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Informal Report

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LASL's FY 1978 Supporting Research Program

University of California

LOS ALAMOS SCIENTIFIC LABORATORY

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LASL'S FY 1978 SUPPORTING RESEARCH PROGRAM

by

E. F. Hammel, S. J. Merlan, and D. A. Freiwald

ABSTRACT

This report gives a brief overview of Los Alamos Scientific Laboratory's supporting research program, including philosophy, management and program analysis, funding, and a brief description of the kinds of work currently supported.

I. INTRODUCTION

The design of nuclear weapons requires the best available staff and data base in many areas of physical science and technology. The weapons supporting research program at the Los Alamos Scientific Laboratory (LASL) has been organized to maintain and improve those basic science capabilities that are necessary to support the many individual weapons development programs. It is a program of disciplinary research on both directed and nondirected problems.

The importance of more intensive research into basic weapons phenomena has been emphasized by recent events in strategic and tactical nuclear weapons planning and by greater restrictions on the testing of nuclear devices. For example, new weapon designs must now meet such strict criteria of size, weight, output, and survivability in such a variety of hostile environments, that the weapon designer is forced to design very close to the maximum theoretical limits of a weapon. Under these circumstances, an improved understanding of the basic physics of weapons systems is essential. Because nuclear tests are restricted by the provisions of the Threshold Test Ban Treaty to a yield limit of 150 kt, and because a complete test ban is a possibility, the importance of acquiring this information in the immediate future is further enhanced.

These constraints put a premium on the weapon designer's capability to understand the basic processes that occur in a nuclear burst, to understand the trade-offs among various aspects of weapons design, and to produce a new weapon type with a minimum number of nuclear tests. The behavior of many types of materials in the nuclear environment must be better understood to give confidence in the performance of new designs entering the weapons stockpile.

Research is a long-term effort, with results that often cannot be neatly divided fiscal year by fiscal year. Continuity of effort is important in recruiting staff in the basic sciences and in maintaining connections between LASL and the national and international research communities. This continuity and these connections insure that new developments in the physical sciences are almost immediately recognized and available at LASL and that their implications for the weapons program are evaluated.

Contributions from LASL's supporting research to nonweapons programs are also valuable to the Laboratory and the nation. Many of the current programs at LASL, such as the laser effort, the hot dry rock geothermal energy project, and the major efforts in accelerator technology, grew from work originally sponsored by LASL's supporting research program. Eventually, these projects developed sufficiently to take on a distinct purpose of their own and to secure separate funding.

As shown in Fig. 1, supporting research constitutes about 17% of LASL's military application dollar allocation [19% of the full-time-equivalents (FTEs)], and constitutes about 7% of the Laboratory's total operating funds. Supporting research funds have been extremely important to LASL—scientific knowledge acquired from supporting research programs has, in part, led to LASL's recognition as one of the world's centers of scientific excellence.

II. ORGANIZATION AND ADMINISTRATION

Supporting research work is organized according to the 13 subject areas shown on the left side of Fig. 2; supporting research funds are currently allocated to 12 of LASL's 19 technical divisions, as shown across the top of Fig. 2. The matrix elements of Fig. 2 show how the FTEs maintained by supporting research funds are distributed by technical division and subject area.

General policy regarding supporting research is handled by LASL's Associate Director for Research (ADR), with consultation with the Director and the Associate Director for Weapons (ADW). About two

