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The Role of the DOE Weapons Laboratories in a Changing National Security Environment

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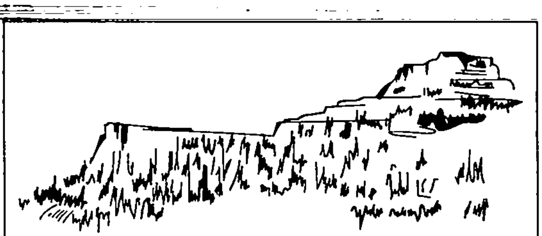

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FOREWORD

This paper was prepared as the written statement for the March 3, 1988, FY1989, authorization hearing of the Subcommittee on Procurement and Military Nuclear Systems of the House Armed Services Committee. It represents Los Alamos National Laboratory management's view of the role of the weapons laboratories in national security and research.

ABSTRACT

The contributions of the Department of Energy (DOE) nuclear weapons laboratories to the nation's securıty are reviewed in testimony before the Subcommittee on Procurement and Military Nuclear Systems of the House Armed Services Committee. Also presented are contributions that technology will make in maintaining the strategic balance through deterrence, treaty verification, and a sound nuclear weapons complex as the nation prepares for significant arms control initiatives. The DOE nuclear weapons laboratories can contribute to the broader context of national security, one that recognizes that military strength can be maintained over the long term only if it is built upon the foundations of economic strength and energy security.

THE ROLE OF THE DOE WEAPONS LABORATORIES IN A CHANGING NATIONAL SECURITY ENVIRONMENT

Siegfried S. Hecker

SUMMARY

The DOE nuclear weapons laboratories have served the nation well over the past forty years. They have continued to provide the nuclear weapons technology to support evolving national security policy and deterrence. Through this support and by guarding against technological surprise, they have helped to deter war between the superpowers.

The laboratories face new challenges as the world stands at a crossroads of geopolitical change. The INF Treaty and START negotiations are beginning the process of reducing the nuclear arsenals of the superpowers. However, the transition to a significantly lower number of nuclear weapons will entail risk. The superpowers must maintain stability and decrease the risk of war, not simply reduce the number of weapons. The laboratories will continue to provide the technology for modernization to maintain stability.

Nuclear weapons will remain an essential component of national security for the foreseeable future. We must retain our nuclear competence and retain our capability to field safe, secure, effective, and survivable nuclear weapons. The DOE weapons laboratories will play an even more important role in this period because their traditional roles will be augmented by increased activities in arms control and verification, safeguards and security, intelligence, and improving the productivity in the DOE production complex through technological innovations.

The laboratories have evolved over the years into true national laboratories serving the nation, not only in the nuclear weapons area, but also in crucial areas of conventional weapons, strategic defense, energy, and health. The laboratories also contribute to our basic knowledge pool and technology base.

Our contributions were initially made possible by the special capabilities developed for the nuclear weapons program. Now, we rely increasingly on the nonnuclear weapons and nondefense programs to preserve the vital capabilities required for the nuclear weapons work. In times of budgetary restraint, it is important that federal R&D support achieves multiple payoffs, i.e., that R&D contributes not only to defense but also to our national well-being.

It is the laboratories' ability to integrate defense and nondefense technologies, basic science and technology development, and to turn them into end applications that represents a unique resource to this nation.

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THE ROLE OF THE DOE WEAPONS LABORATORIES IN A CHANGING NATIONAL SECURITY ENVIRONMENT

by

Siegfried S. Hecker

I. INTRODUCTION

Since their inception, the Department of Energy (DOE) nuclear weapons laboratories (Los Alamos, Lawrence Livermore, and Sandia National Laboratories) have made significant contributions to U.S. national security. They have contributed greatly toward maintaining a technological superiority that has helped to offset the numerical war-fighting advantages of the Soviet Union. The ensuing balance has been a key factor in avoiding global conflict between the major world powers for over forty years.

The technological edge has been maintained by enlightened federal policies. First, the development and production of nuclear weapons are the responsibility of the DOE, thereby being organizationally separated from the user, the Department of Defense (DoD). This separation has assured operational checks and balances and a vigorous R&D program. Second, the DOE weapons laboratories were assigned the principal mission of developing nuclear weapons technology to assure a viable deterrent and to guard against technological surprise, along with the specific requirement of developing nuclear weapons to meet defense policy requirements. This broad charter encouraged building a science and technology base second to none, which has served this nation well in assuring deterrence and in strengthening other defense and nondefense areas.

Although nuclear deterrence has successfully prevented global conflict and will continue to do so, in a world with tens of thousands of nuclear weapons it provides for an uneasy peace. Political leaders and citizens are understandably concerned; it is clearly desirable for the nuclear powers to start on a road to meaningful, equitable, and verifiable nuclear *and* conventional arms reductions.

The road to arms reductions must be traveled with strong determination but also with great caution. National security policy must move toward a greater reliance on conventional weapons and defenses. However, we believe that large reductions of nuclear weapons by the major powers will take careful restructuring of nuclear forces over several decades. Treaties designed to reduce the nuclear arsenals must be crafted to increase U.S. security by decreasing the risk of nuclear war, not to simply reduce the number of weapons. Nuclear deterrence will remain the cornerstone of U.S. national security policy for the foreseeable future, even in an atmosphere of mutual arms control and arms reduction.

The technical competence for nuclear deterrence rests heavily on the shoulders of the three DOE weapons laboratories. Under almost every conceivable arms control scenario, we see the responsibilities of the laboratories increase, not decrease. Smaller nuclear arsenals still need to be safe, secure, effective, and survivable, which requires modernization. The expertise of the laboratories will be required in maintaining the stockpile and verifying compliance with arms control agreements. Modernizing the DOE weapons production complex will depend on improved technologies developed at the laboratories. And, most importantly, the laboratories will still be required to guard against technological surprise, which becomes even more important in a world with fewer nuclear weapons.

However, we are concerned that adequate support for the laboratories is threatened by lean defense budgets, which reflect concerns about the federal deficit, international competitiveness, and the balance between federal defense and nondefense funding. There is increased appreciation for the need to bolster the underlying economic strength of the nation, which provides the necessary foundation for lasting military strength. Hence, it will become increasingly important to look for multiple payoffs from federally sponsored research and development.

The DOE weapons laboratories are already involved in R&D in the broader context of national security, which includes economic strength and energy security along with military strength. Strong support of a broad science and technology base at the laboratories has not only helped to preserve this nation's nuclear competence but also contributed significantly to new SDI technologies, advanced conventional munitions, and energy technologies. Current work on the human genome project and high-temperature superconductivity also holds great promise to contribute to human welfare and international competitiveness.

Today I would like to leave three messages with you:

First, the DOE weapons laboratories have been key contributors to this nation's security for over forty years. We continue to span all aspects of nuclear weapons, from basic research to engineering development, production oversight, stockpile surveillance, and retirement. To continue in this role we need the continued strong support this Subcommittee has always provided.

Second, as this nation prepares for significant arms control initiatives and achievements, the laboratories will be essential to ensure that arms reductions increase our security rather than jeopardize it. Our technology will contribute to maintaining the strategic balance through deterrence, treaty verification, and a sound nuclear weapons complex. Our technology also will contribute to developing advanced conventional defense, which will become increasingly important.

Third, the laboratories can effectively contribute to the broader context of national security, one that recognizes that military strength can be maintained over the long term only if it is built upon the foundations of economic strength and energy security.

For the remainder of my statement, I would like to expand upon these three points.

