high explosives; a low-field, broadband electromagnetic radiation facility; a radiant heat facility; a facility to provide large quantities of molten metal oxides for studying nuclear reactor accident conditions; a 10,000-foot rocket sled track; a multiple-stroke lightning facility capable of simulating natural lightning; drop towers (including one to simulate water impact); and a 5,000-foot aerial cable for impact tests.

Other major facilities include a full-service technical library for employees; a primary standards laboratory; transonic, supersonic, and hypersonic wind tunnels; and design, fabrication, and process development laboratories.

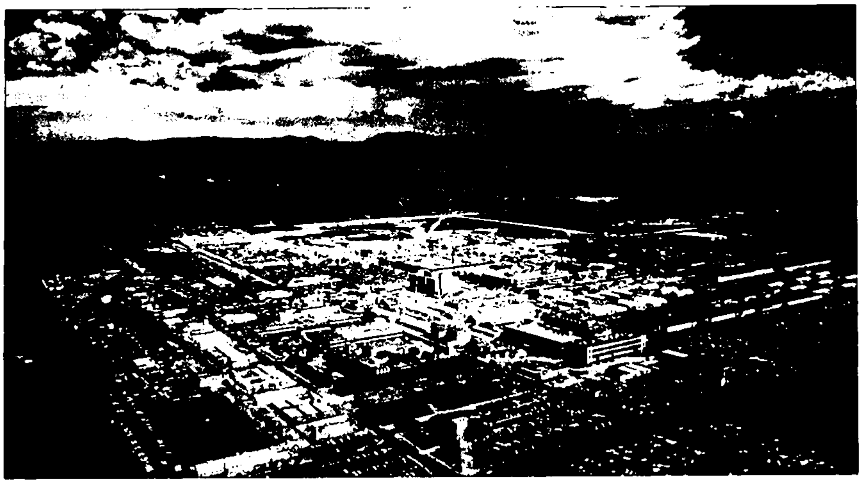
The Tonopah Test Range, a major test facility for DOE-funded weapons programs, is a permanent outdoor testing laboratory with unique capabilities for gathering data from a variety of test vehicles. This 525 square mile area is located on the north end of the Nellis Bombing and Gunnery Range about 32 miles southeast of Tonopah, Nevada. The range provides state-of-the-art instrumentation systems for test vehicle tracking and data acquisition.

The Kauai Test Facility (KTF) on the Navy's Pacific Missile Range Facility (PMRF) in Hawaii has a rocket preparation and launching capability for both rail-launched and vertically launched rockets. Sandia maintains its own launch, ground handling, and launch control equipment, augmented when necessary with assets of the PMRF (*e.g.*, radars, communications, and aircraft).

Many of our specialized research facilities constitute major national resources. A few examples are:

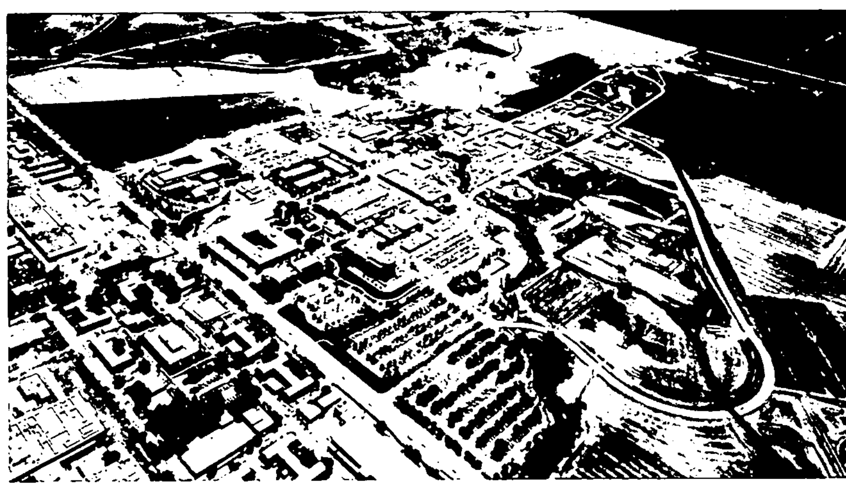
- Pulsed power accelerators, including the Particle Beam Fusion Accelerator II (PBFA II), the Saturn x-ray simulator, and the Hermes III gamma-ray generator, to simulate nuclear weapon effects and permit study of pulsed power approaches to fusion energy;

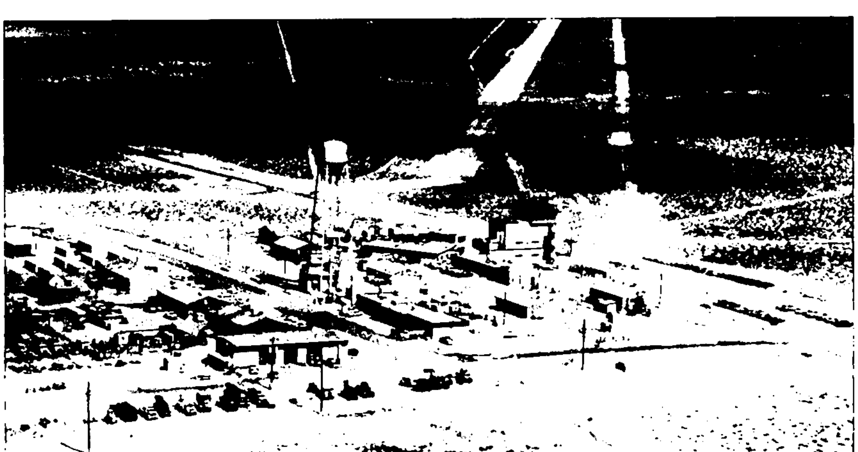
- Reactor facilities to evaluate the effects of nuclear weapons on components and simulate the internal environments of power reactors;



Sandia National Laboratories, Albuquerque, New Mexico

Sandia National Laboratories, Livermore, California





Sandia National Laboratories, Tonopah Test Range, Tonopah, Nevada

- Facilities and equipment to study semiconducting materials; environmental test facilities (shock, vibration, temperature, etc.) for nonnuclear, aboveground field tests; and dedicated facilities and test equipment at Pantex in Amarillo, Texas, for quality assurance and stockpile evaluation operations;

- The Combustion Research Facility in Livermore, California, to contribute to solving problems in combustion science, energy, and the environment;

- Robotics laboratories for basic scientific research and engineering development of prototype advanced systems with application to DOE weapon production activities and the retrieval and repackaging of radioactive wastes;

- A unique complement of solar thermal facilities for testing distributed receivers, central receivers, and high-temperature materials and processes, along with an advanced photovoltaics facility for testing concentrator and flat plate systems;

- And extensive computing facilities to support our growing use of computational methods and computer-aided engineering.

Facilities plans and options

Sandia's Site Development Plan, updated annually, contains a comprehensive description of planned facilities changes. The plan describes an optimum site development projection with short-range and long-range plans for the three principal Sandia sites.

Two essential factors underlie Sandia National Laboratories' site and facilities plan. One is a problem that has existed from the Laboratories' founding, when the nation was in great urgency to build a nuclear arsenal. The Laboratories did not have adequate permanent buildings then and the problem has never been fully corrected. The second recognizes that profound changes have occurred in engineering and supporting scientific technologies since Sandia was founded.

During the 1950s much of Sandia's engineering work was straightforward and was checked with extensive field testing. But for many years now, cost-conscious engineering has been intensely analytical, relying heavily on elaborate, sophisticated instrumentation and measurements that require control of temperature and vibration to achieve repeatability and reliability. With this evolution, staff moved from the field to the laboratory. Laboratory work proliferated, the complexity of measurements and apparatus increased, and professional requirements for staff were raised. These changes created new facility needs.

Two other important factors are the need to conserve energy and the requirement to provide special purpose buildings for certain applications. Older structures, particularly temporary buildings, waste energy and are expensive to maintain. New technologies demand facilities designed to accommodate their special requirements. Examples are buildings for equipment to fabricate microstructures, inertial confinement fusion machines, special instrumentation systems, and computer centers.

The intent of Sandia's site development planning is to relieve space shortages and construct permanent buildings as replacements for temporary ones. As the construction program permits, we will retire mobile offices, trailers, transportable buildings, and other substandard space.

The Laboratories must also reduce dependency on buildings borrowed from the military. Sandia's Albuquerque location relies heavily on borrowed or leased buildings for warehousing, and should the Air Force need these buildings, they would have to be returned. Planned on-site construction will relieve problems of availability and accessibility.

Facilities resource requirements

Some of our laboratory facilities are being upgraded and new ones are being proposed. Several new construction projects address long-standing insufficiencies. Other projects accommodate changing functions and requirements.

Environment, safety, and health

concerns are actively addressed in planning for all facilities. Accordingly, all new buildings and major renovations are reviewed internally and by DOE for adequacy of ES&H design features. In the area of environmental protection, DOE now requires that all contractors comply with the provisions of the National Environmental Policy Act. This law stipulates that major construction projects be reviewed for potential impacts on the environment and compliance with environmental laws. For each new facility and major renovation, Sandia prepares an Action Description Memorandum for circulation within DOE. If DOE deems that further documentation is necessary, an environmental assessment or an environmental impact statement is prepared and made available to the public.

