Redefining the U.S. Nuclear Weapons Program and the DOE Nuclear Weapons Complex

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Los Alamos: A Rich, Fifty-Year Heritage

As we look back on the fifty-year history of Los Alamos National Laboratory, we can be justifiably proud of the accomplishments that are the foundation of our rich heritage. While the nation faced World War II and then the Cold War, we developed nuclear and thermonuclear explosives. In the early years we were also instrumental in developing the manufacturing technologies employed at the production plants in the nuclear weapons complex.

Over the intervening decades we met the challenges of changing national security needs. As weapons-delivery systems changed and the need for lighter, smaller, and more specialized warheads became apparent, we developed weight- and size-optimized designs. As increased attention was directed toward warhead safety and security, we developed insensitive high explosives, fire-resistant weapon components, and other enhanced surety (safety/security) design features.

Once again the security needs of the nation are changing—this time in the most profound ways since the early days of the Cold War. Once again Los Alamos and the nuclear weapons program must respond by building on our rich heritage and unique scientific and engineering capabilities to meet the new challenges.

Changing Priorities for the U.S. Nuclear Weapons Program

The context of the U.S. nuclear weapons program has changed greatly, in a way that is profoundly affecting the goals of this program and the requirements placed on it. Foremost among these changes are the welcome collapse of the global military threat posed by the former Soviet Union, and the breakup of its old political structures. Simultaneous with these changes come major public concern about continuing problems within the U.S. economy and growing concern over the U.S. federal deficit. These economic issues have put increasing pressure on defense expenditures and have catalyzed a resurgent political emphasis on domestic policy.

While nuclear weapons will not disappear and deterrence remains an essential element of U.S. national security, the Soviet collapse has led to major reductions in the planned size of the U.S. nuclear force, the demise of "traditional" nuclear targeting strategies, and a shrinking and shifting rationale for deterrence. An immediate effect has been the massive pullback of forward-deployed tactical weapons, a relaxation of strategic alert, and the cancellation of all near-term weapon production. The reduced nuclear threat has also resulted in less public acceptance of the perceived risks of nuclear weapons ownership. Increased attention is therefore being given to nuclear weapons safety and to the environmental impacts of the nuclear weapons complex.

The United States must continue to have a credible nuclear capability for the foreseeable future, given the reality of continued nuclear weapons deployment by several other nations. On the other hand, the bilateral initiatives for a much-reduced stockpile (culminating in the recent START II agreement) have created an increasingly clear mandate for a very much smaller, as well as more environmentally sound, manufacturing and maintenance capability. These initiatives for stockpile reduction have resulted in a concomitant requirement for massive weapon dismantlement by the complex as well as significant reductions in the future need for new tritium production.

Though the end of the cold-war era is apparent, increased concerns about proliferation of nuclear and other weapons of mass destruction have been highlighted by revelations of Iraq's nuclear weapons development, and activities in North Korea are raising additional questions. These concerns have been made poignant by a resurgence of ethnic conflicts; meanwhile Russia, with its nuclear weapons and expertise, continues to skirt economic collapse. The specter of a wider number of states or groups possessing nuclear weapons is a frightening one, and the questions of how to prevent, detect, and mitigate such proliferation are vital.

Within the nuclear weapons program and nuclear weapons complex there have been distinct but synergistic roles played by the national laboratories and by the production complex. The weapons laboratories (Los Alamos, Lawrence Livermore, and Sandia National Laboratories), which carry out the research, development, and testing for U.S. nuclear weapons, are responsible for weapons design, engineering, certification, safety, and security. Their expertise supports nonproliferation activities, including analysis and assessment of emerging foreign nuclear technology, and supports our emergency-response capability. The technical expertise and judgement available in the nuclear weapons laboratories proved vitally significant in helping to uncover and evaluate the Iraqi program. The laboratories' unique nuclear expertise and technology will be used to guide the restructuring of the production complex.

The production complex (for example, Savannah River, Rocky Flats, Pantex) has been responsible for weapons component and material production, material processing, and weapons maintenance and dismantlement. Both the laboratories and the production complex have had roles in materials management and surveillance (monitoring) of the stockpile.