II. THE ROLE OF NUCLEAR WEAPONS IN NATIONAL SECURITY

A. An Historical Perspective

In the nearly half-century since the first atomic weapons were designed and built at Los Alamos, the United States has adopted national security policies that have relied heavily on strategic and tactical nuclear forces. During the late 1940s and 1950s, the principal role of U.S. nuclear forces was to provide what would later be called extended deterrence—to deter the Soviets from attacking or intimidating vital but exposed U.S. allies (notably in Western Europe), while permitting those allies to recover their military strength and political and economic well-being. Nuclear weapons provided security for our allies at far less cost than the remobilization of full-scale conventional forces.

Beginning with the Kennedy administration in 1961, the United States began to focus increasingly on the problem of deterring the Soviet Union from attacking the American homeland, especially during a crisis (crisis stability), while not inhibiting efforts to foster improved Soviet-American relations or detente (political stability). The most prominent concept of nuclear deterrence for achieving these ends was that of mutual assured destruction (MAD), in which a stable political and military environment would be guaranteed by the vulnerability of both sides' population and industry to second-strike retaliation.

Since that time, the United States has developed another capability for its nuclear force structure: the ability to respond flexibly to a wide range of Soviet conventional or nuclear operations without being forced to choose between capitulation and massive escalation.

As this brief summary suggests, since 1945 a wide range of demands has been placed on U.S. nuclear forces: deterring attacks against the American homeland; deterring aggression against vital U.S. overseas interests; alleviating the economic stresses of military spending; reassuring allies; supporting crisis, political, and arms race stability; and providing American leaders with the flexibility and leverage to deal with a wide range of political and military contingencies. Further, these roles and requirements have tended to accumulate rather than replace one another, so that the U.S. nuclear force structure is at once expected to be militarily effective, stable, and flexible—to say nothing of affordable.

B. Arms Control and the Changing Strategic Environment

We are now witnessing, however, the beginnings of what could be an historic shift in basic nuclear policies and relationships between the two large nuclear weapons powers. This shift is signalled by the beginning of a nuclear arms control process that may finally achieve one of our principal arms control goals: significant reductions in the numbers of deployed nuclear weapons.

The recently signed INF agreement (the ratification of which is now being considered by the U.S. Senate) and a prospective START agreement encompassing 50% reductions in strategic weapons will obviously affect U.S. defense policy and R&D programs. This changing strategic environment will involve critical challenges for our political, military, and scientific communities.

First, how should the United States treat its remaining nuclear forces to maintain stability and ensure deterrence? Unless there is a fundamental change in basic U.S. national security policy, the demands placed on our nuclear forces—effectiveness, survivability, flexibility, and cost effectiveness—will remain high for the foreseeable future.

Over the next few years, we will therefore undoubtedly explore options to assure stability and deterrence by redefining some nuclear missions, restructuring existing forces, and modernizing nuclear weapons and weapon systems. Some aspects of this modernization are clearly desirable whatever the number and mix of weapons—e.g., developing new weapons that are even safer, more secure in all environments, and impervious even to catastrophic failures of their launchers. Other modernization efforts may be driven by changes in the theater and strategic targets that the United States seeks to hold at risk as part of its policy of deterrence. Strategic defenses, whether comprehensive or limited, may also play a vital role in the process of adjusting offensive nuclear roles and requirements.

Second, what should the relationship be between nuclear and nonnuclear forces? Over the past several decades, the United States has never relied exclusively on nuclear or nonnuclear forces but has instead sought a balance between the two.

Reductions in nuclear weapons, combined with other changing strategic conditions, will require us to rethink this balance—not so much in terms of numbers but in terms of the military (and political) roles and missions assigned to them. The United States may wish to respond by exploring the possible substitution of conventional weaponry in selected tasks previously assigned to nuclear weapons. In the NATO theater, this substitution could involve redefining military strategy and implementing a new set of conventional technologies. If so, what are the options; what are the impediments?

Third, what steps should the United States take to guard against technological surprise in an era of reduced nuclear forces? Technological surprise is a particular problem for the United States because the Soviet society and developmental sector are almost completely closed, which means the Soviets have rather rapid and full access to our breakthroughs, and we have essentially none to theirs.

A properly designed nuclear testing program, as described below, is clearly an important hedge against technological surprise. We will also probably be interested in designing strategic and tactical nuclear systems and warheads that emphasize flexibility, so that they can support national policy under rapidly changing technological and military conditions.

Finally, this nation and its allies are rapidly becoming interested in monitoring technologies that can address an increasingly broad spectrum of activities, e.g., detecting and characterizing Soviet nuclear platforms, weapons assembly points, nuclear processing facilities, and satellites. These monitoring technologies, in turn, will be critical for the verification of increasingly ambitious arms control agreements.

C. Strategic Defenses—Another Alternative

In addition to the arms control process, another major issue is causing us to rethink the traditional roles and requirements of nuclear weapons: the Strategic Defense Initiative. SDI has raised the possibility of making a transition to a world of mixed offensive and defensive forces and strategies, and possibly even to a defense-dominant strategic environment.

In their most ambitious form, strategic defenses are conceived to defend a wide range of military and civilian targets. In the next ten to fifteen years, such defenses would consist of a modest number of ground- and space-based homing interceptors, or kinetic-energy weapons (KEW). These first-phase defenses would be limited essentially to the protection of missile silos and other critical military assets.

In the subsequent decade, strategic defenses could incorporate a modest number of directed-energy weapons (DEW)—lasers and particle beams. This second-phase defense would permit some limited protection of civilian targets. And in the long term, i.e., the era starting in twenty to thirty years and lasting as long as the technology continued to improve usefully, strategic defenses would involve more of the earlier technologies, plus whatever other new concepts emerged that could further reduce the threat.

Are such defenses technically feasible? The best judgment at this point is that the KEW and DEW concepts no longer appear to be as capable as advocates once thought when subjected to the full range of possible countermeasures, but neither are they as easy to defeat as critics once claimed. The final answer to this question and to the related questions of economic feasibility will emerge only through time and continued research.

Major current issues are the relative priorities of near- and long-term research and the focus of potential near-term deployments. After several attempts at resolution and much controversy, it is clear that there are no simple answers. Even limited deployment schemes, such as Senator Nunn's Accidental Launch Protection System (ALPS),[1] could require a decade to field a sufficiently robust system that could not be easily defeated with existing countermeasures. Technology development on these time scales as well as long-term research will benefit immensely from the expertise at the DOE weapons laboratories, which have maintained a broad science and technology base.

If defenses prove to be technically feasible, are they in fact strategically desirable? Because the deployment of substantial ballistic missile defenses would raise a series of complex diplomatic, military, and technical issues, there is no simple way to make this judgment—and there is obviously no domestic political consensus about SDI. I would raise one important point here: if ballistic missile defenses are demonstrably cost effective, both sides would have a positive incentive to reduce their offensive forces. Such reductions would in turn increase the potential effectiveness of the defense. Thus, SDI may be necessary for arms control to proceed beyond a certain point, and conversely arms control may be necessary for SDI to succeed.

At very low levels of offense, defense may be necessary to protect against cheating. There are also the considerations of nuclear arms held by third parties and accidental launches. Defensive configurations can be theoretically stable when more than two parties are involved, whereas offensive configurations are not. Defenses, properly deployed, could improve the overall perception of security. But no matter what the future brings in defensive technology, the composition and role of remaining nuclear weapons, the importance of conventional forces, and concerns over technological surprise are key issues we must address today.

III. THE ROLE OF THE WEAPONS LABORATORIES IN NUCLEAR DETERRENCE

A. The Research-to-Retirement Responsibility

The primary mission of the Los Alamos National Laboratory remains the development of nuclear weapons technology to maintain this nation's deterrent. We have been successful in this mission for the past forty-five years. Slightly more than half of the Laboratory's current activities are dedicated to this primary mission. Although renowned for success in the areas of weapons design, development, and testing, the real accomplishment has been maintaining excellence in all aspects of nuclear technology. We share the responsibility with the DoD for the safety, security, production oversight, surveillance, and retirement of nuclear weapons.