Projects required to meet environmental laws, regulations, and DOE orders are included in Sandia's Five Year Plan for Waste Management Operations and Environmental Restoration. DOE also requires a safety review of new construction projects and major renovations.

Funded construction

The principal goals of Sandia's construction plan are to provide facilities needed to achieve programmatic objectives, eliminate substandard conditions and overcrowding, and replace temporary and inadequate space with permanent facilities. Items listed in the table of major construction projects are briefly discussed below.

Strategic Defense Facility (Albuquerque)—This facility will provide space for research on directed energy weapons and weapon effects. Research will explore basic physics and the technical feasibility of particle beam, x-ray laser, microwave, and kinetic energy weapons. Evaluation will be based on the lethality and vulnerability of weapon systems and cost trade-off analyses. The facility will also provide engineering and field test support for weapon and component tests at NTS and other locations. At present, there is no laboratory for post-shot evaluation of experiments exposed in underground tests, and no adequate docking facility is available for reworking trailers between shots.

Defense Engineering Laboratory (DEL) (Livermore)—The Defense Engineering Laboratory is a controlled environment, state-of-the-art, engineering laboratory that will be used to support the engineering of modern nuclear weapons and the reengineering of the aging stockpile. These capabilities do not currently exist at Sandia Livermore, and are necessary to support ES&H compliance, to handle new materials with increased environmental sensitivity, and to enable the instrumental accuracies needed to characterize these materials and structures. The DEL will centralize many of our chemistry, materials, and nuclear directed energy capabilities to better meet ES&H and programmatic requirements, and enable new capabilities in lightweight structures, SDI materials, and pointing and tracking.

Integrated Materials Research Laboratory (Albuquerque)—Modern weapon requirements for safety, command and control, reliability, long life, and low system and life cycle costs are being met by the introduction of novel materials; smaller, lighter, and more closely coupled system designs; and more capable on-board intelligence. Further progress depends on a close integration of materials development and the design process for both electronic and structural materials. The laboratory is intended to provide space for materials development, characterization, and processing research; constitutive theory research; computer modeling; and advanced concept development in a highly integrated environment focused on the development of advanced weapon systems.

Explosive Components Facility (ECF) (Albuquerque)—Sandia is DOE's technology center for ordnance for nuclear weapon systems, and four of Sandia's departments will utilize the ECF: Explosive Components, Neutronic Components, Power Sources, and Weapons Evaluation. ECF capabilities include internal test fire chambers, an x-radiographic diagnostic laboratory, an explosive mild detonating fuze and timer development laboratory, remote postmortem and disassembly areas, and a pulse heat laboratory. A significant feature of the ECF will be improved explosives handling and safety.

Weapon Production Primary Standards Laboratory (Albuquerque)—We operate the Primary Standards Laboratory for the DOE/AL Standards and Calibration System. Very precise control of laboratory environments is essential for accuracy. In most cases, environments in current facilities are marginal or unacceptable. This building will provide appropriate space for the primary standards operation. Upgrading and concentrating all standards activities will enhance our ability to perform this vital function.

Technology Support Center (Albuquerque)—In order to minimize potential radiation exposures, this center will reduce the Tech Area V population by providing a new office, light laboratory, and conference center for the staff who support the nuclear facilities. An improved facility is particularly important because Tech Area V receives many visitors as a consequence of its nuclear development and testing programs for DOE, DoD, and other agencies.

Main Electrical Service and Switchgear (Livermore)—The existing main electrical service and associated switchgear is not adequate to supply site power requirements beyond 1992. The proposed service is dual-source, separate-direction, and will provide backup capability and additional capacity when required.

Robotic Manufacturing Science and Engineering Laboratory (Albuquerque)—This Laboratory will facilitate progress in the development of robotics and associated automation technologies, which have been identified as strategically important to the nation. It has become evident that these technologies can minimize the need to use human beings in hostile environments or near potentially hazardous materials; accomplish tasks which stretch normal human capabilities for complexity and reliability; and reduce production and operating costs within both the weapons production complex and the domestic industrial sector.

Center for National Security and Arms Control (Albuquerque)—Sandia is a recognized leader in advanced systems concepts for nuclear and conventional weapons and arms control verification. This facility will bring together work in four areas: (1) Systems Analysis and Advanced Concepts, (2) Arms Control and Verification Technology, (3) Intelligence, and (4) Threats and Countermeasures. The new center will significantly assist in ensuring our ability to continue to respond creatively and effectively in these four areas.

Combustion Research Facility, Phase II (Livermore)—This facility will provide resources to adequately deal with the critical combustion research needs of the 1990s. It will emphasize centralized next-generation laser diagnostic facilities and specially designed laboratories, including a high repetition rate laser system. Phase II will also provide additional offices required to support visiting researchers and staff.

The Weapons Production Primary Standards Laboratory at Sandia Albuquerque is now under construction. The facility will provide reliable, precise laboratory environmental controls essential for standards work.

MAJOR CONSTRUCTION PROJECTS
($ in Millions)

	Site*	Sponsor	Total Estimated Cost	BA thru FY89	FY90 BA
FUNDED CONSTRUCTION					
Strategic Defense Facility**	A	DoD	31.3	22.7	7.0
		DASMA	35.0	35.0	
Defense Engineering Laboratory	L	DASMA	45.6	19.7	7.8
Integrated Materials Research Laboratory	A	DASMA	27.9	21.1	4.4
Explosive Components Facility	A	DASMA	27.8	1.3	3.0
Primary Standards Laboratory	A	DASMA	17.7	17.7	
Technology Support Center	A	DASMA	30.0		
Main Electrical Service & Switchgear	L	DASMA	5.3		
Robotic Manufacturing Science and Engineering Laboratory	A	DASMA	33.0		
Total DASMA					15.2
Center for National Security and Arms Control	A	OAC	34.5		1.0
Combustion Research Facility, Phase II	L	ER	23.3	4.8	
Total Funded					16.2
PROPOSED CONSTRUCTION					
Power Systems Modernization	A	DASMA	42.5		
Storm and Waste Systems Modernization	A	DASMA	10.5		
Processing and Environmental Technology Laboratory	A	DASMA	81.3		
Program Support Center	A	DASMA	17.6		
ES&H Facility	L	DASMA	14.6		
Water Systems Modernization	A	DASMA	6.6		
Infrastructure Modernization	L	DASMA	16.8		
Transportation Systems Modernization	A	DASMA	7.9		
Falcon Test Facility	A	DASMA	91.3		
Micro Technologies Laboratory	A	DASMA	131.0		
Computing/CAE Building	A	DASMA	50.0		
Center for Environmental Technology Res.	L	DASMA	35.0		
Site and Seismic Modernization	L	DASMA	25.0		
Total DASMA					
Consolidated Waste Management Cmpx.	A	EM	90.9		
Geoscience Research Laboratory	A	ER	25.5		
Total Proposed					

* A=Albuquerque site; L=Livermore site
** DoD contribution is reimbursable funding—not included in construction funds total

FY90	FY91		FY92	FY93	FY94	FY95	FY96	FY97
Actual	BA	Actual	BA	BA	BA	BA	BA	BA
4.5	1.6	1.6						
4.5								
9.7	10.1	10.1	8.0					
2.1	2.4	2.4						
0.7	13.7	13.7	6.7	3.1				
0.2								
	2.6	2.6	6.5	8.4	12.5			
	1.0	1.0	3.3	1.0				
			1.0	6.9	17.0	8.1		
17.2	29.8	29.8	25.5	19.4	29.5	8.1		
0.4	5.0	5.0	10.0	10.0	8.5			
				11.0	7.5			
17.6	34.8	34.8	35.5	40.4	45.5	8.1		
					6.1	12.2	15.0	9.2
					3.2	5.3	2.0	
					4.0	33.0	35.0	6.0
					1.0	10.0	6.6	
					1.8	6.0	4.0	2.8
						2.2	4.4	
					1.8	10.0	5.0	
						2.6	5.3	
						14.0	18.0	25.0
							11.0	30.0
							5.0	20.0
								3.0
								5.0
					17.9	95.3	111.3	101.0
						4.3	11.2	26.2
						1.5	11.0	8.0
					17.9	101.1	133.5	135.2

Proposed construction

Power Systems Modernization (Albuquerque)—Existing electrical distribution systems at Sandia Albuquerque are aging and obsolete, as is the series-connected security lighting system. The project includes converting to higher distribution voltage, replacing aging and obsolescent transformers and switchgear, and replacing cable as required. It will also replace the remaining series security lighting system and begin replacement of aging master unit substations.

Storm and Waste Systems Modernization (Albuquerque)—This project will rehabilitate storm drains and sanitary sewers, construct storm water monitoring stations to check for contamination before discharge, and eliminate remaining septic systems.