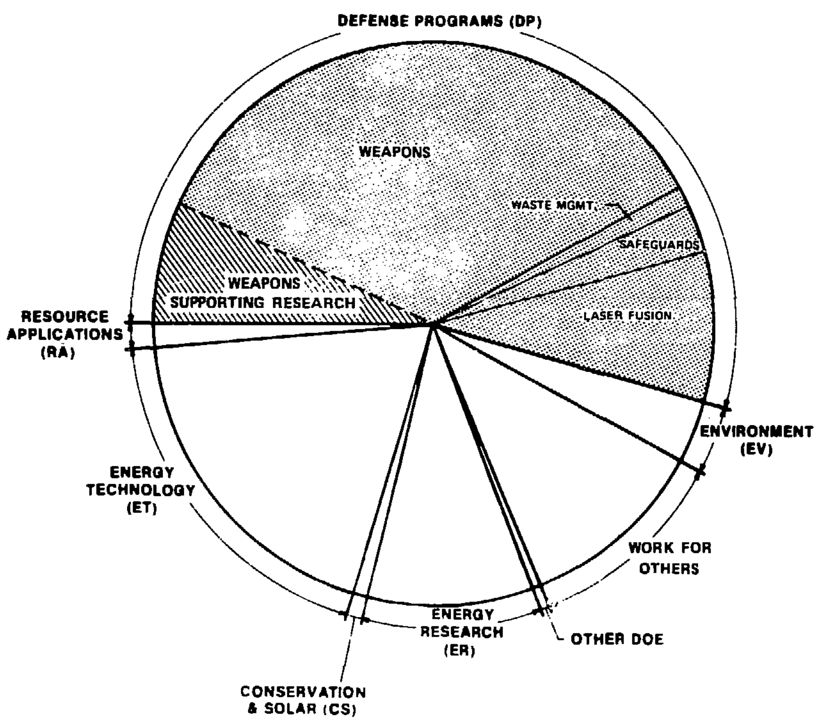

Fig. 1.
LASL FY 78 operating costs (total $275 million), April 1978.

DIVISIONS / SUBJECT AREAS	HEALTH (H)	THEORETICAL DESIGN (TD)	DESIGN ENGINEERING (WX)	DYNAMIC TESTING (M)	FIELD TESTING (J)	CHEMISTRY MATERIALS SCIENCE (CMB)	GEOSCIENCES (G)	THEORETICAL (T)	PHYSICS (P)	CHEMISTRY-NUCLEAR CHEMISTRY (CNC)	ENERGY (Q)	ELECTRONICS (E)	TOTAL FTE'S
NUCLEAR PHYSICS			2.0			1.1		11.7	29.1	1.1	4.4		49.4
EQUATION OF STATE AND OPACITY			1.4	11.3	0.6	0.2		5.4	6.9		4.2		31.3
FLUID DYNAMICS AND TRANSPORT THEORY		1.5						8.5					10.0
DETONATION RESEARCH			5.7	5.0		0.1		1.6					12.3
GENERAL PHYSICS AND MATHEMATICS	1.1	2.1		0.2	5.9			26.1	0.1			0.2	35.7
ELECTRONICS RESEARCH	0.6					0.4						5.6	6.5
COMPUTATIONAL SUPPORT		2.0		2.4				3.6					8.6
ACCELERATOR SUPPORT AND GENERAL SERVICES			0.2			0.4		2.9	27.5		3.1		34.2
GEOSCIENCES				1.4	0.6	0.1	8.6			0.7			11.4
PLUTONIUM & ACTINIDE RESEARCH	1.9				0.2	21.3							23.5
GENERAL CHEMISTRY			3.5			5.5		1.3		22.5			32.7
MATERIAL SCIENCES				3.5		19.0		2.1	3.4		4.2		32.3
MISCELLANEOUS							1.0	1.8			0.1	0.4	3.4
TOTAL FTE'S	3.6	5.6	12.8	23.8	7.2	48.1	9.6	65.0	66.9	24.3	16.1	6.1	289.8

Fig. 2.
FY 78 supporting research FTE matrix, June 1978.

years in advance of a given fiscal year, ADW issues a memo to Division Leaders, soliciting their requests for weapons program funds (including supporting research) as well as for information regarding each Division's proposed allocation by subject area. A weapons budget matrix is formed, which is reviewed by LASL's Weapons Program Review Committee-Budget Committee. This committee makes recommendations to ADW on weapons budget allocations by program and division, including a total target number for supporting research.

After final ADW approval of the proposed budget totals (which includes a preliminary supporting research allocation—pending DOE Headquarter's approval), ADR allocates funding to Laboratory Divisions by an iterative process with the Division Leaders that leads to a final funding allocation matrix similar to that shown in Fig. 2. These allocations are designed to be compatible with the annual research needs of the Laboratory. Division Leaders are free to make minor redistributions among subject areas during a fiscal year, but major changes must be approved by ADR, who shares management of the supporting research budget with LASL's Financial Management Office.

III. BRIEF PROGRAM SUMMARIES

The 12 supporting research subject areas are described briefly in this section. In most cases, there are several subprograms within a subject area.

It should be remembered that most of the supporting research funds are used for salaries; that research continuity, especially for the nondirected research, often spans long periods of time, even decades; and that the capability to perform a specific item of directed research may exist only because it was preceded by a long period of nondirected research.

The descriptions were taken largely from the set of Revisable Program Descriptions prepared annually to aid in evaluating and assigning priorities to the various activities (see the inset for further detail on these program descriptions).