The changes in the budgetary, environmental, and national security arenas over the last five to ten years have produced significant changes in the weapons program and the complex. An increasing awareness of the impact of human activities on the environment has led to both regulatory and cultural change. Faced with significant environmental or safety concerns, some major, one-of-a-kind production facilities have had their operations curtailed for extended periods; some, such as Rocky Flats, will never resume their previous production role. Reduced production requirements and cost concerns have halted the development of a new production reactor to supply tritium. Furthermore, total defense funding is being significantly reduced, and there are increasing demands on the DOE's nuclear-defense-related funds—for reconfiguration of the nuclear weapons complex, environmental restoration, waste management, and increased attention to the environment, safety, and health in operations.

Motivated in part by the reduced threat, as a response to concerns for the future of the nonproliferation treaty, and in light of the Russian and French moratoria on nuclear testing, in late 1992 Congress passed the Hatfield amendment to limit and eventually end U.S. nuclear testing. The laboratories' level of Weapons Research, Development, and Test (RD&T) activity had already been reduced by about 38 percent between 1987 and 1992–93. The rate of nuclear testing was reduced by more than half in the same period—even before accounting for the Bush administration's restrictions of fall 1992 and the subsequent passage of the Hatfield amendment. Cost savings are still being actively sought in RD&T activities as well as by reconfiguring the production complex.

The nation is now approaching a critical juncture in which appropriate decisions must be made to transition the nuclear weapons complex and program to a new equilibrium that is designed to effectively support the new priorities and expectations, while assuring the quality the nation needs in its nuclear capability. The laboratories will, of necessity, play a key role in this transition and a vital one in the new state of the complex that emerges.

New Goals for the U.S.Nuclear Weapons Program

We must define a new national nuclear weapons capability, including a new state of the DOE nuclear complex, that is consistent with the following long-term goals and requirements.

With the drawdown and aging of the nuclear force, it will increasingly be the competence and capability of the RD&T laboratories, and the competence of the U.S. nuclear complex to produce, modify, and maintain weapons, that will represent deterrence. In other words, "deterrence by capability" will increase in strategic importance relative to deterrence by targeted nuclear forces. Thus the U.S. must maintain a technological nuclear edge—defined by system effectiveness, not large numbers—and we must provide for the stewardship of the ongoing stockpile. The principal elements of the DOE's nuclear stewardship will be stewardship of technology and stewardship of nuclear materials.

The ongoing nuclear force will be based on a much-reduced stockpile of no more than 2500 to 5000 weapons. The number of distinct weapons systems in the stockpile will be similarly reduced. The emphasis of the program will therefore be to assure adequate safety, security, reliability, and flexibility of these remaining forces. There will be few new starts of weapons development programs—none in the short term, though safety modifications to existing weapon systems will be pursued. In the long term, any new weapons development programs will be primarily driven by aging of stockpiled weapons to the point where reliability or safety is no longer acceptable or (potentially) by the desire to incorporate significant safety improvements.

There will be a permanent shift in emphasis within the complex from production of nuclear materials to management and control of nuclear materials and waste. There will also be limited needs for perishable materials such as tritium. Only a very limited fabrication capability will be needed, small compared to the previous capability.

A New Equilibrium for the Redefined Weapons Program and Complex

We suggest that following a transition period a new and different "equilibrium state" will emerge, both for the nation's nuclear-security posture and for its nuclear weapons program. Below we outline our vision of the principal elements of this new equilibrium.

Stewardship, safety and security, and prototyping. The research and development program must center around stewardship of the remaining stockpile, providing both expert judgement regarding the safety, security, reliability, and vulnerability of U.S. weapons as well as the ability to address problems that may arise within the stockpile, particularly as it ages. Although new production will be rare, the need for replacements in the stockpile will be inevitable. Under the anticipated test-ban regime, we must still be able to guarantee the safety and performance of these replacements. We must also maintain the ability to manufacture them in a new minimum production complex.