Processing and Environmental Technology Laboratory (Albuquerque)—The purpose of this facility is to maintain Sandia's capability in providing high-quality engineering R&D support to DOE's weapons program in consideration of new ES&H requirements. It will co-locate activities dealing with materials and processes research, waste reduction, management of hazardous materials, and ES&H. Occupants will include the Materials and Process Sciences directorate, the ES&H directorate, and organizations supporting DOE's efforts to manage hazardous wastes.

Program Support Center (Albuquerque)—Work areas for several support activities will be located in this building, including laboratory space for video graphics and instrument repair services and standard office space for the Safety, Personnel, Benefits, and Medical organizations.

Environment, Safety, and Health Facility (Livermore)—This facility is designed for several functions, including ES&H, emergency medical, the emergency operations center, fire protection, safety, employee and security training services, and environmental monitoring services, including monitoring of tritium and other environmental hazards. It includes offices, laboratory, and support space.

Water Systems Modernization (Albuquerque)—The water system modernization project will rehabilitate water systems at the three principal Sandia sites.

Infrastructure Modernization (Livermore)—This modernization project is a multiphase effort to renew site systems, modify and add to infrastructure facilities, and upgrade structures to meet seismic reinforcement requirements.

Transportation Systems Modernization (Albuquerque)—This project will upgrade and replace roads, parking lots, and pedestrian circulation facilities.

Falcon Test Facility (FTF) (Albuquerque)—The FTF will be a multiprogram reactor facility to provide the capability to perform laser physics, optical beam extraction, and reactor operational tests to demonstrate the scalability necessary for a large, reactor-driven laser system. The FTF will also provide a high-intensity, large volume, irradiation capability for radiation effects simulation, reactor safety, and nondestructive testing.

Micro Technologies Laboratory (Albuquerque)—The Micro Technologies Laboratory is essential to developing and maintaining expertise in state-of-the-art, miniature, solid-state component technology. This facility is necessary in order to keep pace with the rising level of research activity in compound semiconductors and optoelectronics.

Computing and Computer-Aided Engineering (CAE) Facility (Albuquerque)—This facility will provide properly designed space to house our growing central computing and CAE resources. The design will consider such needs as physical security, safety, configuration layout constraints, and provision for cooled air and water. Associated office space will provide an efficient environment for the support staff and will be designed to accommodate terminals, printers, and other needed equipment. Continued expansion of present facilities into buildings not designed for computers is becoming increasingly expensive and is presenting difficult security, layout, and utility problems.

Center for Environmental Technology Research (Livermore)—Work performed at this facility will identify and develop advanced thermo-mechanical treatment technologies to be used to minimize or process waste generated at DOE weapon production facilities. It will also accomplish the technological base research necessary to facilitate technology development.

Site and Seismic Modernization (Livermore)—The seismic modernization project is a multiphase effort to renew site systems, modify and add to infrastructure facilities, and modify structures as required to meet seismic reinforcement requirements.

Consolidated Waste Management Complex (CWMC) (Albuquerque)—The CWMC will support all waste management activities at the Albuquerque location, including radioactive and mixed waste, waste oil, explosive waste, and supporting facilities.

Geosciences Research Laboratory (Albuquerque)—The Geosciences Research Laboratory will provide a unique center for use by Sandia and the scientific community to study active processes in the earth's crust. This facility will allow Sandia to meet both its research and Drilling Research Office responsibilities in the Continental Scientific Drilling Program. The laboratory will also perform work in fossil and geothermal energy research as well as waste disposal and seismic verification programs. The proposed facility will accommodate mechanical and geophysical testing of large samples as well as development and testing of advanced instrumentation systems.

General plant projects

Consistent funding of general plant projects (GPP) is crucial for facility changes, structural improvements, and non-line item buildings to meet special programmatic needs and upgrades to meet new standards. Funding requirements approximate between one and one and one-half percent of total operating funds. Nearly all of the required funding is provided by the Assistant Secretary for Defense Programs. We expect substantial GPP support from the Office of Environmental Restoration and Waste Management in the future to support ongoing projects for ES&H compliance. Projected GPP requirements are shown in the table.

General Plant Projects
(BA $ millions)

	ASDP	ER	ERWM	Total
FY90	7.0	0.4	3.2	10.6
FY91	7.6	0.4	0.8	8.8
FY92	8.0	0.6	2.8	11.4
FY93	8.0	0.6	0.9	9.5
FY94	17.5	0.6		18.1
FY95	17.5	0.6		18.1
FY96	18.0	0.6		18.6
FY97	18.0	0.6		18.6

Computational facilities and telecommunications

Scientific computing

Sandia is dedicated to providing its scientists and engineers with the computational tools they require to compete successfully in today's rapidly moving technical environment. This dedication implies a commitment to a high-performance computing environment ranging from advanced workstations to the latest modern supercomputers.

Sandia's supercomputers include large vector architecture machines, such as the Cray Y-MP systems, and a growing number of massively parallel systems (SIMD and MIMD architectures). Supercomputers are primarily used for solving large scientific and engineering problems. Application areas include materials studies, nuclear safety calculations, particle beam calculations (for pulsed power and other research), weapon systems development, missile defense and countermeasures analysis, facilities vulnerability analyses, combustion chemistry, and more. With supercomputers, it has become possible to model three-dimensional effects and to perform increasingly higher resolution approximations.

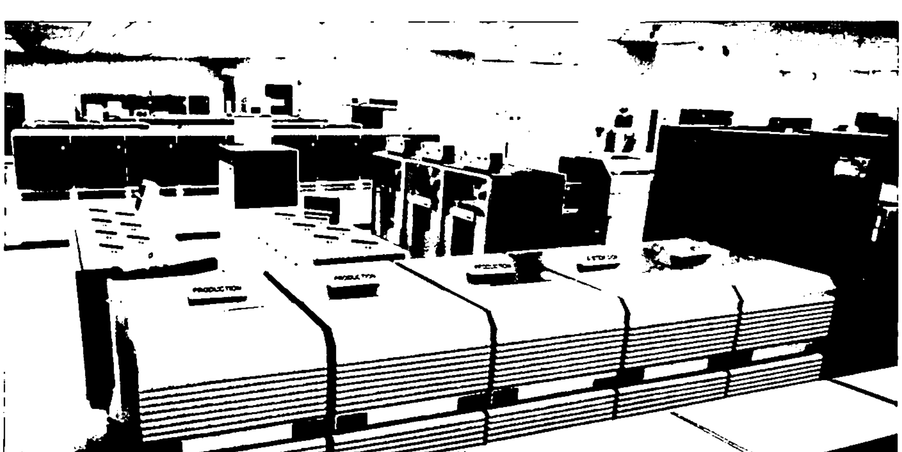
In order to accommodate the computational demands of its mission activities, Sandia has developed a number of interlinked networks of computers based upon increasingly more capable communication links. Linkage of desktop computers and workstations to central systems is accomplished through reliable, high-speed networks. At our Albuquerque location, such a network is presently centered around a PBX switching system handling transmissions at roughly the Ethernet level. Higher speed dedicated lines are used for special applications and FDDI and Hyperchannel connectivity between centrally residing systems.

The major delineation in the networking realm is the separation of secure (classified) and open (unclassified) computing resources. Individual computer systems reside in one or the other of these domains. The secure domain is capable of processing classified information through secret restricted data.

Supercomputer systems are presently distributed between our two laboratory sites as follows: The Albuquerque site includes a Cray Y-MP/864 in the central computing facility along with a terabyte Integrated File Store. These machines are linked to other systems within a secure partition. The Livermore site includes a Cray Y-MP/264 in a secure partition and a Cray X-MP/24 for protected unclassified work in an open partition. Livermore presently has a Central File Store comparable to the Integrated File Store at Albuquerque. Livermore and Albuquerque computer facilities communicate via high-speed links with up to Tl data transfer rates.

Progress is underway toward locating all of Sandia's supercomputers at the Albuquerque site, with production systems slated to be moved there by the end of 1993. Data telecommunication capabilities will be upgraded to T3 at a minimum in order to facilitate the use of these production systems by staff at either site. Our massively parallel systems (CM-2 and NCUBE computers) are currently housed at the Massively Parallel Computing Research Laboratory in Albuquerque. However, as massively parallel systems enter the production mode, some of them will be moved to the Central Computing Facility.

Sandia's scientific computing acquisitions during the FY1992-1997 time frame are intended to increase computational power and improve the performance of support servers both at the central facility and within distributed Local Area Networks. Plans are also being implemented to bring Sandia's network technology into the gigabit range during the same time frame. By the end of the planning period, it is anticipated that the major computer servers will be massively parallel systems. The growing demand for unclassified communications will result in the unclassified computing environment being dominant by 1995. This change will require flexibility in how we allocate the primary computers and support servers between classified and unclassified networks.



Sandia's central computing facilities provide a range of capabilities from supercomputing to general purpose time-sharing for use by program engineers and scientists.

Computer-aided engineering (CAE)

The CAE Operational Plan calls for continued acquisition of resources in sufficient quantities to furnish appropriate computer assistance in the analysis, design, and fabrication of products for which Sandia has responsibility. Total Computer-Aided Design (CAD) product definition was achieved in 1989 for Sandia drafters and in 1990 for contract drafters.