A. Nuclear Physics

A strong base in nuclear physics (the original science upon which nuclear weaponry is based) enhances LASL's ability to design and test developmental weapons and to understand the nuclear phenomena that occur in fission and fusion weapons systems. Many processes, such as fission, neutron production and transport, and gamma-ray interactions, are investigated at LASL; the resulting data are used directly in design calculations and in field-test diagnostic methods. Some reactions, such as double neutron capture, proceed at high rates in weapons systems but cannot be observed in the laboratory because of the much lower particle fluxes available. A combination of experimental observations and theoretical analyses offers reliable predictions from simulations of such processes performed at accelerators. Studies of the fission process improve our understanding of the behavior of currently used fissile and fertile materials and permit predictions of the behavior of materials in other regions of the mass table. This program involves professional expertise in both experiment and theory in areas such as (n,xn) reactions related to diagnostics, which normally are not studied in nonweapon laboratories.

B. Equation of State and Opacity

Equation-of-state and opacity data (Fig. 3) are necessary in studies of weapons behavior.

Five basic areas, which are addressed theoretically and experimentally in this program, are

(1) Equation of state: equilibrium relations among thermodynamic variables such as pressure, internal energy, density, and temperature.

Supporting Research Program Analysis

Important instruments for evaluating and coordinating the diverse supporting research projects are the Revisable Program Descriptions. These are written for each of the 12 supporting research categories and the preparation of each description is the responsibility of a lead author who gathers information across divisional lines. The compilation is sent to the Office of Military Application yearly, and abbreviated versions are incorporated in the Laboratory's budget document.

The following format was chosen for the Revisable Program Descriptions to aid in the analysis of the various elements of the supporting research program:

1. *Definition and Background:* Introduction, a brief definition of the subject area, and a mention of capabilities unique to LASL.
2. *Goals:* Objectives for the next fiscal year, a general statement of desired results in the particular line of research, fiscal year endpoints, and ultimate endpoints.
3. *Implementation:* Methods of approach, including intermediate goals, facilities, technologies, and expertise available or required in the future to reach these goals.
4. *Utility:* Expected applications for the weapon program; not necessarily near-term, but with identifiable pertinence to the weapons effort.
5. *Significant Events:* A short summary of LASL "firsts" and "breakthroughs" and a list of unique LASL contributions.
6. *Futurity:* Potential spinoffs of dual applications in a nonweapons area.
7. *Financial Contingency:* Effects on the program of 10-15% funding modifications.

Fig. 3.
This 27-m (88-ft)-long accelerated-reservoir light-gas gun is used in equation-of-state experiments by LASL's shock-wave physics researchers.

(2) Material response to stress: elastic-plastic behavior and time-dependent phase transitions.
(3) Radiation transport.
(4) Basic cross sections and rate coefficients for application to general processes taking place in very short time intervals or in very dilute media.
(5) Compressibility and optical measurements at ultrahigh pressures on H_2 and D_2.

Although a number of laboratories conduct various aspects of equation-of-state and opacity research, LASL has a unique opportunity through analyses of tests at the Nevada Test Site (NTS) to obtain experimental data on material behavior under the most extreme temperatures and pressures.

Since the earliest days of nuclear weapon design, equation-of-state data for all component materials have been necessary for the hydrodynamic calculation of device performance. Weapons-effects studies also depend on a reliable opacity data base. As weapons have become smaller and more sophisticated, the need for accurate equation-of-state and opacity data has increased. Elastic-plastic effects are also becoming important. The general goals of this program are therefore to improve the existing equation-of-state and opacity data base, as well as the computer codes using this information, by continued experimentation and improvement of theoretical methods and models.

C. Fluid Dynamics and Transport Theory

LASL's fluid dynamics research consists of the development of numerical methodologies, investigations of fundamental fluid dynamic processes, and the development of computer codes to solve specific problems. A previously developed numerical methodology is the basis for the hydrodynamic treatment by several weapon design codes in use at LASL and the Lawrence Livermore Laboratory. Fundamental investigations into areas such as flow instabilities and turbulence have led the way for quantitative assessment of these processes in weapon-related projects such as the Anomalous Hydrodynamics program. The present research program continues LASL's decades-long pioneering effort in this area, during which we have developed some of the world's most widely used numerical fluid dynamics methods. These have been widely applied—from nuclear reactor safety problems to centrifuge design.

The transport work consists of development of new methods for modeling radiation and particle transport. It involves the development of general analytical and numerical techniques and computer codes, as well as the applicability of these to the analyses of specific weapon outputs. Neutral-particle transport research continues work begun at Los Alamos by Feynman and Serber in 1943 to develop methods for predicting the spatial and angular distributions of neutrons. This research is closely allied with the development of general numerical methods and computing machinery.

D. Detonation Research

Nuclear weapons require high explosives to initiate the explosive release of the nuclear energy.

One of the largest uncertainties in nuclear weapons design is the behavior of the chemical explosive. Weapons designers have been forced to adjust their numerical explosive descriptions by arbitrary amounts for calculating the amount of energy delivered to the pit. Moreover, with the introduction of shock-insensitive explosives (such as TATB and nitroguanidine) into weapons, detonation failure and partial decomposition of the explosive became significant features of explosive behavior. Although our understanding of the detonation process has rapidly increased, more study is needed in several areas such as, for example, the effect of rarefactions on a detonation.

E. General Physics and Mathematics

Research in this area is concerned primarily with theoretical problems in physics, biology, astrophysics, and mathematics, and presents opportunities to work in pioneering areas of science.

Some of the projects are pursued because of their relevance to the weapons program. For example, astrophysical research shares with weapons physics common theoretical tools and comparable phenomena. Consequently, there is a constant exchange of ideas and methods among the astrophysics, weapons, and fusion efforts at LASL. Projects on improved numerical modeling of shock stability and structure are directly related to weapons development. However, the approach to these problems can be more novel than is possible within the normal programmatic weapons activities. It is typical for new approaches in weapons research to emerge from basic research efforts and to be explored and evaluated first under LASL's basic research funding.

Most of the work in this area, however, is not closely allied with weapons physics, but receives support because it is high-quality research on problems of fundamental interest at the frontiers of science. This program maintains Laboratory contact with leaders of academic science and helps LASL to recruit the best scientists and engineers available. Research through informal consulting is also useful for evaluating possible new directions in weapon research. Moreover, because the research typically addresses questions of a general rather than specific nature, new mathematical methods and calculational techniques are often transferable to other fields. For example, techniques for solving nonlinear equations are of fundamental importance to all areas of physics. A recent development of our particle physics research is a new calculational scheme based on a path integral formulation of dynamics in which collective excitations play a fundamental role. This calculational method is also applicable to problems in plasma turbulence that are of general interest to the fusion program. In another example, the techniques of molecular dynamics developed at LASL and supported by this program are now being used to model radiation damage and the propagation and structure of strong shocks under conditions relevant to weapons. The latter study has produced a rather startling result, namely, that there may be no stable, time-invariant structure behind a strong shock front. This unexpected result must be investigated by both numerical and analytical techniques. Particle physicists familiar with soliton theory and its application to nuclear matter are being asked to examine the relevance of soliton theory to these results on strong shocks.

Additional projects include pioneering work in theoretical immunology and radiation damage to cells, atomic-structure calculations for equations of state and opacities needed in weapon output calculations, work in atmospheric physics, and substantial effort in particle physics, field theory, and other areas of statistical and mathematical physics relevant to ongoing programmatic activities at LASL.

F. Electronics

This activity supports weapons and other programmatic needs for research and development of sensors and instrumentation for the detection of radiations ranging from infrared to gamma rays, neutrons, and charged particles. The emphasis is on higher sensitivity and speed in measurements and toward a sensor and instrumentation capability for operation in hostile environments, such as high-temperature and high-radiation fluxes. Research and development is under way in the following specific areas.

- Fiber optics for high-speed communications.

- Josephson devices for picosecond logic.
- Integrated thermionic circuits for high-radiation and temperature environments.
- Radiation sensors for neutrons, charged particles, infrared, x rays, and gamma rays.
- Charge-transport and energy-exchange mechanisms in semiconductors and liquid rare gases.
- Elemental microscopic imaging using an ion microprobe.
- Biochemical effects of radiation using a new laser cell-sorting device.

Today's experimental science is dependent on the rapidly changing field of electronics, much of which is developed in industry. It is possible to keep a staff sufficiently knowledgeable of relevant innovations only if it is also engaged in electronic research.

G. Computational Support

One of LASL's major contributions to applied mathematics was the development of Monte Carlo methods. This continues to be pursued for improving solutions of radiation-transport problems. Monte Carlo transport programs are used in output calculations of nuclear weapons during Phase 3 efforts, as well as in Phase 1 and Phase 2 work, to calculate the vulnerability of reentry vehicles to radiation and neutron fluxes and to calculate intrinsic radiation from warheads.

Digital image and signal-processing research is another area of computational support. LASL's image-enhancement computer programs are used to give images from experimental devices more contrast so that physical measurements are easier to make. These images are produced at NTS, at local firing sites, and in local nondestructive testing activities.

The last general area of computational support is numerical and applied mathematics and statistics. Work carried out under this program in statistics includes a continuing research into the probability of success of a detonation and a targeting analysis done in conjunction with the Joint Strategic Targeting Staff as part of a Phase 2 effort. Work carried out in mathematics includes the application of a new iterative numerical technique to weapons programs.

H. Accelerator Development and General Services

This activity covers a number of general support areas, particularly operational and developmental support of the tandem Van de Graaff facility, the Omega West reactor, the Weapons Neutron Research (WNR) facility, and several prompt, critical-burst assemblies. Support is also provided for development of new accelerator concepts; design of new pulsed x-ray and neutron sources; beam-weapon studies; and nuclear safety. These facilities provide neutron, x-ray, and charged-particle irradiations for many applied programs and specific data measurements, as well as for general supporting research activities.

The LASL tandem accelerator facility (Fig. 4) consists of two electrostatic accelerators that can be used independently or that can be coupled to produce beams of higher energies (up to 25 MeV for singly charged ions). Besides this basic versatility, specialized capabilities include tritium-ion sources on each machine, polarized beams of hydrogen isotopes (including tritium), heavy-ion beams, pulsed-beam capability for pulsed-neutron production, bunching capability for subnanosecond bursts, and a new high-resolution, large-solid-angle spectrometer. An exceptional and well-developed neutron-source capability giving monochromatic neutron sources to 28 MeV (as required in thermonuclear system design and diagnostics) has recently become available.

Omega West 8-MW Research Reactor (Fig. 5) provides extensive irradiation facilities for a wide variety of samples. With one of the lowest background neutron-capture gamma-ray capabilities in the world, this facility is very useful in determining impurity levels in low-Z materials and in providing thermal-neutron-capture spectra for rare or low-cross-section samples. This gamma-ray capability is now being adapted to allow intrinsic weapon radiation measurements. The reactor supports a modest nuclear research program, but its main function is to provide neutron-irradiation services for various LASL programs, such as neutron radiography of weapons components. Uranium-235 burn-up measurements are made routinely with samples obtained on drill-back following underground weapon tests.

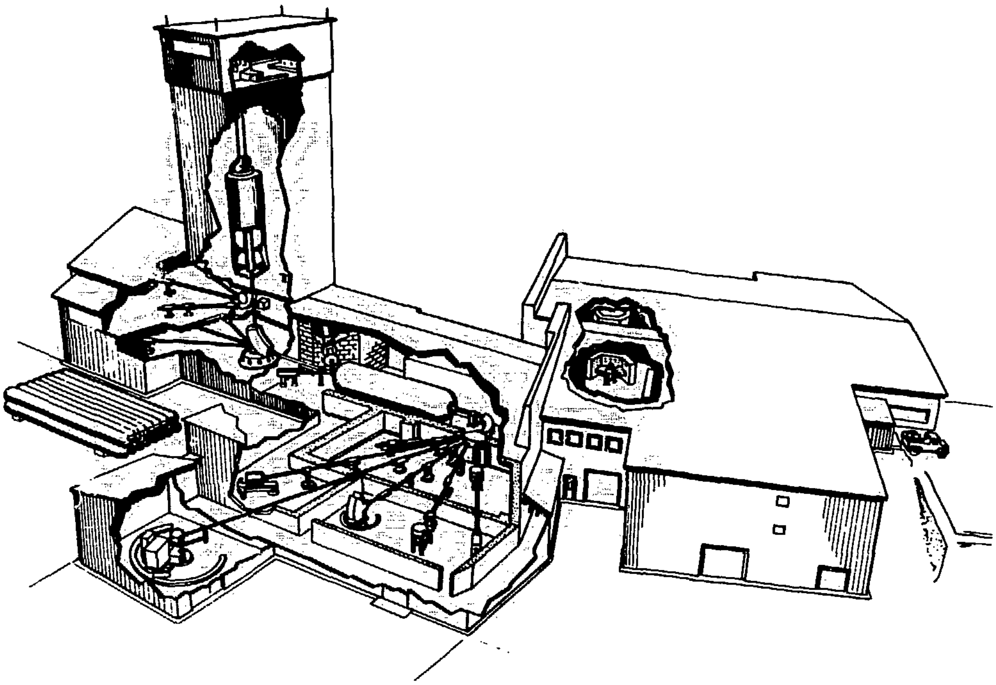

Fig. 4.
LASL three-stage Van de Graaff facility.

The Nuclear Criticality facility at Pajarito Site consists of a number of remotely controlled critical assemblies (Godiva, Jezebel, Big Ten, and Flattop) that provide a variety of neutron spectra. Godiva IV, a pulsed ^{235}U machine, provides relatively short neutron bursts with up to 10^{17} neutrons per burst. A new burst facility, SKUA, now under construction, will provide a more intense neutron pulse over a greatly increased internal irradiation volume.

These facilities are used as benchmark facilities for code and cross-section checking and as irradiation sources for a number of Laboratory programs, particularly for radiochemical detectors in the weapons diagnostic programs.

The Weapons Neutron Research Facility (Fig. 6), a pulsed-spallation neutron source that became operational in 1977, is now yielding a time-averaged neutron production rate of about 1.5 x 10^{16} n/s. With a suitably moderated target, it is possible to achieve neutron intensities in the 100-eV to 20-MeV energy range sufficient for providing weapon-related neutron cross-section and transport data complementary to that obtainable from existing neutron sources.

This facility also provides neutron fluxes more intense than are available from steady-state research reactors in the energy regime important to materials science problems, i.e., in the epithermal to 100-eV range. This resource is now being exploited to investigate the high-pressure phases of plutonium by neutron scattering techniques. Other materials science studies are also in progress.

Finally, a continuing effort to advance accelerator technology is under way at LASL. The objectives of this work are to improve existing LASL facilities, to develop new proposals for upgrading our capabilities in support of weapons programs, and to examine novel accelerator concepts for both laboratory and defense interests.

I. Geosciences

Research in seismology and solid-earth geophysics plays an important role in the weapons program because of problems and applications related to containment, yield estimation, and test-ban verification. The prediction and measurement of geophysical phenomena near underground explosions (Fig. 7), cratering phenomena, geophysical processes pertinent to earth-penetrating weapons, and understanding the differences in seismic signals between explosions and natural earthquakes are all essential elements of LASL's geosciences supporting research program. Some of the specific activities under way in this area are

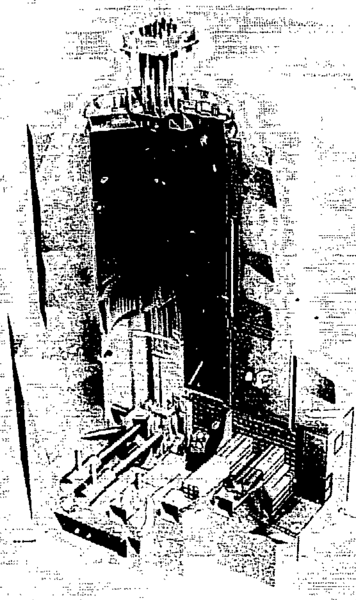

Fig. 5.
Omega West reactor.

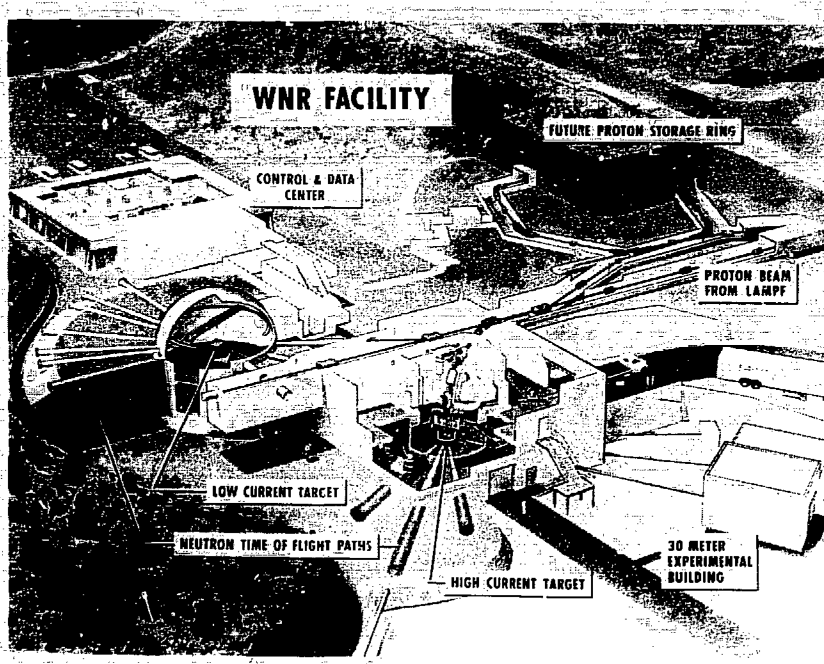

Fig. 6.
Artist's concept of WNR facility.

Fig. 7.
This seismic station is located approximately 61 m (200 ft) into an unused tunnel at NTS. The station is one of several in use at NTS and is designed to monitor natural seismic activity as well as the aftershocks produced by an underground nuclear test.

- Crystallographic studies on several mineralogical and other compounds important in predicting weapons effects on target materials.
- Development and field use of portable, low-power microprocessor data-acquisition systems for seismic applications at NTS.
- Modeling of fracture phenomena in boreholes, including amorphous solids, important in assessing blast effects on rocks and for cratering phenomena.
- Proof-testing modern techniques of seismic reflection surveys to delineate buried Paleozoic structures at NTS.
- Radionuclide migration studies at NTS to provide information on the spread of fission products from the site of an underground nuclear test.

J. Plutonium and Actinide Research

The weapons program has a continuing need for information on plutonium components of weapons.

- When engineering designers deal with new problems, such as designing a weapon strong enough to withstand the stresses encountered in an artillery shell, engineering-strength data for new alloys are needed.
- The hydrodynamic weapon design codes are continually being refined and require more sophisticated constitutive relations describing the behavior of materials under stress.
- Equations of state are also continually refined and, although the conditions achievable in a metallurgical laboratory are not comparable to those in a weapon, the laboratory data can supply a baseline to which the equation-of-state data under more extreme conditions can be related.

In addition to these immediate applications, exploratory studies are being pursued to examine and evaluate new ideas that can lead to improvements and enhance the understanding of metallic actinides.

K. General Chemistry

Research in general chemistry is being pursued in the following areas:

- theoretical molecular structure and chemical dynamics
- experimental chemical dynamics and spectroscopy
- gas-phase reaction kinetics
- vibrational spectroscopy (with applications to chemical bonding)
- synthetic and structural inorganic chemistry
- physical and nuclear chemistry with mesons and fast neutrons
- electrowinning of plutonium from its oxide
- thermodynamic properties of plutonium compounds
- recovery of americium
- quantum chemistry
- chemical stability and compatibility of nuclear weapon components
- weapon-oriented materials research

Of these several projects, the largest are those on synthetic and structural inorganic chemistry and on experimental chemical dynamics and spectroscopy. Brief descriptions of these two programs follow.

1. Synthetic and Structural Inorganic Chemistry. Synthetic inorganic and structural chemistry helps to determine physicochemical characteristics and architecture of molecules, quantify the forces binding them, and develop predictive models. New compounds of uranium are investigated using the powerful combination of modern synthesis and structural characterization, by means of single-crystal x-ray, nmr, infrared, and Raman spectroscopy.

The availability at LASL of separated light isotopes is coupled with synthesis and spectroscopy to provide data critical to development of new pumped lasers and molecular diagnostics.

LASL's experience in transplutonium elements is being applied to the area of curium chemistry and isotopes of possible weapon interest.

2. Experimental Chemical Dynamics and Spectroscopy. Detailed chemical dynamics and information concerning collisions involving reactive, unstable, or excited species are not accessible directly in bulk studies. By contrast, molecular-beam techniques are uniquely suited for investigating reactions between molecules having defined translational or vibrational energies and the interactions of such molecules with radiation. Under study are the dynamics of molecular collisions, the photodissociation of molecules and the reactivity of excited molecules, the preparation of isotopically labeled, excited states of certain molecules, and the properties of weakly bound molecules. Photochemical reactions from vibrationally excited levels of the electronic ground state can be studied using optoacoustic and time-resolved spectroscopy and data are being applied to UF_6 photochemistry and reactivity studies.

L. Materials Science

Research is directed toward development of techniques needed for ongoing, weapons development programs. The topics under study include

- surface studies
- materials characterization studies
- chemical characterization support
- inorganic materials synthesis
- nondestructive testing
- low-temperature physics research
- theoretical materials research.

The overall objective is to provide a reservoir of varied materials science, expertise, and a variety of support functions for the weapons program. New theoretical models and calculational techniques are investigated also to guide and support experimental efforts in materials science.

IV. ANALYSIS AND SUMMARY

These brief program summaries show the breadth of knowledge needed for a weapons effort and how this knowledge is connected to many areas of scientific inquiry.

Further analysis of LASL's supporting research program is given in Fig. 8, which summarizes the 12 supporting research subject areas in terms of the kinds of support each provides for the weapons program. As indicated, most of the effort may be categorized as disciplinary research.

Figure 9 provides information on the relevance of weapons supporting research in terms of direct support of weapons design, indirect support, and general support. The overall 75%-16%-9% split appears to be a reasonable and appropriate distribution.

With the diversity in subprograms and the wide organizational distribution of personnel in supporting research, small staff changes within the program can substantially affect individual projects. However, this can be advantageous in that programmatic emphases can be easily changed by shifting relatively few people to different subject areas. Such changes are routinely made, for instance, by assigning a few of the staff to special problem areas for a year or two. Thus, our supporting research program can and has proved to be a dynamic and responsive component of the Laboratory.

The evolution of our supporting research program since FY 1972 is summarized in Fig. 10. The percentage of LASL's weapon allocation that has gone into supporting research has been decreasing continuously, and has provoked serious concern for the long-term health and scientific vitality of this Laboratory.

TITLE	WEAPONS DATA	DISCIPLINARY RESEARCH	SUPPORT SERVICES	SPECIAL PROJECTS
NUCLEAR PHYSICS	+	0		
EQUATION-OF-STATE	+	0		
FLUID DYN. & TRNS THEORY	0	+		0
DETONATION RESEARCH	+	0	0	
GEN. PHYS. & MATH.		+		0
ELECTRONICS RES.		0	+	
COMPUTATIONAL SUP.		0		
ACCEL. SUP. & GEN. SRVS.		0	+	
GEOSCIENCES		+		0
Pu & ACTINIDE RES.	+	0		
GEN. CHEMISTRY		+	0	
MATL SCIENCES		+	0	

+ = PRIMARY 0 = SECONDARY

Fig. 8.
LASL supporting research functions.

TITLE	% OF TOTAL SR OPERATING FUNDS	% IN DIRECT WEAPONS SUPPORT	% IN INDIRECT WEAPONS SUPPORT	% GENERAL
NUCLEAR PHYSICS	15.3	90	10	0
EQUATION OF STATE AND OPACITY	10.5	95	5	0
FLUID DYNAMICS & PARTICLE THEORY	4.0	80	15	5
DETONATION RESEARCH	4.2	95	5	0
GENERAL PHYSICS AND MATHEMATICS	11.5	30	40	30
ELECTRONICS RESEARCH	3.5	60	30	10
COMPUTATIONAL SUPPORT	4.9	80	15	5
ACCELERATOR SUPPORT AND GENERAL SERVICES	12.9	80	15	5
GEOSCIENCES	3.3	10	50	40
PLUTONIUM & ACTINIDE RESEARCH	6.2	85	10	5
GENERAL CHEMISTRY	12.0	80	10	10
MATERIAL SCIENCES	10.9	85	10	5
OVERALL DISTRIBUTION	100%	75%	16%	9%

Fig. 9.
Distribution of supporting research funds.

In summary, LASL's weapons supporting research provides

- Data bases, which include both the ground work for data-base definition and the fundamental data
- A cadre of experts who interface with other experts in scientific circles. These experts are capable of recognizing the implications for weapons in the results of work of others, are often aware of such results before publication of the information, and do research in new areas.
- Equipment that maintains and advances the state of the art of basic research tools, such as accelerators, instruments, etc.

The payoff for the Office of Military Application has been

- better weapons designs,
- contributions to other needs in the broad areas of national security (e.g., energy), with a feedback to weapons, and
- additional spinoffs for the weapons program and other items of national interest.

Some major supporting research spinoffs are

- Sherwood - Controlled Thermonuclear Fusion
- LAMPF - Medium Energy Physics Facility
- Rover - Nuclear Rocket Research
- Laser R&D and Laser Fusion
- Laser Isotope Separation
- Test Detection
- Cryo-Engineering
- Nuclear Safeguards
- Geothermal Energy.

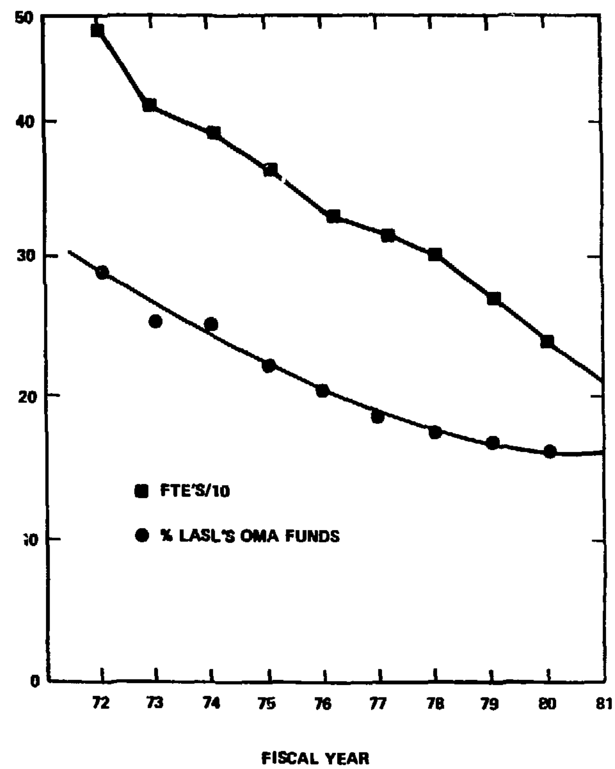

Fig. 10.
Supporting research.