The value of improvements in safety and security was highlighted by two recent government studies initiated by Congress. However, we anticipate that those improvements will be introduced in a "graded" approach paced by need and affordability rather than by the availability of one or another new component. Certification of improved systems is in many cases tied to nuclear testing, particularly when these improvements involve changes in explosives or materials components. If the Congressional mandate to limit testing to the fiscal years 1994 through 1996 stands, we hope in that period to develop and test prototypes of potential back-ups to current systems, which are as robust as possible to uncertainty under a test ban and which have a full complement of modern safety features.

We propose that in the absence of new weapons production, the development of prototypes is an effective way to maintain active technological competence in weapon design, engineering, and production technology. To be effective, prototyping must include both component and integrated testing so that the actual performance of the prototype can be reflected back to its designers and engineers. Above-ground testing without a nuclear explosion will provide many of the needed benchmark experiments, though the full benefit of prototyping for sustaining design judgement and engineering competence would not be obtained without underground tests. Secretary of Defense Les Aspin as well as the Armed Services Committees have suggested that a similar process be used to retain capability and technological expertise in conventional weapons systems.

Active technological expertise is the foundation of stewardship. In addition to providing expert judgement regarding the safety, security, reliability, and vulnerability of U.S. nuclear weapons, that expertise will be called upon to provide assessments of the nuclear forces of other nations. As the national security context continues to shift, the weapons complex will be also be called upon to evaluate some limited technological options—not for tomorrow but for ten or twenty years from now when delivery systems begin to face technological obsolescence.

Nonproliferation/Counterproliferation. During the 1990s security concerns will shift from bilateral arms-control treaties to multilateral control of proliferation. Arms-control, verification, and intelligence efforts will increasingly overlap. The U.S. and former Soviet Union will be securing and dismantling much of the extant stockpile of nuclear weapons. Large amounts of nuclear material will be removed from weapon systems and must be safeguarded in a way that provides international confidence. The world will face an increasing threat of nuclear weapon use from new sources, and the diffusion of missiles and chemical-biological weapons will compound international stability concerns. The Nonproliferation Treaty and International Atomic Energy Agency (IAEA) will be central elements in the diplomatic and political efforts to avert and mitigate proliferation.

The redefined nuclear weapons program will increasingly be called upon to contribute to nonproliferation and arms-control efforts. We will continue to provide qualified teams for nuclear-emergency or accident-response contingencies. We must apply all necessary technical skills to help in the prevention, detection, and mitigation of weapons proliferation. Considerable nuclear-weapons expertise will be needed to safeguard the storage and handling of nuclear materials, to assess foreign technology, to verify treaties, and to provide advanced computing methods and advice related to export controls. The weapons laboratories' capability to field complex physical measurements in difficult environments will be used to detect key indicators of the intent to proliferate. One such technology is LIDAR (Light Detection and Ranging), which has been applied by Los Alamos in a wide range of environmental and atmospheric sampling programs. In addition, the threat of increased terrorism calls for the development of new technologies to aid the intelligence community.

Predictive capabilities, above-ground experimentation, and the issue of nuclear testing. Underpinning stewardship and the ability to support continuing national security needs is the maintenance of nuclear-design competence. To continue to provide this competence now that plans are under way to end tests involving nuclear explosions, the nuclear-weapons-design activities at the laboratories are emphasizing greater predictive calculational capabilities and "above-ground experiments" (AGEX), that is, physics and materials experiments that do not involve a nuclear explosion. The laboratories will use these above-ground experiments in relevant physical regimes to exercise nuclear weapons design expertise and weapons technology. An appropriate suite of complementary experimental capabilities will be needed, since all of the physics aspects of a nuclear explosion cannot be produced simultaneously without an underground test.