CAE is an integral part of Sandia's programmatic responsibilities in nuclear weapons production and surveillance. More information on our CAE capabilities may be found in the description of programs for the Assistant Secretary for Defense Programs on page 55.

Administrative data processing

Sandia's administrative data processing systems activities are managed with a five-year plan called the Administrative Information Systems (AIS) plan. This plan governs information systems migration and development activities. Tasks outlined in the AIS plan are typically accomplished by establishing project teams. The teams use system project methodologies such as SDM/Structured by AGS Management Systems and Information Engineering by Texas Instruments. Programming and documentation standards are used by these teams in delivering application systems.

Centralized administrative systems are in the process of being moved from two UNiSYS processors, an 1100/82 and an 1100/72, to an IBM ES9021-500, designated as the Laboratory Information System (LIS). Applications migrated to the LIS will take advantage of the Multiple Virtual Storage (MVS) operating system and be developed with the COBOL and Cross System Product (CSP) languages. These applications will use an integrated data base implemented with IBM's DB2 data base management product. All three machines operate twenty-four hours a day, seven days a week.

The Laboratories' procurement and payroll subsystems, as well as subsystems of both human resources and financial systems, have been moved to the LIS machine. The remaining administrative systems will be moved to the ES9021-500 by the end of FY 1993. New application systems to support ES&H, cost center activities, and other initiatives are also being developed on the LIS. As migration activities are completed, more resources will be applied to support the changing laboratory environment.

A series of smaller IBM processors, two 4381s and an ES9121-190, provide other services to the Laboratories. The Office Automation machine runs IBM's Office Vision product under the Virtual Machine (VM) operating system on a 4381 processor. This node provides its own electronic mail and routing for other laboratory electronic mail systems such as the ALL-IN-I product. A particular advantage of Office Vision is its ability to integrate with host-based administrative applications.

The VM Reporting machine resides on an IBM 4381 and is used to provide easy access to management information. Detailed personnel information may be obtained through the Personnel Reporting System (PRS). Financial information is provided through the Management Information and Distributed Access System (MIDAS). In the future, the PRS and MIDAS applications will be moved to the LIS machine.

The Classified Information System (CIS) is an MVS-based ES9121-190 that will provide a cost-effective environment for classified administrative applications. Currently, the CIS machine supports the Record of Assembly (ROA) application used to coordinate product information throughout the DOE complex. By FY 1993 we expect that the CIS will also process Sandia Livermore engineering, document accountability, and (possibly) classified library applications.

Telecommunications

Voice communications

In the past, the Kirtland Air Force Base Communications Squadron provided local voice telecommunications service for Sandia's Albuquerque site as well as for all other Kirtland Air Force Base tenants. However, recognizing the importance of telecommunications service to corporate existence, Sandia has begun to assume direct responsibility for providing quality, state-of-the-art services. Sandia is installing a new AT&T 5ESS digital electronic switch that will form the cornerstone of our voice and unclassified data telecommunications services. This switch will provide ubiquitous digital voice and data services while continuing to provide conventional telephone services, such as Direct Distance Dialing, FTS 2000, dial TIE lines, and off-premises extension.

The Sandia 5ESS will consist of a host system and Optical Remote Modules (ORM) to service the Laboratories' remote security areas. We are constructing a switch building to house the host 5ESS and upgrading conduit systems to provide customer access. In addition, we installed and cut-over an Optical Remote Module of the 5ESS to provide services to the remote security areas and alleviate chronic telephone service problems that have plagued customers in those areas. Currently, over 1,200 lines are in service on the first ORM and over 1,100 lines are in service on the 5ESS host, which is temporarily housed at the Kirtland Air Force Base central office.

Sandia's strategy for communications at Albuquerque is to move the host into the new switch building expeditiously, expand the 5ESS to serve all Sandia Albuquerque customers, and assume operational control of all open voice and data telecommunications services. Preparations for this project began in FY 1989 and funding will continue through FY 1994.

Sandia Livermore operates an AT&T 5ESS PBX for its unclassified voice/data communications. The 5ESS is an Integrated Services Digital Network (ISDN) switch capable of handling voice, data, and signaling information over the same line. It provides access to the commercial network for long-distance communications, FTS, and LLNL.

The Tonopah Test Range local voice telecommunications system terminates in a Northern Telecom SL-I PBX with 24 trunks to the SL-100 PBX at DOE's Nevada Operations Office. TTR personnel use FTS and the Nevada Test Site (NTS) tie-line network for the majority of their long distance telephone requirements.

A Motorola Radio Trunking System (selected by competitive bid) was installed at Sandia Albuquerque on November 14, 1991. This is a basic five channel system and will be expanded as required to maintain the necessary grade of service as users are moved to the system from their existing frequencies. The basic system has a capacity of approximately 600 radio users. The site currently has about 2200 radio transceivers in use.

Initial radio networks that will be placed on the trunking system will include the motor pool, transportation, and storage, and reclamation services. The radio frequencies currently in use by these organizations will be made available for other uses. As funding becomes available, most other services, such as plant maintenance, safety, emergency operations, and health physics, will have their radio communications transferred to the trunking system.

When fully implemented, the trunked radio system will become a part of Sandia's National Security Emergency Preparedness communications system. It will fulfill emergency communications requirements mandated by the Specification for Emergency Operations Centers in the DOE Albuquerque Field Office Complex.

Data communications

An era with emphasis on parallel computing, outside collaboration, consolidation, technology transfer, total quality management, and ES&H management makes data communications vital to Sandia's future. To meet the challenge, a variety of technologies are being investigated and deployed. Fibers to the desk, very high speed local area networks, modern broadband switches, high-speed intersite links, video teleconference facilities, and modern network management systems are all part of the arsenal of communications technologies being applied to this challenge. Many of Sandia's new initiatives make necessary a new focus on unclassified communications while Sandia's traditional mission demands continuing support of secure communications.

Sandia operates an extensive internal secure communications system. A large customer base receives services ranging from asynchronous terminal access through 10Mb Ethernet support. Numerous intersite links to a variety of DOE and DoD facilities exist. Video teleconference capabilities also exist to a variety of DOE facilities.

The Massively Parallel Computing Research Laboratory recently moved to a new building. As part of the move, Sandia installed an extensive, state-of-the-art optical fiber distribution system to every desk in the new facility. While full bandwidth Ethernet on optical fiber will initially be installed, the distribution system will support FDDI local area networks and video. This distribution system and the high-speed networks will serve as a model for several other Albuquerque facilities.

An architecture that consists of T3 (45 Mbps) intersite links, asynchronous transfer mode switches, switched multimegabit data service protocols, and high performance routers is being implemented as part of Sandia's plan to locate all of its supercomputers at Albuquerque. Additionally, Sandia is a participant in the BLANCA network sponsored by AT&T, which is a test bed for cross-country gigabit networking.

These activities constitute an aggressive approach to bringing the data communications infrastructure of the Laboratories up to the state of the art. The technical excellence and quality commitment of Sandia's networking and communications staff is evidenced by a number of recent accolades, including an R&D-100 Award, "best paper" recognition at the NEXUS 90 and NEXUS 91 conferences, and the 1991 INTEROP Achievement Award in the government sector.

Resource projections

This section presents a five-year budget projection for Sandia National Laboratories. Dollars are in millions; personnel are in full-time equivalents (FTEs). Operating and capital equipment amounts in FY 1990–1993 are expressed in purchasing power of their respective fiscal years. For FY 1994 and beyond, operating and capital equipment estimates are in FY 1993 dollars. For these years, we consider budget obligation and budget authority to be equivalent. Amounts shown for the current budget year (FY 1992) are best estimates as of a point in time prior to plan publication and are subject to change. Construction funds are expressed in dollars of the year of commencement of each construction project. Amounts for general plant projects are summarized at the total Laboratories level.

Long-range projections contain significant margins of risk. Therefore, planning is continuous and is subject to amendment as assumptions and needs change. We will manage our resources and programs to live within the constraints of actual funding levels as they become known.

LABORATORIES FUNDING SUMMARY

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
DOE Effort	787.2	816.4	839.1	807.6	982.2	1011.1	980.7	1037.5	1020.8	1102.8
Work for Others	335.5	294.4	308.8	327.1	368.4	393.0	415.0	430.0	430.0	430.0
TOTAL OPERATING	1122.7	1110.8	1147.9	1134.7	1350.6	1404.1	1395.7	1467.5	1450.8	1532.8
Equipment	51.5	54.7	59.3	55.5	59.4	104.2	104.4	103.7	103.6	102.8
Major Construction	16.2	17.6	34.8	34.8	35.5	40.4	45.5	8.1		
General Plant Projects	8.8	8.8	10.6	8.8	11.4	9.5	18.1	18.1	18.6	18.6
TOTAL FUNDING	1199.2	1191.9	1252.6	1233.8	1456.9	1558.2	1563.7	1597.4	1573.0	1654.2
Proposed Construction							17.9	101.1	133.5	135.2

PERSONNEL SUMMARY BY ASSISTANT SECRETARIAL OFFICE
(FTEs)

	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97
DOE PROGRAMS								
Defense Programs	2487	2562	2340	2200	2035	2035	2035	2035
Office of Arms Control			200	210	215	215	215	215
Office of Security Affairs			60	70	70	70	70	70
New Production Reactors	30	28	14	10	5	4	3	3
Environmental Restoration and Waste Management	102	179	210	294	295	295	295	295
Energy Research	114	108	137	145	152	153	155	158
Conservation and Renewable Energy	113	117	132	137	148	156	162	167
Civilian Radioactive Waste	100	91	63	70	65	57	50	42
Fossil Energy	39	42	52	53	54	54	54	54
Nuclear Energy	15	12	11	10	10	10	10	10
Other DOE	57	52	61	61	61	61	61	61
Total DOE Programs	3057	3191	3280	3260	3110	3110	3110	3110
OTHER THAN DOE								
Department of Defense	847	917	950	950	950	950	950	950
Nuclear Regulatory Commission	54	54	60	60	60	60	60	60
Other Federal Agencies	135	103	108	122	150	180	180	180
All Others	32	40	42	43	55	60	60	60
Total Work for Others	1068	1114	1160	1175	1215	1250	1250	1250
TOTAL DIRECT PROGRAMS	4125	4305	4440	4435	4325	4360	4360	4360
Direct Support	1339	1221	1080	1050	1010	1000	1000	1000
Indirect	3021	3074	2930	2915	2865	2840	2840	2840
TOTAL LABORATORIES	8485	8600	8450	8400	8200	8200	8200	8200

FUNDING BY ASSISTANT SECRETARIAL OFFICE

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
Total, Assistant Secretary For Defense Programs										
Operating	634.7	644.0	637.6	636.0	660.2	625.9	605.5	605.5	605.5	605.5
Capital Equipment	48.7	50.1	49.1	50.6	48.4	78.9	77.6	77.6	77.4	76.6
Major Construction	16.2	17.6	34.8	34.8	25.5	19.4	29.5	8.1		
Total Cost	699.6	711.7	721.5	721.4	734.1	724.2	712.6	691.2	682.9	682.1
Total, Office of Arms Control										
Operating					46.7	52.0	54.0	54.0	54.0	54.0
Capital Equipment					1.6	2.3	3.7	3.9	4.0	4.0
Major Construction					10.0	10.0	8.5			
Total Cost					58.3	64.3	66.2	57.9	58.0	58.0
Total, Office of Security Affairs										
Operating					11.6	12.0	12.0	12.0	12.0	12.0
Capital Equipment					1.8	1.3	1.2	1.1	1.0	1.0
Total Cost					13.4	13.3	13.2	13.1	13.0	13.0
Total, Office of New Production Reactors										
Operating	4.7	7.7	3.6	4.3	4.5	4.0	2.0	1.5	1.0	1.0
Capital Equipment			3.4	0.3	0.8	1.1	1.1	1.1	1.1	1.1
Construction			0.8	0.8	1.0	0.5	0.5	0.5	0.5	0.5
Total Cost	4.7	7.7	7.8	5.4	6.3	5.6	3.6	3.1	2.6	2.6
Total, Office of Environmental Restoration and Waste Management										
Operating	39.3	40.5	58.3	56.2	112.9	145.9	136.8	191.0	172.6	252.6
Capital Equipment		1.0	2.9	1.9	4.7	4.0	3.7	2.9	3.0	3.0
Total Cost	39.3	41.5	61.2	58.1	117.6	149.9	140.5	193.9	175.6	255.6
Total, Office of Energy Research										
Operating	23.9	24.9	33.5	25.2	32.5	44.7	47.5	48.5	49.5	51.5
Capital Equipment	1.6	2.3	2.6	1.6	1.8	13.4	13.6	13.6	13.6	13.6
Major Construction						11.0	7.5			
Total Cost	25.5	27.2	36.1	26.8	34.3	69.1	68.6	62.1	63.1	65.1
Total, Assistant Secretary for Conservation and Renewable Energy										
Operating	33.3	32.1	39.1	32.0	45.0	46.9	49.0	52.1	54.3	57.3
Capital Equipment	0.6	0.8	0.8	0.6	0.3	1.8	2.1	2.1	2.1	2.1
Total Cost	33.9	32.9	39.9	32.6	45.3	48.7	51.1	54.2	56.4	59.4
Total, Civilian Radioactive Waste Management										
Operating	23.8	30.8	28.5	26.0	18.1	29.1	25.0	24.0	23.0	20.0
Capital Equipment	0.6	0.4	0.4	0.3		0.2	0.2	0.2	0.2	0.2
Total Cost	24.4	31.2	28.9	26.3	18.1	29.3	25.2	24.2	23.2	20.2
Total, Assistant Secretary for Fossil Energy										
Operating	7.9	7.9	10.3	8.6	11.1	12.9	13.1	13.1	13.1	13.1
Capital Equipment						0.9	0.9	0.9	0.9	0.9
Total Cost	7.9	7.9	10.3	8.6	11.1	13.8	14.0	14.0	14.0	14.0

FUNDING BY ASSISTANT SECRETARIAL OFFICE
(CONTINUED)

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
Total, Assistant Secretary for Nuclear Energy										
Operating	4.1	5.9	7.4	5.0	8.3	8.0	8.0	8.0	8.0	8.0
Capital Equipment		0.1	0.1	0.1		0.1	0.1	0.1	0.1	0.1
Total Cost	4.1	6.0	7.5	5.1	8.3	8.1	8.1	8.1	8.1	8.1
Work for Other DOE Locations, Contractors, and Offices										
Operating	15.5	22.6	20.8	14.3	31.3	29.7	27.8	27.8	27.8	27.8
Capital Equipment				0.1		0.2	0.2	0.2	0.2	0.2
Total Cost	15.5	22.6	20.8	14.4	31.3	29.9	28.0	28.0	28.0	28.0
Total DOE Programs										
Operating	787.2	816.4	839.1	807.6	982.2	1011.1	980.7	1037.5	1020.8	1102.8
Capital Equipment	51.5	54.7	59.3	55.5	59.4	104.2	104.4	103.7	103.6	102.8
Major Construction	16.2	17.6	34.8	34.8	35.5	40.4	45.5	8.1		
Total Cost	854.9	888.7	933.2	897.9	1077.1	1155.7	1130.6	1149.3	1124.4	1205.6
Proposed Construction							17.9	101.1	133.5	135.2

ASSISTANT SECRETARY FOR DEFENSE PROGRAMS
DEPUTY ASSISTANT SECRETARY FOR MILITARY APPLICATION
RESOURCES BY MAJOR PROGRAM

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
GB0103 Research and Development										
Operating	364.8	368.9	365.6	361.9	406.9	375.5	352.0	352.0	352.0	352.0
Capital Equipment	33.7	36.3	35.5	37.7	34.4	36.8	36.8	36.8	36.8	36.8
Total Cost	398.5	405.2	401.1	399.6	441.3	412.3	388.8	388.8	388.8	388.8
Direct Personnel		1288		1339	1470	1350	1205	1205	1205	1205
GB0104 Testing										
Operating	48.1	48.5	50.2	49.8	49.0	46.0	46.0	46.0	46.0	46.0
Capital Equipment	3.0	2.0	2.7	2.3	6.1	5.4	5.4	5.4	5.4	5.4
Total Cost	51.1	50.5	52.9	52.1	55.1	51.4	51.4	51.4	51.4	51.4
Direct Personnel		181		193	195	180	175	175	175	175
GB0105 Nuclear Directed Energy Weapons										
Operating	26.3	26.5	15.6	16.1						
Capital Equipment	2.0	2.0								
Total Cost	28.3	28.5	15.6	16.1						
Direct Personnel		73		38						
GB0106 Technology Commercialization										
Operating				1.3	23.0	38.0	38.0	38.0	38.0	38.0
Direct Personnel				5	45	70	70	70	70	70
GB02 Inertial Confinement Fusion										
Operating	27.4	27.5	29.3	29.2	31.4	30.0	31.0	31.0	31.0	31.0
Capital Equipment	1.8	1.8	2.0	1.6	3.2	7.1	4.3	4.4	4.4	4.4
Total Cost	29.2	29.3	31.3	30.8	34.6	37.1	35.3	35.4	35.4	35.4
Direct Personnel		90		92	90	90	90	90	90	90
GB03 Production and Surveillance*										
Operating	116.2	118.0	122.3	122.8	146.7	133.0	135.0	135.0	135.0	135.0
Capital Equipment	3.8	4.4	6.1	7.3	4.4	29.6	31.1	31.0	30.8	30.0
Total Cost	120.0	122.4	128.4	130.1	151.1	162.6	166.1	166.0	165.8	165.0
Direct Personnel		587		635	530	500	485	485	485	485
GB05 Program Direction										
Operating				0.2	3.2	3.4	3.5	3.5	3.5	3.5
Capital Equipment				0.1	0.3					
Total Cost				0.3	3.5	3.4	3.5	3.5	3.5	3.5
Direct Personnel				1	10	10	10	10	10	10

* For FY 1990 and 1991, includes P&S reimbursable work for DOE.

ASSISTANT SECRETARY FOR DEFENSE PROGRAMS (CONTINUED)
RESOURCES BY MAJOR PROGRAM

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
GB Weapon Activities										
Operating	582.8	589.4	583.0	581.3	660.2	625.9	605.5	605.5	605.5	605.5
Capital Equipment	44.3	46.5	46.3	49.0	48.4	78.9	77.6	77.6	77.4	76.6
Major Construction	15.2	17.2	29.8	29.8	25.5	19.4	29.5	8.1		
Total Cost	642.3	653.1	659.1	660.1	734.1	724.2	712.6	691.2	682.9	682.1
Direct Personnel		2219		2303	2340	2200	2035	2035	2035	2035
GC Verification and Control Technology										
Operating	37.8	39.5	43.7	43.3						
Capital Equipment	1.7	1.5	1.5	1.0						
Major Construction	1.0	0.4	5.0	5.0						
Total Cost	40.5	41.4	50.2	49.3						
Direct Personnel		181		200						
GD Nuclear Materials Safeguards & Security										
Operating	9.9	12.4	10.9	11.4						
Capital Equipment	1.1	1.1	1.3	0.6						
Total Cost	11.0	13.5	12.2	12.0						
Direct Personnel		71		59						
GF Defense Waste Management										
Operating	4.2	2.7								
Capital Equipment	1.6	1.0								
Total Cost	5.8	3.7								
Direct Personnel		16								
Total, Assistant Secretary for Defense Programs										
Operating	634.7	644.0	637.6	636.0	660.2	625.9	605.5	605.5	605.5	605.5
Capital Equipment	48.7	50.1	49.1	50.6	48.4	78.9	77.6	77.6	77.4	76.6
Major Construction	16.2	17.6	34.8	34.8	25.5	19.4	29.5	8.1		
Total Cost	699.6	711.7	721.5	721.4	734.1	724.2	712.6	691.2	682.9	682.1
Direct Personnel		2487		2562	2340	2200	2035	2035	2035	2035
Proposed Construction							17.9	95.3	111.3	101.0

OFFICE OF ARMS CONTROL
RESOURCES BY MAJOR PROGRAM

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
GC Verification and Control Technology										
Operating					46.7	52.0	54.0	54.0	54.0	54.0
Capital Equipment					1.6	2.3	3.7	3.9	4.0	4.0
Major Construction					10.0	10.0	8.5			
Total Cost					58.3	64.3	66.2	57.9	58.0	58.0
Direct Personnel					200	210	215	215	215	215

Note: Amounts for FY90 and FY91 are included in the table for Defense Programs.

OFFICE OF SECURITY AFFAIRS
RESOURCES BY MAJOR PROGRAM

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
GD Nuclear Materials Safeguards & Security										
Operating					11.6	12.0	12.0	12.0	12.0	12.0
Capital Equipment					1.8	1.3	1.2	1.1	1.0	1.0
Total Cost					13.4	13.3	13.2	13.1	13.0	13.0
Direct Personnel					60	70	70	70	70	70

Note: Amounts for FY90 and FY91 are included in the table for Defense Programs.

OFFICE OF NEW PRODUCTION REACTORS
RESOURCES BY MAJOR PROGRAM

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
NP New Production Reactors										
Operating	4.7	7.7	3.6	4.3	4.5	4.0	2.0	1.5	1.0	1.0
Capital Equipment			3.4	0.3	0.8	1.1	1.1	1.1	1.1	1.1
Construction*			0.8	0.8	1.0	0.5	0.5	0.5	0.5	0.5
Total Cost	4.7	7.7	7.8	5.4	6.3	5.6	3.6	3.1	2.6	2.6
Direct Personnel		30		28	14	10	5	4	3	3

* Title I effort in support of construction at Savannah River

OFFICE OF ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT
RESOURCES BY MAJOR PROGRAM

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
EW Environmental Restoration and Waste Management										
Operating	39.3	40.5	58.3	56.2	112.9	145.9	136.8	191.0	172.6	252.6
Capital Equipment		1.0	2.9	1.9	4.7	4.0	3.7	2.9	3.0	3.0
Total Cost	39.3	41.5	61.2	58.1	117.6	149.9	140.5	193.9	175.6	255.6
Direct Personnel		102		179	210	294	295	295	295	295
Proposed Construction								4.3	11.2	26.2

OFFICE OF ENERGY RESEARCH
RESOURCES BY MAJOR PROGRAM

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
AT Magnetic Fusion										
Operating	5.0	5.7	5.1	4.5	5.5	6.0	6.0	6.0	6.0	6.0
Capital Equipment	0.2	0.6	0.3	0.2	0.2	0.9	1.0	1.0	1.0	1.0
Total Cost	5.2	6.3	5.4	4.7	5.7	6.9	7.0	7.0	7.0	7.0
Direct Personnel		24		22	27	28	28	28	28	28
KC Basic Energy Sciences										
Operating	17.9	18.3	25.1	18.3	22.2	21.7	24.0	25.0	26.0	28.0
Capital Equipment	1.4	1.7	2.3	1.4	1.6	12.2	12.2	12.2	12.2	12.2
Major Construction						11.0	7.5			
Total Cost	19.3	20.0	27.4	19.7	23.8	44.9	43.7	37.2	38.2	40.2
Direct Personnel		88		82	95	88	92	93	95	98
KP03 Biological and Environmental Research										
Operating			0.9	0.7						
KP05 Carbon Dioxide Research										
Operating			0.9	0.9	2.3	14.3	15.0	15.0	15.0	15.0
Direct Personnel				3	14	28	31	31	31	31
KS Superconducting Super Collider										
Operating	0.2	0.2	0.2	0.1						
Direct Personnel		1								
KT01 Laboratory Cooperative Science										
Operating	0.8	0.7	1.3	0.7	2.5	2.7	2.5	2.5	2.5	2.5
Capital Equipment						0.3	0.4	0.4	0.4	0.4
Total Cost	0.8	0.7	1.3	0.7	2.5	3.0	2.9	2.9	2.9	2.9
Direct Personnel		1		1	1	1	1	1	1	1
Total, Office of Energy Research										
Operating	23.9	24.9	33.5	25.2	32.5	44.7	47.5	48.5	49.5	51.5
Capital Equipment	1.6	2.3	2.6	1.6	1.8	13.4	13.6	13.6	13.6	13.6
Major Construction						11.0	7.5			
Total Cost	25.5	27.2	36.1	26.8	34.3	69.1	68.6	62.1	63.1	65.1
Direct Personnel		114		108	137	145	152	153	155	158
Proposed Construction								1.5	11.0	8.0

ASSISTANT SECRETARY FOR CONSERVATION AND RENEWABLE ENERGY
RESOURCES BY MAJOR PROGRAM

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
AK Electric Energy Systems										
Operating	0.8	0.7	0.9	0.9	1.1	1.0	1.0	1.0	1.0	1.0
Capital Equipment						0.1	0.1	0.1	0.1	0.1
Total Cost	0.8	0.7	0.9	0.9	1.1	1.1	1.1	1.1	1.1	1.1
Direct Personnel		4		4	4	4	4	4	4	4
AL Energy Storage Systems										
Operating	4.8	4.2	4.2	2.8	5.6	4.3	4.3	4.3	4.3	4.3
Capital Equipment			0.3	0.1			0.3	0.3	0.3	0.3
Total Cost	4.8	4.2	4.5	2.9	5.6	4.3	4.6	4.6	4.6	4.6
Direct Personnel		7		5	9	8	8	8	8	8
AM Geothermal										
Operating	3.4	3.4	4.4	3.8	4.5	4.0	4.0	4.0	4.0	4.0
Capital Equipment	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Total Cost	3.5	3.5	4.5	3.9	4.7	4.1	4.1	4.1	4.1	4.1
Direct Personnel		12		15	16	14	14	14	14	14
EB Solar Energy										
Operating	20.4	20.5	23.7	19.6	26.8	30.0	30.0	30.0	30.0	30.0
Capital Equipment	0.4	0.6	0.2	0.4	0.1	1.3	1.3	1.3	1.3	1.3
Total Cost	20.8	21.1	23.9	20.0	26.9	31.3	31.3	31.3	31.3	31.3
Direct Personnel		73		73	78	79	79	79	79	79
ED Industrial Sector										
Operating	3.4	2.8	3.4	3.7	4.5	4.6	4.7	4.8	5.0	6.0
Capital Equipment	0.1	0.1	0.2			0.2	0.2	0.2	0.2	0.2
Total Cost	3.5	2.9	3.6	3.7	4.5	4.8	4.9	5.0	5.2	6.2
Direct Personnel		14		17	20	23	26	27	28	30
EE Transportation										
Operating	0.5	0.5	2.5	1.2	2.5	3.0	5.0	8.0	10.0	12.0
Capital Equipment						0.1	0.1	0.1	0.1	0.1
Total Cost	0.5	0.5	2.5	1.2	2.5	3.1	5.1	8.1	10.1	12.1
Direct Personnel		3		3	5	9	17	24	29	32
Total, Assistant Secretary for Conservation & Renewable Energy										
Operating	33.3	32.1	39.1	32.0	45.0	46.9	49.0	52.1	54.3	57.3
Capital Equipment	0.6	0.8	0.8	0.6	0.3	1.8	2.1	2.1	2.1	2.1
Total Cost	33.9	32.9	39.9	32.6	45.3	48.7	51.1	54.2	56.4	59.4
Direct Personnel		113		117	132	137	148	156	162	167