This broad research-to-retirement responsibility has made the DOE weapons laboratories an essential element of deterrence. It has also fostered an atmosphere of innovation, with the ability to transfer basic ideas into concepts and hardware useful to the military. Innovation requires a close coordination of research, development, manufacturing, and customer relations.

Los Alamos has a vigorous research program encompassing many of the basic disciplines critical to nuclear weapons. Research at the DOE weapons laboratories is imperative because universities, which conduct 60% of the basic research in the United States, are generally not inclined nor equipped to work on ideas relevant to nuclear weapons.

The weapons laboratories have been able to foster an atmosphere that is particularly conducive to multidisciplinary research, easily crossing the boundaries of traditional physics, chemistry, mathematics, materials, or engineering departments at universities. We have also earned a reputation for developing and operating special large research facilities, both for our staffs and for university and industry researchers. For example, at Los Alamos we have the largest scientific computing capability in the United States, equivalent to 25 Cray 1 supercomputers. With this capability we are developing novel, ultrahigh-speed computer graphics techniques that may ultimately allow us to visualize complicated time-dependent, three-dimensional hydrodynamics effects with the potential of greatly enhancing the nuclear weapons design process.

Nuclear weapons design and development is conducted at the two design laboratories, Los Alamos and Lawrence Livermore. We integrate theory, design, testing, and engineering into a successful program. Successful integration requires not only individual scientific brilliance but also teamwork and engineering. The current program examining the concept of an earth-penetrating weapon (EPW) to hold at risk hardened or deeply buried targets is an excellent example. A successful design will require innovative new physics and extraordinary engineering to have the warhead penetrate the ground, survive, and detonate. We have worked closely with Sandia National Laboratories on the engineering aspects of the EPW concept.

Manufacture and assembly of nuclear weapons are the responsibilities of the DOE/Defense Programs production complex. The DOE laboratories have an important role in production oversight. There is constant interchange between the manufacturing community and laboratory designers and engineers during the production cycle of weapons. In fact, Los Alamos designers and engineers consistently work producibility and manufacturing efficiency into their designs.

We are involved in process development at our laboratories to ensure a smooth flow of the product through the manufacturing lines. At Los Alamos we are particularly proud of the fact that our recent warhead systems, the W80 (for the Air-Launched Cruise Missile and Sea-Launched Cruise Missile), W76 (Trident I), and W78 (Minuteman III) all have low production cost and little schedule delay because of excellent design, engineering, packaging, and continued integration with the production facilities. The B61 bomb is an excellent example of a robust and flexible system; over the years we have upgraded the safety and security of this single system to meet evolving military requirements.

Producibility is a critical function and requires frequent interchange on development and test hardware early in the program. As an example, recently we participated in the first assembly of a W88 warhead for the Trident II D-5 missile at Pantex in an effort to improve the assembly sequence, even to the point of making minor design changes in some hardware. This close interface continues through the production process and while systems are in the stockpile through an integrated production and surveillance program that supports each plant in maintaining the stockpile.

The DOE laboratories have an extensive stockpile surveillance program for both nuclear and non-nuclear components. We are also a vital part of the U.S. Nuclear Emergency Search Team (NEST) and Accident Response Group (ARG). We are involved in the retirement of all nuclear systems. In essence, we see the weapon through all its stages and provide a life-time guarantee.

This extensive set of responsibilities requires a continued high level of nuclear competence.

B. Nuclear Competence

Nuclear competence is imperative if the United States is going to continue to ensure the safety, security, reliability, survivability, and military effectiveness of its nuclear weapons. This competence has carefully evolved at the DOE nuclear weapons laboratories over the past forty years and will be required as long as there are any nuclear weapons at all. It is reinforced in all stages of the laboratories' involvement discussed above.

Crucial to any successful policy of mutual nuclear deterrence is the belief beyond reasonable doubt of national leaders that their own and their adversaries' nuclear forces are survivable, are deliverable, and will function as intended. This belief does not rest on any technical knowledge on the part of the national leaders. It rests on assurances given to those leaders by scientists and this assurance requires that these scientists have credibility with their leaders. This confidence comes from the technical expertise we call nuclear competence.

The nuclear competence and, therefore, the credibility of the U.S. nuclear deterrent policy rests indispensably upon the credibility of the three DOE nuclear weapons laboratories. These laboratories represent a unique and fragile technology base. The laboratories have supported arms reductions for decades, and we continue to support them. But we also recognize that we must retain nuclear competence in the laboratories and in the DOE/Defense Programs complex.

Testing is one of the most important elements of assuring competence in any high-technology venture. It is indispensable in the automotive industry where hydraulic shakers take an automobile frame through millions of cycles simulating road tests; in the aeronautics industry where wind tunnel tests help shape new designs; in the aerospace industry where almost every component is flight tested before acceptance; and in almost every other industry imaginable. In fact, government, taxpayers, and consumers alike would consider it a breach of professional ethics not to test a product before placing it on the market. Congress has recently instructed the DoD to improve all its testing procedures, an instruction manifest in the creation of the Office of Operational Test and Evaluation.

The need for testing nuclear weapons is fundamentally no different from the need for testing any other technological system, and our goal should be adequate nuclear testing as long as we rely on our nuclear deterrent. Nonnuclear components receive immense scrutiny and are statistically tested. The nuclear components, however, present a problem because of their enormous destructive power, the complexity of the tests, the limitations already placed on nuclear tests, and the substantial costs and effort. These factors currently restrict us to a few tests on configurations that often must be modified from the actual weapons eventually deployed in our forces.

The physical phenomena that occur in nuclear fission and thermonuclear weapons are so complex and insufficiently understood that even today we cannot design weapons from first principles or by computers alone. Furthermore, the conditions that exist during a nuclear explosion, with temperatures and pressures similar to those in the interior of stars, cannot be simulated adequately in the laboratory. Hence, the design process is an iterative one involving theory, computer modeling and calculations, nonnuclear laboratory tests, and underground nuclear tests. Nuclear tests are essential in calibrating the theoretical models. In a similar fashion, nuclear tests provide the final word on warhead engineering and packaging of components. The subtleties of many engineering changes on warhead design are often more difficult to model and predict than physics design changes. Nuclear tests also help assess the effects of stockpile conditions such as aging and stockpile-to-target environments, including potential effects of hostile nuclear environments.

Hence, nuclear testing is imperative to maintain the nuclear competence and judgment of our nuclear designers and engineers. Every nuclear test is important in building and validating their nuclear competence, regardless of whether the test was aimed at elucidating the physical principles of nuclear implosions or checking the performance of stockpiled weapons. Both the successes and failures in the test program contribute to a better understanding of nuclear weapons.

These arguments make the point for the technical importance of nuclear testing. The risks associated with a cessation of nuclear testing are great because we believe that our nuclear competence will erode. Yet we recognize that there are other considerations in the nuclear testing debate since testing has acquired great symbolic and political significance. In the end, the nation's policymakers must trade off any potential benefits of increased testing restraints against the technical risks and military consequences that these restraints will bring about.

I believe that if we can truly usher in a new era of strategic arms control, then the nuclear testing issue should become less controversial. Nuclear testing will then be able to support a rational and equitable arms reduction treaty instead of being a symbolic substitute for real arms control. This administration's policy on nuclear testing has been to achieve nuclear testing limitations in parallel with arms reductions, leading to an eventual cessation of all nuclear tests.