We have recommended that a minimum program of underground testing be retained to provide confidence in weapon reliability and quality, to maintain expertise, and to investigate technical options or design modifications for prototype weapons. However, because of the end of the Cold War and the hope of further discouraging proliferation, the nation plans to end nuclear testing as a matter of policy, and we do not anticipate a change in that policy unless there is substantial provocation. When testing is in fact ended, the laboratories will rely on the above-ground capabilities as their principal experimental resource to address technical issues, maintain expertise, and validate theoretical models and calculations used to predict weapon behavior. This will ameliorate but not prevent a decline in weapon expertise and judgement. The best available high-performance computational capabilities, including massively parallel computer architectures, will be utilized to enable more accurate and complete simulations and design codes. These codes will be extensively tested against available nuclear-test data and the results of above-ground experiments to provide the best possible predictive capability for weapon reliability and safety.

Consolidation of the RD&T complex. With the recognition that maintaining active competence in people and confidence in equipment is essential, the infrastructure of the complex will be consolidated and reconfigured to reduce cost and reflect new goals. It is important that this consolidation continue to integrate design, materials, and experimental capabilities at a common location to preserve program quality, and it should try to preserve the current architecture of two weapons-design laboratories for interlab peer review. However, to retain this architecture while reducing RD&T funding, the weapons infrastructures of these laboratories would have to be significantly supported by activities related to stockpile support, environmental restoration, and waste-management roles.

Nuclear weapons are complicated systems, and a *very* high value is placed on their performing when desired, not accidentally. In many areas of weapons technology, repetitive statistical testing is not possible, and national security precludes open technical exchange. Further, the nuclear testing of weapons designs is expected to be prohibited by the late 1990s. To maintain reliability and preserve quality, some form of intellectual competition and peer review is essential. In the U.S. this has historically been provided by two independent nuclear design laboratories and one warhead systems engineering laboratory. Whatever the future form of the weapons program, adequate intellectual competition and peer review must be maintained through some appropriate mechanism.

Minimum Complex 21. "Complex 21" is the designation for the downsized and cleaner nuclear weapons complex that will meet the needs of the twenty-first century. The safe storage of plutonium and enriched uranium (either as dismantled weapons components or in other forms) is a dominant requirement of the new complex; another is processing dismantled material. While sealed weapon components can be stored for many decades, some of these units will have to be reprocessed as they age. Also, the world community will likely press for permanent storage (as vitrified waste) or energy conversion (via reactor or accelerator burning) of excess Russian and U.S. fissile materials. The capability to fabricate a modest number of new warheads or remanufacture those in the enduring stockpile will be optimally located at the chosen nuclear-materials storage and processing site. (One way of assessing the needed capacity for fabrication is to compare the number of weapons in the long-term stockpile with a typical weapon lifetime. From this basis we can estimate a need for about 100 to 200 units per year—down by an order of magnitude from peak Cold-War production rates!) We expect that Complex 21 will be a radical departure from the present complex: some of today's plants will not have direct counterparts in Complex 21, though their technologies will live on.

In the future the traditional distinction between responsibilities of the production complex and the design laboratories will become somewhat more diffuse. While processing and fabrication for the stockpile will be based within the manufacturing and storage facilities, each such technology, for example plutonium processing and fabrication, will be based upon an R&D capability at the laboratories. Modern manufacturing and process technology will be developed at the laboratories to minimize waste and worker exposure and to resolve environmental and safety concerns. Fabrication of some nonnuclear components and the few weapon prototypes necessary to support the nation's weapons RD&T program will be accomplished by the national laboratories. This evolution of the national laboratories' responsibilities will allow the nation to effectively maintain both its research and development capabilities and an essential back-up processing and fabrication capability.

Although we expect no new production of plutonium or highly-enriched uranium, Complex 21 will eventually include a limited new tritium-production capability to replace current reactors. In addition, the nation will continue to move toward a strategy that satisfactorily manages long-lived radioactive wastes from defense and other sources.

Environmental Management. Similarly, Minimum Complex 21 must address those DOE sites at which weapons production took place in the previous four decades. Their environmental restoration and closure poses immense technological and financial challenges. Vitrification and storage of high-level waste at Yucca Mountain; the testing and safe operation of WIPP; the management and cleanup of the Hanford storage tanks; liquid effluent cleanup at numerous sites; acceptable disposal of mixed waste; effective long-term environmental monitoring; and residue elimination, cleanup and decommissioning of Rocky Flats are some of the large—and costly—environmental hurdles the DOE has yet to clear.

