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(11)

Planning

PART IV

APPENDICES

US DOE ARCHIVES
326 US ATOMIC ENERGY COMMISSION
RG
Collection Division of Biology & Medicine
Box 3375
Folder 1

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Appendix A

ATOMICS INTERNATIONAL

The work of the Atomics International Division of North American Aviation, Inc. is discussed separatsly since it is conducted both in commercial and in government facilities. The fact that the AEC has a substantial investment in the facilities and is overwhelmingly the principal customer of Atomics International requires that AI be considered in this study, while the commercial character of the organization and of a large portion of the facilities clearly distinguishes AI from the AEC laboratories.

The AEC's contract relationship with North American Aviation began in 1948, when limited reactor development and physical research work was assigned to that Company. The relationship has been continuous since that time; the program is now carried out through North American's Atomics International Division.

Atomics International occupies company-owned buildings in Canoga Park, California (Los Angeles), company-owned and government-owned buildings in the nearby Santa Susana Mountains and government-owned facilities at the National Reactor Testing Station, Idaho. The company has financed general service equipment in the buildings it owns, while AEC has generally supplied specialized equipment necessary to specific development projects. Total investment is approximately $20 million by the AEC and approximately $20 million by Atomics International. The latter figure includes approximately $3.6 million which was contributed by Atomics International to the cost of the Sodium Reactor Experiment (SRE) and the Organic Moderated Reactor Experiment (OMRE).

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The AI program can be broadly described under six major headings:

1. Sodium Graphite Reactors. This reactor concept was among the the first studied by North American under its contract. As part of the AEC's first five-year civilian power reactor program, North American developed and constructed the SRE. Operation of the SRE to obtain technical data on this concept has continued and has led to the development of the Hallam Nuclear Power Facility, a 75 megawatt-electrical, sodium graphite reactor being built at Hallam, Nebraska under the Power Demonstration Program. Construction of this facility has begun and is scheduled for completion in 1961. In addition to these specific reactors, North American carries on an advanced development program on the sodium-graphite concept, including materials and components development and safety studies.

2. Organic Cooled Reactors. North American has under way an intensive program in the development of the organic cooled reactor concept. North American was given a major project in this concept in 1955 with the assignment of responsibility for the development, design and construction of the OMRE. This work led to the power reactor demonstration project of the City of Piqua, Ohio, contracts for which were signed in 1959. To advance this concept, North American has also under way general development work in the organic reactor field and has made studies for the AEC of various applications of this reactor concept.

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COMMENTS BY SPIKES

I-2-11: It seems to me that we should stress the fact that we cannot in good conscience carry out any sort of program involving radioactive materials without an understanding of the biological-medical factors and hazards involved. This implies a program much broader than health physics. DBM was not originally and primarily set up to exploit the peacetime applications of atomic energy, but rather to protect the health of our workers and citizens -- to this end the order of the items should be changed, and the more programmatic items emphasized. After all, it is impossible to develop a nuclear technology completely segregated from living material.

In general, I agree that this list does not represent the ranking of our actual support program. However, it is consistent with the way the other program objectives are slanted. A.

I-3-22: The first part looks OK - Leroy should check it. The case for the National Labs is weak here.

In the parts about chronic irradiation on I-3-23 should we not stress the long-term stability of the National Labs as compared to the more shifting interests of the universities. This is not always true but we should make a stronger case for the National Labs here if possible.

I strongly agree. This was the pitch we initially turned in. A.

I-3-24 - Genetics - Doug or Max should work this over.

I-3-26 - Radiation Protection - Mainly medical - although Leroy should carefully look over the stuff on I-3-28.

Looks fine to me. A.

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I-3-30 - Plant Sciences - Doug should look at the genetics statement. I would like to see the statement on basic plant sciences improved and the case stated more strongly.

I-4-18 - Roles in Biomedical Research - This write up is reasonable.

OK. A.

II-5-4 - Argonne - Life Sciences - Statement is brief but probably OK.

II-5-7 - Argonne - " " - future plans in Biology & Medicine - Doug should look this over.

II-5-10 - BNL - general statement - Very brief. ? A.

II-5-13 - Biology program - future plans - Not too bad. Leroy should look it over.

OK. A.

II-5-19 - ORNL - Biol. Sci. statement - Very brief.

Too brief. A.

II-5-22 - ORNL - Biomed. future plans - Reasonable. Max should look at this. No real mention that they do quite a bit of work with plant materials.

II-5-23a - ORINS - Not much biology

II-5-28 - Lawrence RL, Berkeley - Biology - Very brief.

II-5-31 - Lawrence RL, Berkeley - Biol. & Med. future plans - Sounds reasonable.

OK. A.

II-5-40 - LASL Biomed. Statement - Seems OK

OK. A.

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II-5-42 - LASL Biomed. future plans - I have never been there - sounds OK - Jim or Leroy should examine.

Quite accurate and specific. A.

II-7-1 - Hanford Biology - Max examine.

II-7-3- Hanford future plans - probably OK, except should add I-131 work and emphasize. Max examine.

I think that Sherman and Quastler and Lamerton (England) will probably solve the NA metabolism in irradiated gut. Might they not better concentrate their limited resources on other problems where there is less coverage? A.

II-8-7 - U. Rochester - I presume Med. Branch will work this over.

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Oak Ridge: p. 5 - very brief statement re life science.

In what activities is health physics to significantly expand? A.

p. 15 - 18 - expanded statement - Leroy see p. 17

p. 16 - Is their botany expansion in line with the committee report? A.

p. 17 - Looks non-specific but OK to me. A.

p. 18 - Do we want to keep on increasing support of all their biochem? I would like to indicate that intermediary metabolism will be deemphasized. A.

p. 18 - I am a bit concerned about giving blanket approval for "increasing emphasis on further development of dosimetry devices" unless we add something to restrict it to areas where we are bad off and not to getting a 4th significant figure. A.

Lawrence Radiation Lab, Berkeley: p. 2 - Very brief statement, probably OK

p. 6 - Expanded statement - does not seem to mention Calvin's work.

I agree this statement doesn't do justice to Donner even if they did write it. A.

LASL: p. 2 - biology is almost mentioned.

It is? A.

Part IV

Summaries of long range programs

Argonne: p. 1 - Doug read - the general statement here emphasizes two things we may not agree to -- (a) production of labelled compounds in plant chambers, and (b) major expansion in the plant sciences.

I vote NO on both expansions and feel the write-up should be modified appropriately. A.

p. 4 - Are these estimates of increase in staff OK? Wow! A.

p. 6 - Mentions biology reactors.

p. 7 - Do we want megamouse, increases in B&M and plant sciences listed on page 7? A.

p. 13 - More detailed outline of proposed expansion. Doug should look at this critically. Most of it looks OK except item (2), p. 15, Plant sciences is a little off since the Plant Science Institute idea appears to be moribund. Right! A.

C.4. needs to be reworded. I am against the statement (Newly .. . . . . this program.) and proposed expansion if this for more exotic dosimetry. A.

Brookhaven: p. 1 - Leroy read - general statement - no details

p. 3.- staff increases

p. 4 - buildings & facilities proposed - especially pathogen-free animal labs, etc.

p. 12 - mentions increase but no details are given.

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3. Military Reactors. A growing portion of the work relates to the aircraft nuclear propulsion program. It encompasses development of compact reactors for military purposes under the SNAP program and development of materials for the Pluto nuclear ram-jet program.

4. General Reactor Technology. In this field AI is engaged in developing advanced methods for nuclear measurements; reactor statics theory; development of advanced fuel, control, and structural materials for reactors; and development of reactor safety devices and reactor components.

5. Separations Systems. Investigations of improved processes for the separation and decontamination of spent reactor fuels is an important adjunct to the programs of reactor development. Emphasis at AI is placed on low decontamination pyrometallurgical processes, with particular application to thermal reactor systems.

6. Physical Research. In this field, North American carries out fundamental studies in materials, chemistry and physics.

The Atomics International staff numbers approximately 2,200, of whom approximately 1,300 are professional technical personnel.

The facilities include general engineering and office space, a sodium laboratory building, an organic laboratory building, critical experiment facilities, a component development hot cell building, the SRE, OMRE, a water boiler reactor, KEWB (Kinetic Experiment on Water Boilers), as well as supporting facilities and special purpose test installations. Goverment-owned buildings are located on North American-owned land which the Government has an option to buy at any time during the life of the contract.

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In addition to the AEC work described above, Atomics International is engaged commercially in the nuclear reactor field. This work is carried out using only Company-owned facilities, but in the same general locations as the AEC program. Currently, the commercial activities account for about 4 percent of Atomics International's effort.

Future Plans

Civilian Reactors: As is the case generally with thermal converter reactors, the work on the organic cooled and sodium-graphite reactors will be continued at the present level for the next two or three years. At that time the programs will either be terminated or will be gradually reduced each year looking toward their elimination by 1968.

Nuclear Technology: An approximate 25 percent increase in the nuclear technology program as conducted at Atomics International is expected. The major programs will continue to be in low decontamination separations development and in the fuels and materials programs.

Missile Propulsion: The AI role in the Pluto program is currently a supporting one in the materials field to LRL. It is expected that the importance of this role will diminish after approximately two or three years; thereafter, there is no current planning for the utilization of AI in the Pluto program.

Auxiliary Power: The AI role in the SNAP reactor development program is made critical by the fact that the program is geared to a tight schedule prescribed by the Department of Defense and that there is increasing interest in this program on the part of the National Aeronautics and Space Agency. We expect, therefore, that AI will have a very important role in the SNAP program at least for the next five years. The trend of the effort thereafter will depend on the flow of new requirements and applications.

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Physical Research: Basic research in the physical sciences at Atomics International has primarily been concerned with chemistry and metallurgy and materials studies. This work will not be continued.

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ATOMICS INTERNATIONAL
Los Angeles, California

Ten Year Trend - Costs, Staff and Facilities
(dollar amounts are in millions)

Fiscal Year	1960 b/	1959	1958	1957	1956	1955	1954	1953	1952	1951
Research and Development Costs: a/										
Production Program	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ .1	$ -
Reactor Development Program:										
Civilian power reactors	16.8	18.0	14.7	9.5	5.3	-	-	-	-	-
Merchant ship	-	-	-	.2	-	-	-	-	-	-
Missile propulsion	1.4	1.4	1.1	1.4	.1	-	-	-	-	-
Satellite power sources	7.3	4.1	1.6	.7	-	-	-	-	-	-
General reactor research and development	3.4	4.1	3.5	2.5	1.4	3.2	3.2	3.1	2.5	1.4
Total Reactor Development	28.9	27.6	20.9	14.3	6.8	3.2	3.2	3.1	2.5	1.4
Physical Research Program	1.0	.8	.6	.5	.5	.2	-	-	-	.1
Total Research and Development	$29.9	$28.4	$21.5	$14.8	$ 7.3	$ 3.4	$ 3.2	$ 3.1	$ 2.6	$ 1.5
Personnel at June 30:										
Scientific and engineering		1,295	1,041	758	609	371	260	228	244	192
Other		968	898	746	681	c/				
Total Employees		2,263	1,939	1,504	1,290					
Completed Plant and Equipment at June 30: d/										
By Type										
Reactors		$ 8.8	$ 6.2	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Other		6.0	3.2	1.8	1.1	.9	.7	.6	.4	-
Total		$14.8	$ 9.4	$ 1.8	$ 1.1	$ .9	$ .7	$ .6	$ .4	$ -
By Location										
Los Angeles, California		$12.7	$ 9.0	$ 1.8	$ 1.1	$ .9	$ .7	$ .6	$ .4	$ -
National Reactor Testing Station, Idaho		2.1	.4	-	-	-	-	-	-	-

a/ Excludes depreciation on AEC facilities and the cost of source and nuclear materials consumed in research.

b/ Estimated.

c/ Not available prior to establishment of Atomics International as a Division of North American Aviation.

d/ Plant projects authorized but not completed at June 30, 1959 totaled $5.9 million, of which $5.7 million will be located at Los Angeles, California.

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ATOMICS INTERNATIONAL

Current Budget and Recent Costs by Categories of Work
(in thousands)

	F.Y. 1958 Costs	F.Y. 1959 Costs	F.Y. 1960 Budget
TOTAL	$ 21,516	$ 28,405	$ 29,867
Reactor Development - Total	20,865	27,573	28,894
Civilian Power Reactors - Total	14,684	17,930	16,753
Sodium Graphite Reactor - Total	7,147	6,378	6,980
Research and Development	5,993	4,804	5,580
Fuel Fabrication	-	264	-
Test Operations	1,153	1,310	1,400
Organic Moderated Reactor - Total	5,014	2,765	5,030
Research and Development	4,114	1,634	3,700
Fuel Fabrication	106	166	370
Test Operations	795	965	960
Assistance under Power Demonstration Program - Total	2,523	8,786	4,743
PRDC Costs	13	14	86
CPPD Costs	2,455	5,921	4,268
Piqua Costs	55	2,852	389
Nuclear Technology and General Support - Total	3,532	4,119	3,441
Engineering Physics and Advanced Reactor Development	214	146	150
Reactor Fuels and Materials Development	463	1,857	1,400
Separations Development - Closed Cycle Process	1,987	1,117	725
Thermal Reactor Safety	868	999	1,166
Merchant Ship Reactors - Advanced Studies	21	25	-
Missile Propulsion Reactors	1,089	1,378	1,400
Satellite Power Sources	1,539	4,122	7,300
Physical Research - Total	651	832	973
Chemistry Research - Total	366	492	583
Process Chemistry	143	91	112
Chemical Properties and Reactions	223	401	471
Metallurgy and Materials Research - Total	285	340	390
Alloy Theory and the Nature of Solids	178	188	213
Effects of Irradiations on Materials	107	152	177

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Appendix B

SUMMARIES OF LONG RANGE PROGRAMS SUBMITTED BY THE LABORATORIES

Beginning in the latter half of 1958 the AEC has asked a number of the laboratories, including all of the multi-program institutions, to prepare long range programs for consideration. It was anticipated that such programs would be helpful in planning not only the work of the individual institutions, but of the agency as a whole.

The recommendations of the laboratories are included in this appendix. Some of them, being lengthy documents, are summarized here for convenience rather than being presented in full text.

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DOE ARCHIVES

SUMMARY OF LONG RANGE PROGRAM
SUBMITTED BY ARGONNE NATIONAL LABORATORY

(Section I of this summary sets forth highlights of the program as projected by the Laboratory, including tabular summaries of facility and personnel requirements. Section II presents a more comprehensive summary of the program in outline form.)

1. PHYSICAL SCIENCE RESEARCH is now principally in low-energy physics; work also is carried on in general chemistry with particular emphasis on the heavy elements, high temperature research, solid-state science, and physical metallurgy. Significant expansions are proposed in high-energy nuclear physics, solid state science, high temperature research, the physical metallurgy of plutonium, electronic instrumentation in general and computing devices in particular.

2. LIFE SCIENCE emphasis currently is on effects of radiation on living systems, including studies of the effects of both internal and external radiation on animals and epidemiological studies of exposed human beings. An immediate practical aspect is the evaluation of hazards and the setting of permissible dose rates. Tracer techniques are used in studies in plant science, and labelled organic compounds are produced by growing plants in special growth chambers.

   Major expansions are contemplated in the study of the chronic effects of continued irradiation of animals at low levels of intensity, and in plant science.

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3. REACTOR DEVELOPMENT AND ENGINEERING work at the Laboratory is now directed principally toward the development of reactors for civilian uses with emphasis on the breeding principle. Future emphasis is proposed to focus on general engineering research fields rather than on specific reactor problems.

   a. GENERAL ENGINEERING RESEARCH includes reactor physics, heat engineering, reactor control, metallurgy related to reactors, chemical engineering involved in the processing of fuels, remote control and meteorology (as it bears on reactor safety); a general expansion is proposed for work in this area with the most striking increase in micrometeorology.

   b. SPECIFIC REACTOR PROBLEMS fall into the general categories of boiling water reactors, fast reactors, and special-purpose reactors (such as high-flux research reactors). Tapering off of laboratory work on boiling water reactors is foreseen. Future emphasis appears aimed at fast reactors with their associated problems in metallurgy, chemical engineering and remote control; there is no end to the list of possible special-purpose reactors.

4. EDUCATIONAL RESPONSIBILITIES are more capable of being met under the increasing relaxation of security restrictions. Laboratory activities in this field, frequently in cooperation with mid-western colleges and universities, include: appointments for senior faculty members on sabbatical (or other) leave; two year post-doctoral research appointments; appointments for graduate students to carry out research for their master's and doctor's

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theses; summer appointments for faculty members and graduate students; appointments for undergraduates, including cooperative students; and finally, summer institutes for faculty members of engineering colleges and technical institutes. An increase from the present approximately ten percent of staff effort at the Laboratory to at least twenty percent is proposed over the next few years.

5. FACILITIES AND PERSONNEL

a. Facilities expansions, totaling $167 million, can be grouped in three categories as follows:

(1) Specialized research and development facilities, including such items as new reactors, additions to presently existing or authorized facilities such as the ZGS, and maintenance and improvements to these facilities.

(2) Laboratory and office space.

(3) General service facilities.

b. Personnel strength is proposed to be expanded from the current 3450 to 5850 by 1964 and 6700 by 1969.

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Table I*

ESTIMATE OF STAFF REQUIREMENTS
SCIENTIFIC AND TECHNICAL DIVISIONS

	1959[1]/	1964	1969
Analytical Services	(17)	30	35
Applied Mathematics	27	65	75
Biology and Medical	79	104	120
Chemistry	139	180	185
Chemical Engineering	91	160	168
Computer Research and Development	(4)	15	30
Electronics	30	75	100
High Energy Physics	(5)	100	150
Idaho	26	65	65
International School	18	25	25
Metallurgy	80	143	160
Meteorology	(4)	15	20
Particle Accelerator Operation and Development	41	75	100
Physics	76	95	100
Plant Sciences	(5)	60	80
Radiological Physics	22	26	27
Reactor Engineering	202	250	260
Reactor Operations	6	30	35
Remote Control	25	59	65
Solid State Sciences	(15)	50	80
Technical Information	23	28	45
Total Staff	885	1650	1925

1/ Numbers in parentheses under 1959 represent staff members currently carried under other divisional totals.

Table II*

SUMMARY OF ESTIMATED PERSONNEL REQUIREMENTS

	1959	1964	1969
Scientific and Technical Divisions Staff	885	1650	1925
Scientific and Technical Divisions Direct Support	864	1550	1825
Supporting Technical Services	595	990	1050
General Services and Administration	1060	1615	1850
Laboratory Director's Office	35	45	50
Total	3439	5850	6700

*See notes on following page.

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Tables I & II (Cont d.)

*In Tables I and II the term "staff" refers only to academically qualified scientists and engineers engaged in their professional capacities directly on the research and development program of the laboratory. The term "direct support" refers to technicians, secretarial assistance, and certain administrative assistance assigned directly to the divisions responsible for the research and development program. The term "supporting technical services" includes primarily the machine shop, the industrial hygiene and safety and the medical personnel regardless of any professional classification.

The staff requirements for the scientific and technical divisions are presented in Table I essentially along divisional organization lines. However, in those cases where the long range program of the laboratory indicates significant expansion which might not fit into the present divisional pattern or which might affect programs in more than one division, the pertinent staff figures are itemized separately. The staff numbers in Table I include temporary personnel which, at present, account for about 10% of the total staff. It is expected that this will increase to about 20% in the next few years. The temporary personnel would consist primarily of individual with temporary post-doctoral appointments and faculty members from universities on temporary leaves or sabbaticals. The percentage of temporary appointments will undoubtedly vary widely, ranging from only a few percent in the case of divisons with large programmatic responsibilities to perhaps 50% or greater in the case of high energy physics research.

In Table II are listed the total personnel requirements of the Laboratory. Given first the number of staff, the requirements for direct support, for the supporting technical services and for general services and administration have been based on the experience of the last several years with suitable allowance being made for the trends indicated in the long range scientific and technical program. Thus, the increased use of higher levels of radioactivity will mean an increase in ratio of personnel involved in radiation safety activities to the total staff. The rapid expansion of the Idaho reactor program likewise will result in an increased ratio of service personnel to total staff. On the other hand, the decrease in security and classification problems should decrease the ratio of service personnel to staff. From the over-all standpoint, the sum of such trends is expected to result in a significant decrease in the ratio of total service personnel to total staff as the size of the staff grows. This is borne out by the trends in recent years.

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Table III

CURRENT STATUS OF FACILITIES 1/

	ESTIMATED	
Facilities Currently Under Construction	Completion	Cost
Zero Gradient Synchrotron	1-63	$29,800,000
Experimental Breeder Reactor II (Idaho)	12-60	29,100,000
Fuels Technology Center	11-61	17,000,000
Fuel Fabrication Facility	4-59	4,000,000
EBWR Improvements (100 MW)	3-60	1,600,000
CP-5 Improvements (10 MW)	3-60	880,000
Biology Building Addition - Dog Kennels	12-59	600,000
Coincidence Beta Spectroscopy Facility (Chem. Bldg. Addition)	9-59	500,000
Biology Reactor ("Janus")	3-60	330,000
Fast Source Reactor (Idaho)	7-59	120,000
		$83,930,000
Facilities Authorized by Congress - Construction Not Started		
Chemistry Hot Laboratory	*	4,500,000
Zero Power Reactor Facilities	12-60	3,000,000
Tandem Van de Graaff (10 Mev)	*	2,500,000
Borax V	6-60	2,000,000
		$12,000,000
*Funds not yet available.		
Facilities Included in FY 1960 Congressional Authorization Request		
Utility Additions		3,000,000
Radioactive Waste Processing Plant		1,300,000
EBR-I - Modifications		1,000,000
Education & Training (East Area Modifications)		1,000,000
Animal Quarters Addition		500,000
		$ 6,800,000
Facilities Considered for Inclusion In the FY 1961 Argonne Budget Request		
Zero Gradient Synchrotron - Additions		$10,000,000
High Energy Physics Building		5,000,000
High Flux Research Reactor		15,000,000
Chemical Engineering Laboratory Addition		2,000,000
Applied Mathematics (Physics Building Addition)		2,000,000
Reactor Engineering Building		3,000,000
Solid State Science Building		5,000,000
Heating Plant - Additional Boiler		1,500,000
Administration Building (Includes Chicago Operations Office)		6,000,000
Cafeteria		2,000,000
High Level Alpha-Gamma Hot Laboratory		6,700,000
		$58,200,000

1/ As of March, 1959, the date of the laboratory's submission.

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Table IV

FACILITIES TO BE REQUESTED IN FUTURE YEARS

Special Research and Development Facilities

Zero Gradient Synchrotron Additions
Meteorological Modeling
Mouse Experiment
Low Energy Particle Accelerator(s)
Solid State "Fast Flux" Reactor
Chemical Engineering Hot Laboratory Addition
Library Facilities

Total Approximate Cost $60,000,000

Scientific Space Requirements	(Net Square Feet) Laboratory	Office
Biology and Medicine	14,100	5,700
Plant Sciences	28,300	11,400
Chemistry	20,300	6,900
Chemical Engineering	17,700	6,000
Analytical Chemistry	6,200	2,100
Computer Development	8,400	4,400
Radiological Physics	9,300	4,900
Engineering and Electronics	39,900	16,400
	144,200	57,800

Laboratories	144,200
Offices	57,800
Shops	37,300
Storage and Stores	60,300
Scientific Services and Special	95,000
Total Net Space	394,600

Total Approximate Cost
(921,000 sq.ft. gross at $38 per sq.ft.) $35,000,000

Supporting Services

Mechanical Shops
Idaho Service and Administration
Industrial Hygiene and Safety
Fire Security and Emergency Center
Auditorium
Special Material Vaults
Maintenance Shops
Warehouse

Total Approximate Cost $14,000,000

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SECTION II
PROGRAM SUMMARY

1. GENERAL DISCUSSION

a. THE PRIMARY PURPOSES of ANL are held to be to contribute toward realization of the potential peacetime benefits of atomic energy by (1) conducting a balanced comprehensive program in basic nuclear research, (2) doing applied research and development to hasten widespread practical applications of nuclear science, and (3) disseminating information in the nuclear field.

b. FUNCTIONS to be performed to fulfill these purposes include:

(1) providing objective and competent technical advice to the Commission.

(2) providing the mechanism necessary to establish and execute the research and development programs necessary for the Commission to attain its objectives.

(3) providing the means for mobilizing the research and development potentials of both universities and industry in support of AEC objectives.

(4) providing a mechanism for the dissemination of information with respect to the objectives and accomplishments of the atomic energy program.

c. SUPPORT FROM THE AEC is required if the laboratory is to accomplish its purpose. Such support must include:

(1) active aid in establishing and maintaining adequate staff by providing "good working conditions" -- both intellectual and material -- and equipment and facilities (twenty to

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forty percent of annual operating budget to go for equipment and facilities).

(2) active support of cooperative programs with the universities, industry, other Government agencies and those related to international programs.

d. LIMITATIONS ON THE LABORATORY SCIENTIFIC AND TECHNICAL PROGRAM include:

(1) Atomic Energy Act of 1954 (Chapter 1, Sections 1, 2, 3; Chapter 4, Sections 31, 32, and 33).

(2) Limitations imposed by relationships with universities.

(Laboratory will not put major research effort into an area which is being investigated in a university unless there is an overriding need to obtain the research data in a much shorter period of time than the university effort would require.)

(3) Limitation imposed by relationships with industry.

(Laboratory will not build an instrument or a component when it is possible to purchase a fully satisfactory item on the market; also -- ANL has adopted the principle of proposing development projects which require the Laboratory's unique facilities and the diverse understandings and skills of its research and development staff, with development carried only to the point at which industry should be able to take over the responsibility for further development.)

e. GENERAL CHARACTER OF THE LABORATORY'S SCIENTIFIC AND TECHNICAL PROGRAM is determined by the needs of the atomic energy program, in terms of the scientific and professional disciplines which experience has shown are needed for successful accomplishment.

(1) Research -- principal responsibility is to attain as complete an understanding of the nature of the nucleus

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of the atom and of the forces which hold it together as it is possible to achieve through theoretical and experimental investigation.

(2) Applied development work -- basic principle is the timely selection of projects which can make clear contributions to the national welfare.

(3) Education -- the educational activities of the Laboratory form an integral part of its scientific and technical program; other programs effective only to the extent that their need and results are used and understood by both the scientific community and the public.

2. SCIENTIFIC AND TECHNICAL LONG-RANGE PROGRAM PROPOSALS

a. PHYSICAL SCIENCES

(1) Low energy physics -- Among the branches of low energy physics that will be pursued actively are the following: nuclear spectroscopy, neutron interactions, fission, charged particle reactions, asymetry of decay of the neutron, and neutrino cross sections.

(2) High energy physics -- Relatively new program at ANL. Primary objective of ANL for next few years will be to build, operate, and use the ZGS for experimental research. Expand present small staff to 100-150.

(3) Chemistry --

(a) Major effort will center on chemistry of heavy elements, with emphasis on actinide elements;

expanding work on transplutonium elements.

(b) Expansion of effort in plutonium field.

(c) Research on fluorine will continue in at least two major areas: Radioactive F^{18} and the liquid phase chemistry of the reactive fluorides.

(d) Continued investigation of properties of liquid and solid He^3 and solutions of He^3 and He^4.

(e) Extensive program to measure heat capacities and magnetic susceptibilities of various neptunium, uranium, and thorium compounds between 1 and 350 degrees Kelvin.

(f) Basic studies in radiation chemistry and photochemistry. Build a new high-flux reactor at earliest possible date; also, new chemistry hot laboratory to handle high levels of activity.

(4) High temperature research -- Progress in reactor technology and other fields is limited by paucity of basic data concerning the properties of materials at high temperatures. Work in this field must be expanded as rapidly as possible. Doubling of staff is proposed for the next four years and another doubling in the following five years; in addition to the usual space problem, a factor limiting the rate of expansion in this area may be the national scarcity of qualified personnel.

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(5) Solid state -- Research is proposed to be increased rapidly, not only in areas currently engaging laboratory personnel, but also in other fields such as the studies of metals, alloys, semi-conductors, ferro-electrics, and other non-metals, and in solid state research at low temperatures. Expand the current fifteen-staff members to fifty by 1964 and to eighty by 1969; additional facilities required include those for X-ray diffraction and electron diffraction studies and also for further progress in the study of radiation damage a special reactor -- to provide adequately thermostated irradiation facilities with temperatures down to the liquid helium range.

(6) Physical metallurgy -- Major objectives include the study of the basic metallurgical physical properties of U, Pu, and Th and the advancement of understanding of the fundamental principles that govern the structures and properties of all solids that appear to be potentially significant for future development of nuclear energy. Effort to be continued on principles of corrosion, theory alloys, effects of radiation on the structures of metals and on metallurgical reaction, and the structure and properties of high temperature ceramic materials. Expanded effort on plutonium and compounds of uranium, plutonium, and thorium means some reduction in work on uranium.

(7) Computer research -- Enormous growth in use of computer services has not been matched by adequate research in new computer techniques.

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(8) Potential interest in thermonuclear work.

b. LIFE SCIENCES

Broadly speaking objectives here are the achievement of an understanding of the action of radiation on living systems, and also, the use of radiation to achieve a better basic understanding of life processes. Both animal and plant systems are studied.

(1) Animal Studies --

(a) Effects of External Radiations:

1. Recent trend towards broadening the studies in an attempt to determine the chronic effects produced by continued exposure at or near background levels. Expansion of this effort is proposed; special reactor for this purpose is under design and should be in operation in early 1960.

2. Studies of species and genetic variations, and of the influence of age, sex, and previous history on ray toxicity will be continued and extended to cover fission neutrons.

(b) Effects of Internal Radiations (studies of animals and humans whose body burdens of radium are appreciable) --

1. Animals -- expanded effort on the toxicity of fission products and other radioactive materials.

2. Humans -- major goal is establishment of maximum permissible level of radium in man (to be reached within next five years). Also, studying

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relationship between bone sarcoma and radium in drinking water, bone physiology, and seeking discovery of chemical compounds useful in treatment of poisoning by radioelements and metals.

(c) Basic Studies --

1. Genetic studies -- current work to be continued and expanded.

2. Cancer studies -- direction to be determined by developments in related programs; anticipate increasing attention to predisposing factors in carcinogenesis.

3. Biochemical investigation of problems in general metabolism and the intracellular localization of biochemical events will be continued and broadened to (a) provide background information for the interpretation of radiation effects, and (b) evaluate physical and biological factors in radiation sensitivity and to develop protective agents.

4. Current studies to determine the effects of radiation and age and growth potential and the regenerative capacity will be expanded to include other parameters.

5. More attention to be given to problems in embryology and to phenomena of cell and tissue differentiation.

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6. Studies in theoretical biology will continue at about the present level although more computer time will be used.

(Newly-initiated work in the study of the fundamental problems in the primary effects of radiation will require the establishment of a group dedicated to this program.)

(The further development of basic and applied radiation dosimetry is imperative.)

(2) Plant Sciences -- Effort in this area has been small; work must be extended and expanded.

(A Plant Science Institute is proposed to carry out a broad program of research in plant science, and to serve as a center for training in the application of specialized tools and techniques to investigations in plant science. This is conceived to be a cooperative laboratory, AMU to play a prominent role, in addition to the U. S. Department of Agriculture, Agr. Exp. Stations and others. Total employment eighty scientific people, forty regular staff, forty resident research associates; facilities required include a special biology reactor (Janus) and a Bio. Building addition for dog kennels -- construction to begin shortly -- plus animal quarters addition (authorized FY 1960); additional animal quarters, office and laboratory space will be necessary.)

c. ENGINEERING RESEARCH AND DEVELOPMENT PROGRAM

This program is comprised of specific reactor programs and general engineering research.

(Long range program contemplates that the staff in general engineering research be doubled (approximately) as soon as possible and specific engineering projects be increased only to the extent necessary to meet current commitments, e.g., EBR II. Work on boiling water to be decreased and emphasis to be directed to fast reactor concepts; associated increased emphasis on plutonium, ceramic fuels and fuel cycles. Laboratory re-emphasizes need for additional reactor engineering building and for the two-wing addition to the chemical engineering building.)

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(1) General Engineering Research --

(a) Reactor physics -- Gaps in our knowledge exist, forcing empirical or intuitive solutions to vital questions.

(It is proposed to emphasize reactor theory, plan for a comprehensive program of physics measurements on water moderated systems, devote added attention to fast reactor physics and critical assemblies, fueled with U^{235} and Pu, explore properties of coupled fast-thermal systems and fast-thorium systems and others, and study applied nuclear physics.)

(b) Heat engineering -- The heat engineering program at the Laboratory includes studies on the heat transfer properties, etc., of fluids which have application as reactor coolants; main interest at ANL has been in water and sodium with the bulk of effort devoted to water. Work will be continued on water, with an expansion of sodium work anticipated. As efforts to exploit high temperature reactors increase, additional problems in this area will be encountered.

(c) Reactor control engineering -- Results of this work are applied directly to existing reactor installations; examples of future work include broadening of program on reactor simulators, improvement of techniques of measurement and analysis, and investigation and development of new control systems.

(d) Metallurgy and materials engineering -- Aims are to produce fuel elements of simple design, to make high

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quality fuel and cladding materials, to design simple, fool-proof and automatic manufacturing processes, and to perfect highly refined non-destructive testing techniques for detecting defective materials and components.

(e) Chemical engineering --

1. Work directed toward aqueous, volatility, and pyro-processing of uranium fuels can be finished in some five years; future work will be on fuels based on Pu alloys and oxide or ceramic fuels -- also fuels of reactors operating on the thorium-uranium breeding cycle.

2. Continue study of promising new separations process in which fluoride volatility processes are carried out in fluidized beds.

3. Continue studying reactor safety problems of a chemical nature.

4. Study problems in reactor chemistry in the proposed slurry reactor programs.

(f) Remote control engineering --

1. