Challenges and Prospects

by Donald M. Kerr

On this occasion of the 40th anniversary of the founding of the Los Alamos Laboratory. I would like to shape in broad outline my hopes for the Laboratory in the next decade. Though some of what I will say may go beyond what might be labeled as realistic, we must have such high hopes, for they help us stretch our capabilities. I will also address some substantial obstacles that could, if not countered, negate our best attempts to help the nation solve some of its pressing problems.

My first hope is that Los Alamos scientists will play a prominent role in reshaping the defense posture of America through efforts along three lines—arms control, nuclear weapons, and advanced weapons concepts.

The people of this planet have no more important task than to subdue the spiraling arms race and to eliminate the fear that, by accident or by design, nations might eliminate large portions of life on this earth by engaging in a massive nuclear exchange. While science cannot solve the political problems that snarl arms control talks, improved technology in satellite surveillance, seismic detection, and information analysis can help decrease the possibility of agreement violations through surprise actions, clandestine activities, or new developments. Such technological assistance is not likely to be the key element in advancing attempts to curb the arms race but may be useful if political developments become favorable.

Our nation's efforts toward arms control must be made from a position of strength. And that strength depends on being at the forefront of all scientific areas likely to yield new military applications. In the area of nuclear weapons, Los Alamos can make the following specific contributions.

- Encourage the modernization, where appropriate, of nuclear warheads to provide the best safety and security features technology can offer.
- Assure the effectiveness of nuclear weapons over a wider range of operating conditions.
- Improve the protection of warheads against newly developed electronic countermeasures designed to defeat our weapons.
- Develop new means of making our weapons more effective

against hardened targets in the Soviet Union.

° Improve the techniques for defending our own strategic forces from a first strike.

° Determine the feasibility of newer weapons, including those involving particle beams and lasers.

Finally, Los Alamos can contribute to the nation's defense through efforts in what we call advanced weapons concepts. This Laboratory was created to meet what was viewed as the most critical defense issue facing the country in World War II—the possibility that our enemies were developing a weapon based on new science and new technology. It is vital that the critical military needs currently facing the nation be met in a similar fashion today.

One advanced weapons development would be the introduction of truly intelligent weapon systems to the battlefield. Such systems have been discussed and popularized, but the immensely difficult task of developing them, although possible, remains to be done. I have in mind a weapon system including multiple sensing techniques coordinated by sophisticated electronics and computing capabilities. The intelligent weapon system would be integrated into an overall battlefield posture involving land, sea, and air forces.

Ten years or so ago the prospects for artificial intelligence were oversold, and work in that area received a bad name. But significant developments over the past decade suggest that now is the time to initiate its application. Already a number of techniques for using computers as expert systems are in the early stages of application. For example, one computer manufacturing company is using a modest form of artificial intelligence to establish the appropriate configurations of computer systems for purchasers. A computer programmed with more than two thousand rules and fed the requirements of the purchaser determines the configuration of equipment that best meets those requirements. Another and perhaps the most widely noted example is the use of computers in medical diagnosis to help physicians make the complex judgments required of them when faced with multiple symptoms and test results. In over 95 per cent of the tests thus far, diagnoses made by the computer agree with those of expert physicians.

The eventual goal in a military context is a weapon system that can be sent into a battle situation to sense and analyze many complex, perhaps rapidly varying factors, such as terrain, environmental conditions, and the nature and movement of enemy forces and weapons. The system, controlled by artificial intelligence, would make the decision as to which of its weapons to deploy and in what manner they would best be utilized. Such a system may sound far-fetched to some, but the technology required has progressed to the point that it should be vigorously pursued.

A nation possessing an intelligent weapon system would have a great tactical and psychological advantage over its enemy. Furthermore. smart weapon systems equipped with today's advanced nonnuclear warheads could displace low-yield, short-range nuclear weapons and thus considerably reduce the tension associated with the posting of nuclear weapons close to an enemy's borders.

Research along these lines should be pursued, and Los Alamos, together with Livermore and Sandia, can make important contributions in the next ten years, if properly supported and freed of extensive program strings, milestones, and reporting requirements. Modest funding of a few million dollars per year to each of the weapon-related national laboratories would be a sufficient beginning.

There are many other exciting advanced weapons concepts; I will mention only a few. We have ideas for antiterrorist technology that could reduce the impact of threats in many areas. We see means for detecting and protecting against chemical and biological threats. And we see a possibility of developing microwave weapons, which could become very important as electronics becomes more and more integrated into the battlefield.

My second hope is that the Laboratory will make major contributions to solving a problem that has commanded great public attention—the problem of supplying the energy needs of the nation and the world. The Laboratory has devoted a substantial effort to energy programs during the past decade, and it is my hope that as these efforts reach maturity in the coming decade, they will bear technological fruit in the following forms.

Safety and engineering advances that will make nuclear power a more acceptable approach when the world turns again to this energy source, as I believe it eventually will.

° Nuclear waste disposal techniques that will satisfy public concerns.

° Techniques for extracting fossil fuels from the earth that will provide greater efficiency and worker safety and cause less pollution and environmental damage.

° Practical fuel cells that will power many diverse activities, from transportation to materials production.

° Geothermal projects that will tap the heat of the earth's mantle to provide a clean and safe supply of heat and electricity.

° Advances in renewable energy technologies that will allow for decentralized energy supplies so necessary in rural America and in many developing nations.

Controlled fusion is a major area in which we have made and continue to make important contributions to the development of a new energy source for future use. Since the early 1950s Los Alamos has played a major role in the international development of magnetic confinement science and technology. This cooperative effort has led to such a high level of sophistication that demonstration of energy break-even, using the mainline

tokamak approach, seems assured during this decade, The ability to confine reactor-grade plasmas for times close to those required for thermonuclear ignition is an enormous scientific accomplishment that could not have been achieved without the resources that national laboratories, universities, and industry brought to bear on this problem.

At the same time it is clear to me that the demonstration of scientific feasibility on the tokamak will not automatically assure its economic feasibility as a power-producing system. It is likely that proof of commercial feasibility will fall to a different fusion concept whose inherent confinement requirements reduce engineering complexity and therefore cost to the point where it can become a practical system for the nation to adopt, or perhaps commercial feasibility will fall to much more advanced tokamak systems yet to be developed.

I believe the work going on at Los Alamos will play a significant role in developing a power-producing fusion reactor. I am encouraged in this respect by recent successful developments in our Reversed-Field Pinch and Compact Toroid programs because the efficient confinement properties of these schemes provide the magnetic fusion program with a new possible end-product: the compact, high-power-density reactor. This new approach efficiently utilizes resistive copper magnets and therefore differs qualitatively from the conventional reactor models, based on superconducting magnets, in greatly reducing the size, mass, complexity, and cost of a reactor and the time required for reactor development. These alternative fusion concepts are at an earlier stage of scientific development than the tokamak. Their potential for resulting in a significantly better commercial product provides the rationale for support in a well-balanced and prudent national program. Ideally, in such a program the allocation of resources will permit the full potential of these alternative concepts to be realized so that their best reactor attributes can merge with the more mature development base for the mainline approach to produce an optimized fusion system.

Diverse funding of numerous approaches is the best means for overcoming the great technical challenges posed by controlled fusion. If such funding occurs, I believe that Los Alamos can develop fusion power systems that are smaller, cheaper, and more easily maintained. Such developments may enhance the willingness of society to adopt this form of technology.

My third hope concerns the application of the Laboratory's expertise in physics, chemistry, and engineering to the new challenges in the fields of biology and medicine. Two instruments of fundamental importance to biomedical research have been developed at Los Alamos. These are the liquid scintillation spectrometer, which makes possible simultaneous counting of different radioisotopes, and the flow cytophotometer, which allows rapid analysis and isolation of individual cells. The latter development resulted in the establishment at Los Alamos of the National Flow Cytometry Resource. Current activities give me confidence that the next decades will see developments of similar importance to biology and medicine.

For example, improvements in flow cytometry now allow rapid identification and separation of chromosomes. This capability, coupled with powerful recombinant DNA techniques, opens new approaches in cell biology and genetics. The chromosome rearrangements characteristic of tumor cells can now be closely scrutinized, and this information may provide insight into the origins and abnormal behavior of cancer cells. With similar techniques cultured plant cells may be manipulated to produce new crop varieties with desired genetic characteristics, such as disease resistance and environmental tolerance.

Another example is the development of noninvasive techniques for analyzing human functions with minimal discomfort to the patient. In one such technique a nuclear magnetic resonance coil is used to follow the course of metabolic processes from outside a patient's body. The coil detects important intermediate products of metabolism that have been labeled with a suitable magnetic isotope, such as carbon-13. The labeled materials are available from the Laboratory's Stable Isotope Production Facility, which pioneered in the field of stable isotopes for biomedical research.

The Laboratory is also developing advanced physical techniques for biological and medical applications. Examples include rapid, precise identification of microorganisms based on their scattering of circularly polarized light and detailed structural analysis of biological macromolecules based on neutron and x-ray spectroscopy.

Another venture into the realm of biology exploits our computing capability—the largest in the world—to compile and make available to the scientific community a library of genetic sequences. Los Alamos has recently been designated as the site of the national DNA sequence data bank. This data bank will contribute significantly to unraveling the mysteries of DNA.

The Laboratory has a major responsibility in developing secure alternative energy sources such as shale oil. Experimental shale retorts and advanced capabilities in cellular and genetic toxicology provide the opportunity to choose extraction and processing methods that produce the least harmful pollutants. This will involve using the advanced techniques described above to study the effect of pollutants on cells.

It is my hope that, with strong inputs from academia and industry, the advanced physical, theoretical, and computational capabilities of Los Alamos will contribute to a decade of imaginative and striking benefits in the areas of biomedical research, energy development, and environmental science.

My fourth hope is that the Laboratory will continue to involve an increasing number of scientists from universities and industry in its activities. We have already made great progress in this area by establishing three centers designed to reach aggressively beyond our borders: a branch of the Institute of Geophysics and Planetary Physics, the Center for Nonlinear Studies, and the Center for Materials Sciences,

In terms of new efforts, I see the following possibilities.

- That not one but two or three of the world's most Powerful computers will be available beyond the bounds of our security fences for use by collaborating scientists from other institutions.
- That more and more students and faculty will become familiar with our activities and facilities by choosing to pursue research at Los Alamos.
- That our staff will increasingly aid in the transfer of technical information to industry and to universities by sharing in joint exchange appointments.

It is, of course, impossible to mention all significant advances expected in a laboratory as diverse as Los Alamos. But one final hope is that we will be surprised by some unexpected development or discovery that derives from the exploration of new questions and new possibilities. The very nature of scientific research makes such surprises possible, and for this reason basic research is a fundamental element in our plans.

To realize the hopes that I have outlined, difficult scientific problems will have to be confronted, pursued, and conquered. But those efforts now face challenges beyond the inherent scientific difficulty.

A changed political and social climate challenges these hopes. Some voices now question the major mission of the Laboratory. They ask, "Why is the Laboratory still engaged in weapons work?" That question often comes from those who believe that the thousands of nuclear warheads now in our arsenal are more than adequate and that no more effort in this scientific area is needed, These people deserve a reply.

Three chief factors drive our continued efforts in weapons, I touched on two of these above but their importance leads me to reiterate. The first is the extent to which potential enemies of the United States are making technological advances that could jeopardize the defense posture of the United States. This issue led to the creation of the Manhattan Project during World War II, and it is still a valid concern in the present political climate. Our political leaders generally feel that their ability to influence world affairs is affected by the extent to which the United States maintains technological supremacy in the defense area.

The second factor is the need for solutions to technical problems that may inhibit accords on arms control. Any agreement on this subject rests heavily on the ability to determine that its provisions will be followed by each signatory, The inability to verify compliance has created stumbling blocks in past negotiations. The Laboratory must assist in developing new verification techniques, for they maybe a critical link in reaching the goal of arms control. The Laboratory will also be called upon to help policy makers understand the capabilities and limitations of current approaches to verification,

The third factor is the certain knowledge that the pursuit of science inevitably yields ideas for new technologies that have a wide variety of applications, including military ones. The choice to develop the new military applications is the nation's. But the nation cannot choose to stop the scientific effort that creates those applications without also stifling development in other human endeavors. Science is neither compartmentalized within itself nor isolated from its surroundings. New scientific ideas have a way of leaping traditional boundaries among fields of science and of creating vast and unforeseen changes in the economic and political fabric of society.

Another challenge facing the Laboratory is the idea of some that our research activities be transferred to academia and industry, You might ask, "What is the place of Los Alamos in the midst of the country's large and sprawling research community?" After all, research efforts at universities have grown substantially since World War H, and industry has also seen reason to invest in research and development.

I believe there is a clear place for Los Alamos and other national laboratories. That place goes beyond weapons work, which the government obviously must control directly, to other areas of research in which a strong national interest justifies the presence of a federally supported laboratory.

For example, many areas of research-a notable example being nuclear fusion—face such inherent difficulties that they will yield results only over a very long term, Industry will not be inclined nor financially able to enter such areas. Another example is the area of research on the protection of workers, the public, and the environment from technologies new or old. Here the profit motive of industry may bring into question their objective assessment.

National laboratories such as Los Alamos can address these issues, and, in fact, Los Alamos is extraordinarily well equipped to do so. Our scientific computing capabilities are unsurpassed. We have the experience of dealing with military agencies and understand their needs and procedures. We can work in a way sometimes referred to as vertical integration: that is, we can develop an idea for, say, an instrument all the way from conception to production engineering. Our activities range from undirected basic research to production engineering of devices that weigh tons. We can transform ideas or

bits of Nature's secrets into products useful to mankind. Of the thousands of laboratories in the nation only a small handful match this Laboratory's capabilities.

The world is increasingly specialized, compartmentalized, separated into isolated parts. The concept of integrated teamwork bringing mathematicians, physicists, chemists, biologists, engineers, and economists together for a sustained effort is not a tradition at very many institutions. In fact, it seldom happens. It is difficult to bring about. In many places it is impossible. At Los Alamos it is the usual practice. It is the way we have conducted business from the beginning.

The third challenge facing the Laboratory in the next decade concerns the level of financial support for its activities, particularly for basic research. Funding reductions can harm our work in important ways, and basic research often suffers more harm than other areas because sponsors are inclined to view it as less important than work closely coupled with an approaching milestone.

In the mid 1970s Congress established a new budget process in recognition of the need to review federal economic policy and to reduce the federal deficit. The resulting tighter budgets and economic policies have affected virtually all the Laboratory's activities and present a most serious challenge. My hopes for Los Alamos cannot be realized unless increased funding is available. The requested increases are modest but essential and represent a valuable investment for the nation.

The Laboratory is being asked to make sure that its work in major programs connects directly to program objectives that will yield usable technological applications. This emphasis must not be overdone, and in some cases that line has already been passed. When investigations have reached the stage at which such requests are appropriate, the emphasis may help us do what we want to do—to show that our work can solve national problems and lead to benefits for the nation and the world.

But we must constantly guard against demands for immediate, practical benefits from science. When basic questions are still being explored, when answers are only beginning to appear, and when technological applications are only dimly perceived, then questions of practical benefit must be deferred. If we at the Laboratory do our job well, we will open new areas of science that eventually will yield benefits. The nation must allow competent scientists to explore those areas and to confront the difficulties that may take years to overcome, satisfied that this investment is worthwhile. Budgetary restraints must not be allowed to force out all but research that is immediately applicable, for that course would amount to eating the seed corn of future harvests.

Let me conclude with a final challenge—the desire of some that science should overcome the tangled web of politics and assure that all its results are used only in positive ways. Such a desire is natural, but it is too much to expect of any single sector of society.

At the end of World War II, those at Los Alamos learned with the rest of the world that technical developments were beyond the control of the small group of scientists who pleaded that the results of their work be used solely for peaceful purposes. That control rests with the broader institutions of society. Today we continue to pursue the unanswered questions of science in the belief that our efforts will enhance the peace and prosperity of the world. The ultimate hope of those of us-at Los Alamos is that the voices for peace will prevail in all decisions that affect the use of our endeavors. ■