In the new configuration of the complex, increased investment in environmental science and technology will enable the DOE to more affordably address its own environmental responsibilities and comply with regulations. Such investment will be used to reduce environmental risk on a national scale, mitigate industry's cost for environmental compliance (now over $100 billion per year), help nurture a competitive, high-technology environmental industry, and develop improved foundations for regulatory policies.

Based on a model already implemented at Los Alamos, the laboratories are using a risk-based, cost-benefit analysis (for example, Multi-Attribute Utility Theory) to develop priorities regarding compliance agreements. This approach should be adopted nationwide so that DOE, DOD, and the EPA Superfund resources are applied to the most urgent problems. Local communities need to be increasingly involved in the weighting factors for such analysis. Field sensors developed at Los Alamos for monitoring emissions from facilities are providing an improved and less costly basis for environmental assessment. Such sensors, when extended to a national scale, could provide a better assessment of national environmental issues, and if they are extended to satellite-based capabilities long used by the weapons laboratories, such remote sensing capabilities could be the basis of a worldwide environmental network.

Laboratory capabilities in accelerator design and nuclear-materials processing are being applied to two outstanding issues: safe disposal of long-lived nuclear waste, and the safe, economical production of the tritium needed for the ongoing stockpile. Tritium has a 12-year half-life; therefore, unlike other nuclear materials it cannot be stored or reused indefinitely. Accelerator production of tritium is attractive because it does not produce transuranic waste or build up a large mass of other waste products. It will offer an economical and technically attractive source of tritium as the stockpile is reduced. Accelerator technology also offers an effective, economical means to transmute long-lived, high-level waste and actinides (such as plutonium waste) into shorter-lived waste that decays in roughly 100 years rather than 10,000 years. Such transmutation would dramatically ease the requirements on geological nuclear-waste repositories. The laboratories will continue to support current waste-management efforts such as the Yucca Mountain project; however, accelerator transmutation of waste may produce a major shift in waste-management strategy and could also be used for the conversion of weapons-grade plutonium.

Integration of RD&T with broader national missions—Technology Transfer and Conventional Defense. The RD&T laboratories will be integrated with broader national missions to provide leverage and to make more efficient or dual use of the advanced-technology capabilities primarily developed and maintained for the weapons-program mission. Cooperation and partnerships with U.S. industry will become a routine and significant element of the laboratories' activities, enabling transfer and application of unclassified advanced technology with the aim of assisting U.S. competitiveness and addressing demanding civilian problems such as environment and infrastructure. The 1992 DOE Defense Critical Technologies Plan identifies many such opportunities. For example, the laboratories' computational-science capabilities are already benefitting industry in the areas of combustion modeling, oil-well logging, and simulating performance of complex mechanical systems. They are also being applied to health research through such projects as the HIV database and the modeling of complex biological molecules. We can make a substantial difference to U.S. economic competitiveness by designing an "information interstate highway system" to link government and industrial assets in every state. Mechanisms to expand the ability of the laboratories to develop high-leverage interactions with industry will be encouraged.

Similarly the laboratories' technologies will continue to be tapped by the Department of Defense for conventional (non-nuclear) defense. The synergism between nuclear and non-nuclear work has already been demonstrated in explosives development, armor/anti-armor, advanced munitions, and computer simulations of performance, safety, and lethality. This linkage will be continued as a strategic element in maintaining an effective defense R&D base. In addition, many of the technologies being developed for advanced manufacturing and waste remediation will have significant benefit to the DoD.

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Philip D. Goldstone (right) is currently the Chief Scientist for the Inertial Confinement Fusion (ICF) and High Energy Density Physics programs at the Laboratory. He received B.S. and M.S. degrees from the Polytechnic Institute of Brooklyn in 1971 and 1972 and his Ph.D. in physics from the State University of New York at Stony Brook in 1975. After joining the Laboratory for a postdoctoral appointment in experimental nuclear physics, he stayed to work on shock hydrodynamics, high-energy-density physics using lasers, and the physics of laser-driven ICF. From 1981 until 1989 he led the Laser-Matter Interaction and Fusion Physics group and from 1986–89 was also the program manager for ICF experiments. From 1989 to 1992 he served on the staff of the Associate Director for Nuclear Weapons Technology, providing support and advice on research issues.

Los Alamos: The Ongoing Commitment

Our laboratory has grown and matured with the nation's security needs. Our fiftieth anniversary coincides with sweeping changes in national requirements for military and economic security. We have outlined an effective and achievable vision for the reconfiguration of the weapons complex that emphasizes the critical importance of maintaining the intellectual basis for stewardship as the size of the nuclear force decreases. The key issues that will determine the future of the program are summarized in the accompanying box. Our vision has been put forth as part of our ongoing commitment to the nation. Whatever decisions are made about the future of the weapons complex, Los Alamos will be at its hub to ensure the integrity of the U.S. nuclear capability. ■

Key issues framing today's decisions

The United States must maintain the necessary capability in nuclear weapons technology to provide stewardship of the remaining stockpile, provide technological option and assessment capability, and provide the capability to maintain, modify, and produce weapons when necessary. Technological competence and capability is not sustained simply by maintaining existing, deployed systems. Historically, it has been sustained by a “natural process” brought about by the development/test/production cycle. This is similar to the dilemma now faced by the DoD in maintaining its technical base. An active strategy should be developed to provide for long-term competence and for confidence in the safety, reliability, and relevance of the nation’s nuclear force.

The laboratories will be an integral—in fact central—element of the redefined weapons complex. They will also play a vital role in providing the research and technology needed to enable the transition to it. Cost-effective stewardship of the nation’s nuclear capability cannot be obtained simply by reconfiguring and downsizing today’s capabilities; R&D investments must be made to make it possible and to bound its cost. The laboratories will have to invest in and develop capabilities ranging from more adequate above-ground facilities, to demonstration of lower-waste, lower-cost plutonium processing and fabrication technologies, to more cost-effective technologies for supporting environmental-management goals for the complex.

Although Congress has adopted plans to phase out nuclear testing, it should be recognized that such testing has been a vital element in maintaining long-term competence and confidence in the safety and performance of the nuclear force. Safeguards and investments in appropriate facilities for above-ground simulations and experiments are crucial to ameliorating the effects on technical competence of stringent test limits or a test ban. In particular, investments in improved hydrodynamic testing capabilities and in computational enhancements are now urgent.

Innovation and competence in weapons science and technology areas are critically bolstered by the continued presence at the laboratories of a range of program activities that is broader than their central nuclear-weapons mission. This diversity also enhances the potential for technology transfer and commercialization.

A more than one-third reduction through 1993 (and perhaps an additional 20 percent reduction in 1994) in the level of effort in research, development, and testing has made laboratory consolidation an increasingly important issue. Future RD&T funding is projected to fall below the critical level at which substantial changes in the present architecture of the RD&T complex must be examined. If so, we must consider a careful shift of laboratory missions in a way that preserves the necessary expertise and facilities, provides adequate mechanisms for intellectual competition and peer review, and maintains the quality of such a reduced program.

The national interest places very high value on slowing or preventing proliferation of weapons of mass destruction. Competent weapons-program expertise is required to develop detection and materials-accountability technologies as well as to assess intelligence data.

The DOE must make the transition to a Minimum Complex 21 that supports the new goals and requirements outlined in the main text. The expertise of the weapons Laboratories should be an integral component of this transition. Despite the termination of plutonium fabrication at Rocky Flats, the U.S. will still need to reestablish a long-term facility for nuclear-materials storage and processing as well as a small but flexible fabrication capability to support the stockpile. The laboratories should provide and demonstrate technology for the future U. S. plutonium capability as well as technologies for cleanup of Rocky Flats.

There will likely be ongoing public concern regarding nuclear waste and related issues. The potential of accelerator alternatives for tritium production, waste transmutation, and conversion of weapons-grade plutonium should be aggressively evaluated as possible ways to ameliorate and benefit from these issues economically. □