At the laboratories we continue to examine how we can make the nuclear weapons program more resilient to additional nuclear testing limitations. These efforts include gaining a better fundamental scientific understanding of weapons behavior, improving our computational capabilities, developing better laboratory experimental facilities to approximate weapons behavior, and making the stockpile as robust as possible.

Nuclear competence is vital for all aspects of maintaining nuclear weapons in addition to the design issues discussed above. The judgment of competent designers and engineers is required for (1) answering literally thousands of questions per year about specific fabrication procedures or advisable exceptions to procedures, (2) assessing the effects of long-term variations such as aging in stockpile, (3) maintaining safety and security in both stockpile and transportation environments, (4) assessing risks of potential accidents, (5) assessing the credibility and potential hazards of deactivating a terrorist nuclear device, (6) conducting intelligence analysis of the nuclear capabilities of potential adversaries, and (7) continuing the technical analysis of arms control agreements. This long list demonstrates that nuclear competence is critical as long as the United States depends on nuclear weapons for deterrence. I am convinced that this competence will fade if strong support for nuclear weapons technology wavers.

C. An Evolving Role for the Laboratories

Stockpile Modernization. There is some confusion as to why the United States must continue to modernize weapons that it is making a determined effort to reduce. The simple reason is that the process of arms reductions to very low levels will take a long time, certainly decades. That is one or two cycles of strategic force modernization. Much of the modernization would be directed at improving the safety, security, and durability of nuclear weapons. Such changes are unambiguously in the best interest of all sides and consistent with stability objectives.

We have continued to upgrade the safety of nuclear weapons to mitigate problems that might occur during accidents such as the B-52 Palamares incident in Spain in 1966, the Titan missile explosion in its silo in 1980, and the B-52 Grand Forks AFB fire in 1980. It should be noted that no accidents involving nuclear weapon systems have ever resulted in a nuclear explosion. However, several have resulted in the dispersal of nuclear materials. We have developed insensitive high explosives, an alteration that dramatically reduces the risk of accidental detonation of the high explosive in the weapon and thus of plutonium dispersal in the event of an accident or deliberate attack on the weapon itself. This improvement would have been impossible without nuclear tests. Stockpile modernization conducted with the essential component of nuclear testing has allowed the United States to actually decrease the size of its nuclear arsenal. Over the past twenty years, the number of nuclear weapons in our stockpile has been reduced by 25% and the total yield by a factor of almost 4. Hence, modernization emphasizes building different weapons to maintain a credible deterrent, not building more weapons of greater destructive power.

Other modernization efforts are driven by considerations of maintaining an effective deterrent, that is, being able to hold an adversary's targets at risk. Certain U.S. weapons development has been driven for several decades by the need to pinpoint and destroy a number of hard targets, i.e., missile sites, deeply buried bunkers, communications facilities, and the like. That goal has driven U.S. designers to design ever more carefully tailored weapons to be delivered precisely on those targets so that they can meet military objectives with a minimum loss of related civilian infrastructure. Recognizing that trend, however, the Soviets have recently made strong efforts to make their missiles and other critical assets more survivable by making them extremely hard, mobile, submarine based, or more difficult to detect.

A reconfigured strategic force following a strategic arms reduction agreement will necessarily have to take these trends into consideration. The new missions for the remaining strategic forces will involve targeting deeply buried and superhardened facilities. Earth penetrators and super-accurate reentry vehicles will be required to replace older, very high yield weapons that are no longer able to hold the evolving Soviet target base at risk.

Current weapons are also not appropriate to hold at risk that part of the Soviet target base that is becoming relocatable, such as mobile missiles. The key to success in attacking them is no longer pinpoint accuracy but localization, rapid response, and adequate yield over the targets. Designs for that task will have to be derived in conjunction with development of the sensors required for near real-time localization.

It will also be desirable to modernize the nuclear forces in Europe, a subject that is currently an area of intense U. S.-Allies discussion. From a military point of view, it will be necessary to use the platforms still permitted by the INF Treaty to hold at risk those targets for which only nuclear weapons have the flexibility and damage potential.

Potential nuclear missions include stopping breakthroughs, laying barriers, and targeting rapidly moving reserves. Army General John R. Galvin, Supreme Allied Commander-Europe (SACEUR), recently told the U.S. Senate Committee for Armed Services that the United States should set four acquisition priorities.[2] These include

- Tactical air-to-surface nuclear missiles for fighter aircraft;
- An improved Lance nuclear-armed missile to give a short-range ground-launched nuclear capability;
- Modernized nuclear artillery and bombs;
- Acquisition of the Army tactical missile system.

Current U.S. nuclear weapons in Europe are relatively large and imprecise. If used for NATO missions, these weapons would not only be less efficient but also would inflict a high level of collateral damage—a damage level so high that U.S. military leaders would not release the weapons until it was too late for them to be pivotal. Hence, military strategists argue for stockpiling nuclear weapons that are the most effective, safest, and most precise, which means a continued modernization effort.

In the long term, some of the theater missions that now require nuclear weapons may well be executed effectively by nonnuclear weapons with smart sensors. However, the development of such advanced sensors, weapons, carriers, launch systems, and command systems could take twenty or more years; they certainly cannot substitute for nuclear systems immediately.

Improved Capabilities. The role of the laboratories will have to evolve in a number of key areas to keep pace with the future. In particular, we need to improve our predictive capabilities and laboratory testing. Also, we must continue to pursue concepts such as inertial confinement fusion (ICF) and nuclear directed energy. The possibility of future testing limitations increases the urgency of each of these programs.

We need an improved predictive capability so that we can maintain high confidence in our nuclear weapons with reduced reliance on testing. Even if testing is not further constrained, the ability to more fully understand weapons performance from computer simulations would be important from the standpoint of both cost effectiveness and our scientific understanding. The computer codes that simulate nuclear weapons phenomena have taken many years to evolve and are basically the operating repositories of our scientific knowledge. Present two-dimensional calculations to model the entire explosion of a nuclear weapon can take up to 200 hours of computation time on the world's fastest supercomputers. In many cases, three-dimensional calculations are required, which would increase calculation time even more.

These calculations are typically empirical (not based strictly on first principles) and overly dependent upon intervention, adjustment, and interpretation by weapons scientists. We need increased research in several areas including hydrodynamics, computer simulations in three dimensions, and advanced computer graphics. We need improved computational capabilities to speed up two-dimensional calculations and to make three-dimensional calculations possible.

Improved predictive capabilities also mean we must come to a better understanding of the basic properties of materials so that we can predict how they will perform. We need a better understanding of material substitutions, manufacturing tolerances, behavior of high explosives, and the fundamentals of nuclear behavior. These capabilities are desirable regardless of the future size of the stockpile, and they are imperative if nuclear testing is further constrained.

Another area in which we need increased capabilities is laboratory testing of the technology and components of nuclear weapons. We already test many components of nuclear weapons with experiments not requiring nuclear explosions. We conduct tests on weapons with the nuclear components removed; we can test electrical systems; and we can do experiments to obtain data on how materials react to different environments. At Los Alamos, we have unique facilities such as PHERMEX, a high-intensity 30-million-volt linear electron accelerator that produces x rays to take snapshot pictures of weapons materials as they are being imploded by chemical high explosives. The pictures allow us to determine the effects of changing materials and geometries.

We are presently building DARHT, the Dual Axis Radiographic Hydro Test facility, which will have an even higher penetrating power and better tomographic (as in a CAT scan) capability. But we still need more and better ways to study the behavior and effects of nuclear weapons using advanced *nonnuclear* above-ground testing facilities. These above-ground tests are cost effective relative to nuclear tests, and an improved capability is imperative if nuclear testing is further constrained.

We must continue to maintain and strengthen our ICF program, which contributes to our nuclear weapons program. The conditions for achieving fusion in a small laboratory target with a laboratory driver (laser or particle beam) are much more difficult than full-scale thermonuclear fusion in weapons. Hence, we can learn much from ICF calculations and experiments about the fundamental process controlling fusion, the geometric and materials requirements for implosion, and novel diagnostics, all of which will help our understanding of weapons behavior. ICF physics would be one of the few opportunities of keeping alive at least some weapons physics expertise in case of a low-yield threshold test ban.

The rapid response of the national laboratories to the SDI laser technology requirements was made possible by the laser technology base established in the ICF and other programs. The laboratories' laser isotope separation programs for nuclear materials also contributed.

Another capability that I want to mention here is the area of nuclear directed-energy weapons (NDEW). The energy of a nuclear explosion is released in all directions. However, if this output can be channeled in a single direction, much more energy can be applied to a specified target application with a lower overall yield and with greatly reduced collateral effects on other systems. NDEW concepts could be applicable in a wide range of military missions, including SDI scenarios. Work in the directed-energy area was in progress at the DOE weapons laboratories as a component of our technology base research efforts into advanced nuclear weapon concepts well in advance of the President's 1983 SDI speech, and our efforts have increased since then. Advanced concept research has been and will remain essential to avoidance of technological surprise and to our maintenance of an optimized deterrent capability.

Investigation of nuclear directed-energy weapons is important for understanding any vulnerabilities of U.S. strategic systems to Soviet NDEW weapons. We also must understand technological limitations to assess potential Soviet capabilities. Soviet technological capabilities include several NDEW areas, and there is evidence of substantial Soviet work in these areas. Because NDEW concepts can be developed with underground testing, detailed monitoring of the Soviet advances will be difficult. Today, it may be possible for the Soviets to entirely conceal NDEW development. We need to develop improved surveillance techniques and a better understanding of the capabilities of NDEW technologies.

The SDI program goal of a nonnuclear defense is certainly recognized and supported at Los Alamos. Nevertheless, work in nuclear directed-energy weapons may also contribute to a potential U.S. strategic defense system in that NDEW technologies may be required to supplement other SDI components. For example, warheads not destroyed during the boost or space transport phases must be destroyed upon reentering the atmosphere. The Los Alamos program emphasizes nuclear directed-energy technologies that could potentially be employed in a terminal defense mode. These directed-energy concepts, emphasizing a minimum-yield nuclear driver, would greatly reduce the collateral effects over our own territory when compared with traditional nuclear weapons.

Arms Control Verification. As we move into a military era increasingly dominated by arms control considerations, the laboratories will see a new set of challenges in the area of verification. Verification has been an important Los Alamos activity since 1963, when ratification of the Limited Test Ban Treaty (LTBT) resulted in a mandate for monitoring any possible nuclear tests in the atmosphere, oceans, or outer space. Los Alamos continues to have the principal monitoring responsibility for outer space. This role has become more important as more nations have attained the capability to access outer space. Also, additional restrictions on underground nuclear testing may make outer space more inviting for potential violators.

Today we see the need for verification technology R&D in many areas beyond nuclear test monitoring. The INF Treaty and START negotiations introduce a new array of requirements for inspection, detection, and interpretation. Discussions about control of weapons in space present an array of technical challenges, as do the very difficult areas of chemical and biological warfare. Los Alamos has the technical capabilities in many of these areas and is working toward making this capability address the verification problems of the coming decades.

First, let me briefly review some of the Los Alamos work in nuclear test monitoring. In 1976, the Threshold Test Ban Treaty (TTBT) introduced the element of yield measurement into the nuclear test monitoring problem. This treaty and its companion, the Peaceful Nuclear Explosions Treaty (PNET), have never been ratified because of the inability to measure yields of Soviet nuclear weapons tests with sufficient accuracy. Specifically, we are concerned with the issue of whether an adversary might be able to exploit a predictable underestimation of yield, thereby realizing a "license" to violate the treaty.

To aid with this treaty verification problem, Los Alamos has developed the CORRTEX system for hydrodynamic yield measurement. CORRTEX employs a cable in a hole near an underground nuclear weapons test. The way the nuclear explosion crushes the cable indicates the explosion yield. While it does require an onsite presence, CORRTEX is more accurate than current teleseismic measuring schemes and has been specifically tailored to the needs of arms control enforcement. CORRTEX in a satellite hole reveals no weapon design information other than yield. Hydrodynamic yield has been adopted as the U.S. verification procedure of choice in the nuclear testing negotiations now being conducted in Geneva. Scientists from the United States have just visited the Soviet test site at Semipalatinsk and have hosted the Soviet scientists at the Nevada Test Site to discuss such verification technologies.

Now let me turn to the broader needs for verification technologies. The entire environment for verification of arms control treaties has changed dramatically because the Soviets have *accepted* the principle of onsite inspection. The signing of the INF Treaty has placed immediate demands on the U.S. verification community.

START negotiations are placing even more stringent requirements on verification protocols and technology development, with only a slightly increased time scale. The laboratories are responding to these requirements primarily by drawing upon the technologies that have been developed in other areas, such as the verification program for the LTBT, the techniques developed for the Nuclear Emergency Search Team, and various other capabilities associated with the detection and identification of nuclear materials.

The START negotiations will require increasingly precise and reliable verification systems. New technologies and new applications of existing technologies will certainly be needed for reliable verification, tagging, and tracking of both delivery systems and warheads.

The other area currently under discussion is defense and space. It is not clear at this point exactly where these negotiations will lead, but it is clear that any treaty limiting the materials that can be placed in space or limiting testing that can be done in space will require that some means of verification also be space based. These space-based verification technologies do not currently exist. Such technologies would be required to detect tests of infrared lasers, optical lasers, neutral particle beams, and possibly nuclear power systems associated with such concepts. The detection means would certainly involve remote sensing of infrared signals, microwave signals, and possible disturbances of the natural environment by the injection of high-energy particles from accelerator tests. Also, sophisticated methods for the detection and identification of nuclear materials that might be associated with power systems, or even possibly weapons, in space must be developed.

Many of the detection and monitoring concepts will require significant research and development. We must remember that treaties are sometimes negotiated very quickly, but the underlying verification technologies take years to develop.

Safeguards and Security R&D Program. The Los Alamos safeguards and security R&D program, by virtue of its capabilities to measure and account for nuclear materials, will play a significant role in analyzing the problems and developing technology for verifying some of the future arms control agreements. The current Los Alamos safeguards and security R&D program encompasses nuclear materials detection and assay methods and instrumentation development; nuclear materials control and accounting systems R&D; international safeguards and related nonproliferation R&D; arms control studies relating to special nuclear materials production, processing, and weapons fabrication; and computer security R&D.

Through interactions with the International Atomic Energy Agency (IAEA) and key nations, Los Alamos safeguards and security R&D experts work toward a credible, global safeguards verification system. Our bilateral technical interactions (e.g., with the European Community, Japan, and Brazil) are directed toward the implementation of state-of-the-art nuclear materials measurement and accounting technology and inspection procedures. These interactions also give us access to the large nuclear-fuel-cycle facilities throughout the world and keep us informed of worldwide nuclear materials processing and safeguards plans. Finally, such technical interactions keep communication channels open to key people throughout the nuclear community. In a context dominated by arms control and the concern over the potential of nuclear weapons proliferation, the national security importance of these activities will be at least as great as they are today.

Intelligence. Technical intelligence is a vital link in the avoidance of technological surprise and in verification of compliance with arms control agreements. The activities at Los Alamos supporting the national intelligence community play a significant role in overall national defense program planning. Our scientific analysts support the intelligence community in their efforts to follow Soviet developments in broad areas of science and technology, based on all-source information, to give warning of possible "breakout" scenarios, and to avoid technological surprise. Among other activities, the expertise of our Laboratory is aiding the SDIO and other government agencies in assessing Soviet developments in SDI technologies and also counter-SDI-related technologies.

Despite the growing importance of SDI and conventional armaments, our primitive knowledge of the Soviet nuclear weapons program makes nuclear weapons technology the most important issue for the foreseeable future. Specialized facilities, if undetected or underrated, would allow Soviet scientists to continue some active nuclear weapon development even under restrictive arms control agreements, should they choose to do so.

The Los Alamos intelligence program closely monitors Soviet nuclear weapons developments. The analysts also monitor potential proliferant nuclear states to understand the progress of their nuclear weapons programs, which pose a growing threat to our national security. The role of the Laboratory in intelligence also extends to the development of scientific techniques and devices for use by the intelligence community in such important areas as computer security, field operations, and collections.

We believe that the role of Los Alamos in intelligence will continue increasingly to support the national intelligence community with specialized, advanced science and technology in assessments and hardware not available elsewhere. In the course of these activities, we have benefited from foreign technology in areas such as weapons components and designs, and neutral particle beam weapons. As arms control arguments are reached, the intelligence activities will become even more important.

Production Complex. We support the congressional and Presidential attempt to modernize the DOE weapons complex and size it for future national needs. Los Alamos works closely with the production complex during early design development, engineering development, production, stockpile lifetime, and retirement. Work in these areas is key to smooth transition from development/design to tooling up for engineering development and production.

An important element of support to the production plants is the capability in nuclear materials technology that Los Alamos brings to the production complex. Both in our process development work and in our nuclear materials technology base, we can provide considerable assistance to the production complex in the modernization effort. A critical part of any plan to modernize the nuclear weapons complex must be the incorporation of new, improved, efficient, and reliable technologies for handling and processing nuclear materials. The role of new technologies in the nuclear materials complex of the future should not be underestimated. We must recognize that the future will bring added constraints in the form of fiscal restraint, increased requirements for protection of the environment, enhanced nuclear material safeguards, and improved operational safety and radiation protection. New technologies must address these issues head on and provide reliability that will ensure the viability of our nuclear deterrent.

For the past several years, Los Alamos has contributed directly to material availability through a production support role. Recently, we have placed more emphasis on our traditional role of technology development and the transfer of technology to the plants and facilities with production responsibilities. Secretary Herrington has noted that many production technologies are outdated and that we need to make the transition toward new, more efficient technologies and production processes with construction of improved residue recovery facilities. Los Alamos welcomes the challenge to contribute to accomplishing this modernization goal.

Los Alamos has already achieved impressive results in developing new technologies and transferring them to the appropriate institution to improve operational efficiency. For example, Los Alamos undertook a study of the ion exchange process used in recovering and purifying plutonium. As a result, we developed an enhanced technology that produced a tenfold improvement in the efficiency of the ion exchange process. Other associated gains were reduced radiation exposure for operators, enhanced material safeguards, and reduced waste generation. We transferred the enhanced technology to the Rocky Flats Plant, where it is now in use. Arms control agreements resulting in significant stockpile reductions could also affect the need for plutonium recovery from scrap. To meet the technological challenge of significant stockpile reductions, advanced technologies for scrap recovery are important research areas.

The work at Los Alamos has demonstrated that successful transfers, such as the ion exchange technology, can be made now and in the near future to existing production facilities. If we are to move confidently into the future with processes appropriate for a resized, modern DOE/DP complex, we must continue to invest in new process technologies on a broad front.

The Laboratory also strongly endorses the need for a new production reactor to help ensure the necessary tritium supply for the nuclear weapons program. We are well prepared to provide broad-based technological support for this important effort, including such key areas as reactor safety and target development.

Health, Safety, and Environmental Functions. It is the policy of the DOE and its laboratories to conduct operations in a safe manner and in compliance with federal statutes, regulations, and standards. We support the DOE complex with R&D efforts that can help improve waste cleanup activities. DOE facilities, including Los Alamos, have many sites requiring remedial action. New cleanup technologies could become important in these efforts.

If such techniques can be developed, they will also help the nation generally. There are 18,000 hazardous waste sites identified for Superfund coverage. Current techniques have usually limited regulators to the costly approaches of physically moving contaminated soil or physically immobilizing it. A major R&D program should begin to consider novel, drastically less expensive approaches to this problem. Los Alamos can contribute innovative instrumentation for waste site characterization, advanced incineration/destruction technologies including novel chemical dynamics, and biologically based approaches as well as modeling of toxic waste transport through geologic media.

The DOE/Defense Programs Office is funding some new applied research and technology development in environmental cleanup techniques. Also, the DOE Office of Energy Research has begun planning a major basic research program in this area. We hope these beginnings will receive strong encouragement from your Subcommittee.

Los Alamos has been involved in safety analysis of nuclear reactors for many years. Under Nuclear Regulatory Commission sponsorship, we developed the world's most advanced computer codes for analysis of nuclear power plant accidents. Development of these codes began in the early 1970s using expertise and techniques developed in support of the nuclear weapons program. In the past few years, to come almost full circle, the DOE has asked us to apply these computer codes and related expertise to help examine the safety of the DOE/Defense Programs reactors at Savannah River and Hanford. We expect to expand these efforts for safety analysis of the new production reactor, as mentioned earlier.

D. Deterrence in a Rapidly Changing World

Weapons development can change strategic and tactical capabilities, sometimes abruptly. The best-known example is the Manhattan Project's development of fission weapons, which revolutionized strategic bombing immediately and theater strategy within five to ten years. The development of thermonuclear weapons and their reduction to sizes that could be carried on Polaris submarine-launched missiles was almost as abrupt.

Our nation must constantly guard against technological surprise by maintaining a strong science and technology base with defense implications. The DOE weapons laboratories have been instrumental in this area. We should encourage greater integration with work at universities and in industry. Improving the overall scientific productivity of our defense establishment is the best hedge against technological surprise.

Guarding against technological surprise becomes even more important as the United States and Soviet Union reduce their nuclear arsenals. We will no longer be able to count on the sheer destructive power of tens of thousands of nuclear weapons to overcome a sudden vulnerability. The balance of power will be much more delicate.

In addition, history has taught us that arms control agreements themselves often spur development of new classes of weapons not banned specifically by the agreement language. Also, nations have structured their military research and development programs so as to gain rapid and significant advantages by abrogating treaties or allowing them to lapse.

Classic examples of "designing around" arms control agreements occurred after World War I. For instance, Germany introduced revolutionary shipbuilding innovations to deploy its fleet of "pocket battleships" within (and sometimes beyond) the tonnage limitations of the Versailles Treaty. Japan refused to extend its compliance with terms of the Washington Naval Treaty after 1936 and subsequently "broke out" with battleships that displaced far more tonnage and had larger guns than equivalent American and British ships designed to be compliant with the treaty. Like the Germans, the Japanese prepared for this breakout by building up to and even beyond the qualitative limitations in these agreements.[3]

It is clear that the only certainty in military policy is that it will change. Change is brought about continually by the evolving political climate between nations, the quest for new technology, and agreements to control armaments. A credible deterrent necessary to avoid the risk of war must cope with constant change, reacting to it as well as often anticipating it.

We have learned that almost any military technology is subject to countermeasures if it remains static for a sufficiently long time. So the key to survival is to continue to change and rely on a plurality of technologies. That ability to change is exactly what research and development, such as that conducted at the DOE weapons laboratories, has to offer. For this reason, I firmly believe that the existence of the three weapons laboratories with their close connections to DOE/Defense Programs and DoD is one of the most vital aspects of the U.S. deterrence.

E. Soviet Research and Development

The leadership of the Soviet Union clearly recognizes the importance of research and development to military strength and national security. Although specific data on Soviet R&D expenditures and manpower are difficult to establish and compare with data from Western nations, trends are clear. It appears that the Soviet Union has the largest R&D effort in the world, both in volume and relative to the Gross National Product (GNP).

Comparisons of R&D efforts on the basis of numbers of scientists and engineers may be the most meaningful, although caution is advised even here because the Soviets have a broader definition for engineers than does the United States. Even taking this into account, numbers provide a good, qualitative trend. In 1980, the Soviet Union accounted for nearly 37% of the world's scientific and engineering manpower. Employing over twelve million scientists and engineers, they are far ahead of Japan with just over four million and the United States with slightly less than three million.[4]

In 1983, the Soviet Union was estimated to have at least a 50% advantage over the United States on the number of scientists and engineers engaged in R&D per unit labor force.[5] The graduation rates for students with higher education indicate that the Soviet numerical advantage will not be threatened soon. Statistics for 1982 show that the Soviets graduate 450,000 students per year in the natural sciences and engineering, more than twice the U.S. number.

The United States continues to claim a qualitative advantage over the Soviets in science and technology. However, we must be careful not to belittle their accomplishments just because they have not translated their quantitative advantage into commercially visible accomplishments. We must recognize that the value system of the Soviet government has differed markedly from those of Western nations. In the Soviet Union, R&D for military and space applications gets first priority.

In the military and space arenas, the Soviets have made remarkable progress. Thirty years after Sputnik they significantly outclass the United States in heavy launch capability. Soviet astronauts have also logged nearly three times as many hours in space as their U.S. counterparts. In military technologies, they are world leaders in such areas as high-pressure physics (both static and shock loading), light-weight, high-strength materials, lasers, and particle accelerators. In fact, the radio-frequency quadrupole linear accelerator, developed at Los Alamos and now the basic building block for Los Alamos SDI technologies, was first invented in the Soviet Union.

We know relatively little about their nuclear weapons R&D program. However, to the best of our knowledge, their nuclear weapons R&D effort has continued to increase steadily and appears now to be two to three times the total U.S. effort. It seems not to have slowed down as a result of the current leadership's expressed desire to contain overall military spending.

General Secretary Gorbachev admitted late last year that the Soviets have a vigorous SDI R&D program. It is generally believed that the Soviets have more than 10,000 researchers in more than six major facilities dedicated to laser research for SDI, which greatly exceeds the U.S. effort. It is also alarming to see a significantly increased effort in areas such as chemical and biological agents and genetic engineering.

The Soviets are very concerned about perceived U.S. overall dominance in technology and would like to contain it, as evidenced by their fierce opposition to SDI. In the meantime, they have continued their own uninhibited drive towards technological superiority. I believe that this drive will in no way be tempered by international agreements to control armaments. In fact, the following statement made recently by V. Falin, a candidate member of the Communist Party of the Soviet Union Central Committee, and later paraphrased by the Soviet Press Agency, Novosti, indicates that the military will increasingly turn to science:

> "We won't copy you anymore, making planes to catch up with your planes, missiles to catch up with your missiles. We'll take asymmetrical means with new scientific principles available to us.
>
> "Genetic Engineering could be a hypothetical example. Things can be done for which neither side could find defenses or countermeasures, with very dangerous results. If you develop something in space, we could develop something on earth. These are not just words. I know what I'm saying."[6]

I have provided this brief discussion on the Soviets to reiterate a major point of my statement: the United States must continue to invest in defense-related R&D while it works on the political front to achieve a more secure world. There is no question that the Soviets are.

To close this section on the role of nuclear weapons in national security, let me summarize the four principal points I have made:

(1) *Nuclear weapons will remain the cornerstone of national security for the foreseeable future.*

(2) *The United States must retain its nuclear competence, which rests principally at its three DOE nuclear weapons laboratories. The nation must also modernize the DOE weapons production complex to provide the requisite materials and weapons for the future.*

(3) *The DOE weapons laboratories will be able to fulfill an expanding nuclear-weapon-related role beyond their traditional mission of research, development, and testing. The new roles include increased activities in arms control and verification, safeguards and security, intelligence, production complex technologies, and environmental R&D for cleaning up the DOE defense complex.*

(4) *The Soviets continue to increase their military R&D programs. Their current nuclear R&D is approximately two to three times as large as that in the United States. They have mounted impressive efforts in new technological areas that have important implications in areas such as genetic engineering and strategic defense. They have the world's largest science and technology program and appear to be determined to gain technological superiority.*

IV. THE BROADER ROLE OF THE WEAPONS LABORATORIES

A. Nonnuclear Defense Programs

In the past decade the Los Alamos National Laboratory has broadened its focus to defense problems involving other than nuclear weapons. Currently, approximately one quarter of the Laboratory's effort is in this area. There is a general consensus, as mentioned earlier, that the United States must develop a long-term strategy that relies more heavily on conventional weapons and defenses.

One recent study conducted for the DoD by the Commission on Integrated Long-Term Strategy[7] calls for *discriminating military responses* that do not only depend on threats that are expected to provoke our own annihilation.

A specific recommendation of the Commission is:

> "We must diversify and strengthen our ability to defeat aggression. To this end, we and our allies need to exploit emerging technologies of precision, control, and intelligence that can provide our conventional forces with more selective and more effective capabilities of destroying military targets."

The Commission further states that:

> "Military technology will change substantially in the next 20 years. We have depended on nuclear and other advanced weapons to deter attacks on our allies, even as the Soviets have eliminated our nuclear advantage. If Soviet military research continues to exceed our own, it will erode the qualitative edge on which we have long relied."

It also suggests that both our conventional and nuclear posture should be based on a mix of offensive and defensive systems.

The INF Treaty and START negotiations have helped to focus attention on the current imbalance in conventional military power of the Warsaw Pact countries and NATO. The Warsaw Pact has a considerable numerical advantage in tactical aircraft, rockets, tanks, armored personnel carriers, etc. The Soviets have also developed an apparent performance advantage in some of their tank and personnel carrier armors and in armor-penetrating munitions. We should recognize that this imbalance was created by a powerful, extended, and continuing commitment of major resources by the Soviets to conventional forces and military R&D.

The United States not only must continue to negotiate for greater balance of conventional forces with the Soviets but also must make a strong commitment to identifying and developing the high-leverage technologies suitable for our conventional forces and defense needs.

The major issue is how the United States will focus its resources during a period of major arms reductions so that international stability is maintained. Although we still maintain an advantage in the technical sophistication of our advanced weapon concepts, the Soviets have made great strides in their research, development, and, in some cases, deployment of high-technology battlefield weapons, such as lasers for guidance, anti-sensor, and anti-personnel applications. Thus they are attempting to develop both numerical and technical superiority in the conventional defense arena.

Many technologies could be used to increase the effectiveness of our conventional forces. For example, it is likely that nonnuclear weapons will become more lethal, partly because of high guidance accuracy and partly because of enhanced lethality technology in the warhead itself. In addition, there are electromagnetic weapons concepts, such as high-explosive-driven generators of high-power microwaves, that may have the potential to disrupt or destroy electronic assets over an extended area.

Two new initiatives, Conventional Defense Initiative (CDI) and Balanced Technology Initiative (BTI), begun by Congress are a good first step toward improving U.S. nonnuclear capabilities. This emphasis on R&D will have to be maintained even in the face of constrained defense budgets. No single technology has emerged yet that has the capability to dominate on the conventional battlefield of the future. Instead, a diverse set of weapons and countermeasures is likely to be required for an effective military force. The development of the requisite technologies for an evolving deterrent will require considerable resources, and this development will not occur overnight. Our emphasis must be not only on novel concepts but also on mechanisms to move ideas quickly and effectively from the research phase to deployed assets of proven military effectiveness.

The national laboratories can play an important role in the response to the challenge of producing a deterrent that is increasingly dependent on nonnuclear technology for its success. As in the nuclear weapons arena, we can bring to bear a wide range of multidisciplinary scientific and engineering talents, which have been successful at bringing advanced concepts from their embryonic stages to weapon deployment in an effective manner. We have the potential to play a unique bridging role between the basic research phase and the engineering development phase by focusing our skills and talents on the crucial exploratory R&D that proves the principle and yields the prototype.

In the strategic defense arena, we must maintain a balanced strategy between current and future concepts so that we are prepared to introduce the best technology at the point it can strengthen our deterrent. In particular, the directed-energy concepts are key to the long-term evolution of a strategic defense because they offer potential capabilities that the Soviets would find both difficult and costly to counter.

At Los Alamos, we have been successful in using a combined national laboratory/industry approach in our SDI programs as we team with industry on such advanced directed-energy concepts as the neutral particle beam (NPB) and the free-electron laser (FEL). In the former case, our technology was directly transferred to the industrial team at McDonnell Douglas Corporation who were designing the first major shuttle-based test of the NPB concept. During this same period, we continued to make significant technical advances in designing a Ground Test Accelerator that would demonstrate the requisite weapon-level parameters and would allow industry to take the next major step into space with this technology. In the FEL program, we are teamed with Boeing in developing the technology necessary for the first major experiment of a ground-based FEL at the White Sands Missile Range. At the same time, we are pursuing advanced ideas that could result in much more compact, high-power FELs that could be used for both strategic and tactical defense missions.

In the conventional defense area, we are beginning to play a similar role in the joint DARPA/Army/Marine Corps Armor/Anti-Armor Initiative. We are serving as the Advanced Technology Assessment Center (ATAC) for this program with the responsibility to do independent testing of new industrial concepts for armors or munitions, to serve as a technical coach to industry, and to perform advanced research on key technological issues. A similar role is possible in a wide range of conventional defense programs, from advanced conventional munitions to computer simulations of combat and information processing.

The model of the national laboratories teaming with industry to bridge the gap between research and weapon deployment could be key to this nation's ability to address the challenge of providing a strong deterrent to war with fewer nuclear weapons, with enhanced nonnuclear technology, and within constrained defense budgets. These plans were described in more detail in a recent Congressional hearing.[8]

B. Nondefense Programs

Defense research institutions of unquestioned quality are of paramount importance to the United States because we depend so critically upon advanced technologies for our national defense rather than upon the sheer size of our armed forces. A clearly identified and publicly supported defense mission is one ingredient to ensure first-rate weapons laboratories. Our experience has demonstrated many times that an outstanding basic research program and a challenging set of nondefense programmatic efforts addressing important national problems are also key ingredients to excellence. At Los Alamos these programs constitute approximately one quarter of our total effort.

Nondefense basic and applied research—mainly unclassified—is fundamental to attracting the best professional staff. The peer-reviewed research literature, the unclassified scientific popular literature, and publicly visible accomplishments are keys to institutional reputation and ultimate success in mission accomplishment. Ties to universities, where most of our country's basic research is done, ensure an inflow of talented new graduates to feed the professional work force. Defense programs characteristically have much weaker university ties.

At the weapons laboratories, nondefense basic and applied work is done in an environment oriented toward national defense. Thus, multiple payoffs are common and occur quite naturally. While contributions are made to the solution of nondefense problems and significant additions are made to the international scientific knowledge base, considerations of potential defense applications of research results come as a natural by-product. For example, in our Fluid Dynamics Group, innovative computational fluids models operating on supercomputers have been developed for modeling the complicated combustion and flow processes in internal combustion engines. Collaborating scientists in the same group use similar approaches for modeling the dynamics of fluids in nuclear weapons and in the complicated penetration of armor by very high speed materials. The payoffs to the defense programs are quite substantial and very timely.

Such multiple payoffs abound in a first-rate defense laboratory and are increasingly important as stress increases on national budgets. Payoffs occur in both directions. Results from defense programs can also affect nondefense problems, and technology transfer occurs most effectively in institutions with both types of programs. Technology transfer is especially important in these times of concern about economic competitiveness of U.S. industry. The DOE weapons laboratories are redoubling their efforts in working with industry to use their capabilities where appropriate to develop new and improved products for commercialization.

The exciting discovery of high-temperature superconducting materials is an excellent example of the way multiple payoffs (in both directions) can result from weapons laboratory research. Los Alamos has a comprehensive program to study the fundamental structure of these materials, to develop synthesis and characterization approaches for bulk samples of the material, and to develop approaches to produce thin films. Our staff is developing enabling technologies that could result in specific defense and civilian technologies. We are studying new particle accelerator cavities for potential strategic defense applications while looking at new explosive compaction approaches to producing monolithic superconducting structures for commercial application. The participation of explosive experts, basic researchers, strategic defense technologists, and engineers from the energy technology organizations of our Laboratory is testimony to the incredible excitement, synergism, and multiple payoffs resulting from such a multiprogram institution.

From the point of view of possible contributions to economic competitiveness, we have just scratched the surface. A wide array of technologies has been developed, largely with defense funding, that could potentially be commercialized. Our many years of work with both classified and unclassified research indicate that this can readily be done while ensuring protection of sensitive information and technologies. Examples of capabilities in the DOE laboratories that could be tapped by industry include a wide range of materials technologies, lasers, accelerators, biotechnologies, computer science and engineering, just to name a few. The laboratories have emerging enabling technologies, and industry has the product development and market-pull experience. By teaming in new ways that more effectively use the strengths of both, much more effective utilization of the laboratory capabilities can occur. Mechanisms for new ventures with private industry were described in a congressional hearing in June 1987.[9]

Nondefense research and development at the weapons laboratories must first, of course, accomplish the specific purpose for which the funds were provided. In the basic research arena, the strengths of the weapons laboratories are in multidisciplinary basic research and research requiring the use of large facilities. The largest single basic research activity at Los Alamos is associated with the Clinton P. Anderson Meson Physics Facility (LAMPF), the world's most intense proton accelerator with energies in the 800-MeV range. This user facility brings to Los Alamos 300 to 400 experimenters per year, adding to the institutional prestige and introducing graduate students and postdoctoral fellows to the Laboratory. Key discoveries have emerged from LAMPF, including the first detailed measurement of the electron-electron neutrino scattering cross section, which has helped in the verification of the electroweak theory of fundamental interactions. Returning to the theme of multiple payoffs for a moment, LAMPF was initiated by weapons physicists for nuclear physics studies, then became used primarily by the nondefense basic research community, and has more recently yielded accelerator technology that has provided the basis for the NPB and FEL research programs for strategic defense.

Nondefense basic research at the weapons laboratories is complemented by programs with applications in mind. Research in energy technologies continues, including magnetic fusion energy. Increasingly, the laboratories are applying their capabilities to problems of health and the environment. Capabilities in instrumentation, computer data base management and analysis, automation, and bioscience can contribute substantially to a national effort to sequence the chemical bases comprising the human genome. Similar capabilities can be brought to bear on problems of cleaning up toxic wastes in defense and civilian waste sites. Thus, increasingly, the superb capabilities of the laboratories are being applied to the benefit of mankind in new and important ways. Performing such work in an institution with ongoing high-quality defense research and development allows a mutual strengthening of programs and a multiple payoff for the nation.

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