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
RESOURCES BY MAJOR PROGRAM

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
DB Nuclear Waste Fund										
Operating	23.8	30.8	28.5	26.0	18.1	29.1	25.0	24.0	23.0	20.0
Capital Equipment	0.6	0.4	0.4	0.3		0.2	0.2	0.2	0.2	0.2
Total Cost	24.4	31.2	28.9	26.3	18.1	29.3	25.2	24.2	23.2	20.2
Direct Personnel		100		91	63	70	65	57	50	42

ASSISTANT SECRETARY FOR FOSSIL ENERGY
RESOURCES BY MAJOR PROGRAM

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
AA Coal										
Operating	4.0	3.8	4.1	3.4	4.7	6.6	6.6	6.6	6.6	6.6
Capital Equipment						0.9	0.9	0.9	0.9	0.9
Total Cost	4.0	3.8	4.1	3.4	4.7	7.5	7.5	7.5	7.5	7.5
Direct Personnel		17		16	22	23	23	23	23	23
AB Gas										
Operating	0.3	0.3	0.2	0.4	0.4	0.5	0.7	0.7	0.7	0.7
Direct Personnel		2		2	2	3	4	4	4	4
AC Petroleum										
Operating	1.7	2.1	3.7	2.7	3.3	3.5	3.5	3.5	3.5	3.5
Direct Personnel		11		13	16	16	16	16	16	16
SA Strategic Petroleum Reserve - Storage Facilities Development										
Operating	1.9	1.7	2.3	2.1	2.7	2.3	2.3	2.3	2.3	2.3
Direct Personnel		9		11	12	11	11	11	11	11
Total, Assistant Secretary for Fossil Energy										
Operating	7.9	7.9	10.3	8.6	11.1	12.9	13.1	13.1	13.1	13.1
Capital Equipment						0.9	0.9	0.9	0.9	0.9
Total Cost	7.9	7.9	10.3	8.6	11.1	13.8	14.0	14.0	14.0	14.0
Direct Personnel		39		42	52	53	54	54	54	54

ASSISTANT SECRETARY FOR NUCLEAR ENERGY
RESOURCES BY MAJOR PROGRAM

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
AF/GE Nuclear Energy Research and Development										
Operating	4.1	5.9	7.4	5.0	8.3	8.0	8.0	8.0	8.0	8.0
Capital Equipment		0.1	0.1	0.1		0.1	0.1	0.1	0.1	0.1
Total Cost	4.1	6.0	7.5	5.1	8.3	8.1	8.1	8.1	8.1	8.1
Direct Personnel		15		12	11	10	10	10	10	10

WORK FOR OTHER DOE LOCATIONS, CONTRACTORS, AND OFFICES

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
Miscellaneous Locations										
Operating	15.5	22.6	18.0	12.3	26.7	25.0	25.0	25.0	25.0	25.0
Direct Personnel		57		43	50	50	50	50	50	50
Office of Intelligence										
NT Intelligence										
Operating			2.1	2.0	2.1	2.1	2.1	2.1	2.1	2.1
Capital Equipment				0.1		0.2	0.2	0.2	0.2	0.2
Total Cost			2.1	2.1	2.1	2.3	2.3	2.3	2.3	2.3
Direct Personnel				9	10	10	10	10	10	10
Office of Minority Economic Impact										
WA50 Minority Economic Impact										
Operating			0.7		2.5	2.6	0.7	0.7	0.7	0.7
Direct Personnel					1	1	1	1	1	1
Total, Other DOE Locations, Contractors, and Offices										
Operating	15.5	22.6	20.8	14.3	31.3	29.7	27.8	27.8	27.8	27.8
Capital Equipment				0.1		0.2	0.2	0.2	0.2	0.2
Total Cost	15.5	22.6	20.8	14.4	31.3	29.9	28.0	28.0	28.0	28.0
Direct Personnel		57		52	61	61	61	61	61	61

WORK OTHER THAN FOR DOE
RESOURCES BY MAJOR REIMBURSABLE SPONSOR

	FY90 BA	FY90 Actual	FY91 BA	FY91 Actual	FY92 BA	FY93 BA	FY94 BA	FY95 BA	FY96 BA	FY97 BA
Department of Defense										
Operating	280.6	243.7	254.5	274.8	311.0	327.0	330.0	330.0	330.0	330.0
Direct Personnel		847		917	950	950	950	950	950	950
Nuclear Regulatory Commission										
Operating	14.6	13.3	14.0	13.9	19.6	20.0	20.0	20.0	20.0	20.0
Direct Personnel		54		54	60	60	60	60	60	60
Other Federal Agencies										
Operating	27.0	27.2	28.6	24.1	24.0	30.0	40.0	50.0	50.0	50.0
Direct Personnel		135		103	108	122	150	180	180	180
All Other										
Operating	13.3	10.2	11.7	14.3	13.8	16.0	25.0	30.0	30.0	30.0
Direct Personnel		32		40	42	43	55	60	60	60
Total Work Other than for DOE										
Operating	335.5	294.4	308.8	327.1	368.4	393.0	415.0	430.0	430.0	430.0
Direct Personnel		1068		1114	1160	1175	1215	1250	1250	1250

Subcontracting and Procurement
(Budget obligation dollars in millions)

	FY89	FY90	FY91
Supplier type:			
Commercial business	$527	$561	$490
Government transfers	127	101	62
Educational/nonprofit/GSA/ state and local government	46	42	36
Total activity	$700	$704	$588

Small and Disadvantaged Business Procurement
(Budget obligation dollars in millions; percent of total commercial procurement)

	FY89		FY90		FY91	
Small	$315	58%	$310	54%	$287	56%
Disadvantaged	55	10%	46	8%	51	10%
Woman-owned	32	6%	43	7%	49	10%

Acronyms

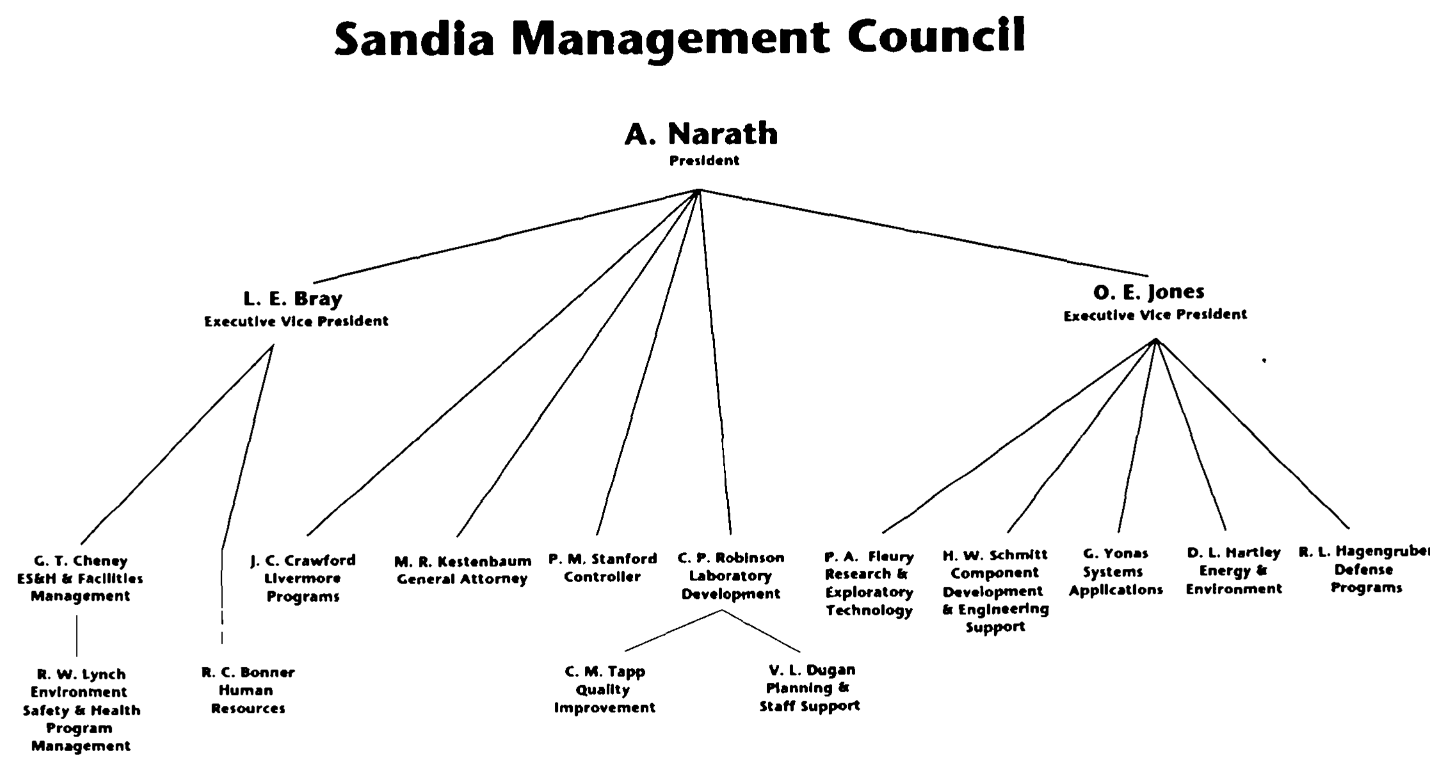
A&F	Arming and Firing
ACRR	Annular Core Research Reactor
AEPT	Advanced Extraction Process Technology
AF&F	Arming, Fuzing, and Firing [assembly]
AFTAC	Air Force Technical Applications Center
AGEX	AboveGround EXperimental [capabilities]
AGT	AboveGround Testing
AIS	Administrative Information Systems
AL-KAO	ALbuquerque field office - Kirtland Area Office
ARM	Atmospheric Radiation Measurements
ASDP	Assistant Secretary for Defense Programs
ATSD(AE)	Assistant to the Secretary of Defense (Atomic Energy)
AVS	Access Validation System
AWU	Associated Western Universities
B&R	Budget & Reporting
BA	Budget Authority
BES	Basic Energy Sciences
BMO/ASMS	Ballistic Missile Office/Advanced Strategic Missile Systems
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CALS	Computer-aided Acquisition and Logistics Support
CAM	Computer-Aided Manufacturing
CCF	Central Computing Facility
CCN	Central Computing Network
CCST	Center for Compound Semiconductor Technology
CDF	Combustion Dynamics Facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFE	Conventional Forces Europe
CHAMMP	Computer Hardware, Advanced Mathematics and Model Physics
CIM	Computer Integrated Manufacturing
CIMET	Center for Intelligent Manufacturing and Environmentally-Conscious Technology
CIS	Classified Information System
CIT	Compact Ignition Tokamak
CMOS	Complementary Metal-Oxide Semiconductor
COMSEC	COMmunication SECurity
CQM	Certification, Qualification, and Monitoring
CRADA	Cooperative Research and Development Agreement
CRF	Combustion Research Facility
CSDP	Continental Scientific Drilling Program
CSP	Cross System Product
CVC	Chemical Vapor Composites
CVD	Chemical Vapor Deposition
DARPA	Defense Advanced Research Projects Agency
DASMA	Deputy Assistant Secretary for Military Application
DC	Direct Current
DDD	Direct Distance Dialing

DEL	Defense Engineering Laboratory
DNA	Defense Nuclear Agency
DoD	Department of Defense
DOE	Department Of Energy
DOE/AL	Department Of Energy, ALbuquerque field office
DOI	Department of the Interior
DSAC	Deterministic Severe Accident Criteria
DSVS	Deployable Seismic Verification System
DTV	Device Transport Vehicle
EAM	Embedded Atom Method
ECF	Explosive Components Facility
ECUT	Energy Conversion and Utilization Technologies
EDNA	Externally-Driven Nuclear Assembly
EMP	Electro-Magnetic Pulse
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Agency
ER	Environmental Restoration
ER	[office of] Energy Research
ER&D	Exploratory Research & Development
ES&H	Environment, Safety, and Health
FAA	Federal Aviation Administration
FALCON	Fission Activated Laser CONcept
FDDI	Fiber Distributed Data Interface
FPU	First Production Unit
FTE	Full-Time Equivalent
FTF	Falcon Test Facility
FTS	Federal Telecommunication System
FWHM	Full Width, Half Maximum
GCD	Greater Confinement Disposal
GCM	General Circulation Model
GEND	General Electric Neutron Devices
GPP	General Plant Projects
GPS	Global Positioning System
GRI	Gas Research Institute
HAZWRAP	HAZardous Waste Remedial Action Program
HITEC	Hispanic and American Indian Technical Education Center
HQ	Headquarters
HR	Human Resources
HTS	Hyperchannel Terminal Server
HVP	HyperVelocity Projectiles
HWR	Heavy Water Reactor
I&C	Instrumentation and Control
IAEA	International Atomic Energy Agency
IBM	International Business Machines
IC	Integrated Circuit
ICF	Inertial Confinement Fusion
IEMP	Internally-generated ElectroMagnetic Pulse
IFS	Integrated File System
INF	Intermediate-range Nuclear Forces [treaty]
IOC	Initial Operational Capability
IR	InfraRed
ISDN	Integrated Services Digital Network

ITER	International Thermonuclear Experiemental Reactor
IWRP	Industrial Waste Reduction Program
JET	Joint European Torus
KAFB	Kirtland Air Force Base
KTF	Kauai Test Facility
LANL	Los Alamos National Laboratory
LIS	Laboratory Information System
LLNL	Lawrence Livermore National Laboratory
LMF	Laboratory Microfusion Facility
LSI	Large Scale Integrated [circuits]
LWR	Light Water Reactor
MAST	Multiple Application Surety Technologies
MCC	Microelectronics and Computer Technology Corporation
MDF	Mild Detonating Fuse
MDL	Microelectronics Development Laboratory
MHTGR	Modular High Temperature Gas Reactor
MIMD	Mingle Instruction stream, Multiple Data stream
MIRV	Multiple Independently targeted Reentry Vehicle
MLS	Member of Laboratory Staff
MTS	Member of Technical Staff
MVS	Multiple Virtual Storage
MWX	Multiwell Experiment
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NCP	National Contingency Plan
NDE	Non-Destructive Evaluation
NDEW	Nuclear Directed Energy Weapons
NMOS	Nitrous Metal-Oxide Semiconductor
NP	office of New Production reactors
NRC	Nuclear Regulatory Commission
NREL	National Renewable Energy Laboratory
NSA	National Security Agency
NTS	Nevada Test Site
NWC	Naval Weapons Center
ODES	Operational Deployment Experiment Simulator
OPM	Operations and Performance Monitor
OPX	Off-Premise EXtension
OS	Office of Space
OSD	Office of the Secretary of Defense
OSHA	Occupational Safety and Health Administration
P&S	Production & Systems
PAL	Permissive Action Link
PBFA II	Particle Beam Fusion Accelerator II
PBX	Private Branch Exchange
PETC	Pittsburgh Energy Technology Center
PMRF	Pacific Missile Range Facility
POET	Phase One Engineering Team
PQMI	Process Quality Management and Improvement
PRS	Plasma Radiation Source
QAT	Quality Action Team
QFD	Quality Function Deployment

R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
RF	Radio Frequency
RPI	Rensselaer Polytechnic Institute
RSP	Rapid Solidification Processing
SAIC	Science Applications International Corporation
SBA	Small Business Administration
SDI	Strategic Defense Initiative
SDIO	Strategic Defense Initiative Organization
SED	Statistical Experimental Design
SEPW	Strategic Earth Penetrating Weapon
SES	Stationary Energy Storage
SETEC	Semiconductor Equipment Technology Center
SICBM	Small Intercontinental Ballistic Missile
SIMD	Single Instruction stream, Multiple Data stream
SNM	Special Nuclear Materials
SPR	Strategic Petroleum Reserve
SPR-III	Sandia Pulse Reactor
SRAM	Short Range Attack Missile
SRAM II	Short-Range Attack Missile II
SRAM-A	Short-Range Attack Missile—Air-to-ground.
SRC	Semiconductor Research Corporation
SREMP	Source Region Electro-Magnetic Pulse
START	Strategic Arms Reduction Treaty
STEP	Stockpile Transition Enabling Program
STM	Scientifically Tailored Materials
STS	Stockpile-to-Target Sequence
SWMU	Solid Waste Management Unit
TASM	Tactical Air-to-Surface Missile
TCG	Technical Coordination Group
TCI	Technology Commercialization Initiative
TFTR	Tokamak Fusion Test Reactor
TLI	Treaty Limited Item
TRA	Teacher Research Associate
TRL	Tritium Research Laboratory
TRU	Trans-Uranic
TSD	Treatment, Storage, and Disposal
TSN	Terminal Switching Network
TTR	Tonopah Test Range
UGT	Under-Ground Testing
UNM	University of New Mexico
USAFE/EUCOM	United States Air Force Europe/European Command
VAWT	Vertical Axis Wind Turbine
VISDTA	Video Imaging System for Detection, Tracking, and Assessment
VLSI	Very Large-Scale Integrated [circuit]
VLSIC	Very Large-Scale Integrated Circuit
VM	Virtual Machine
VRLA	Valve Regulated Lead-Acid [batteries]
WIPP	Waste Isolation Pilot Plant
WRD&T	Weapons Development, Research and Testing
YMP	Yucca Mountain Project

Organizational chart



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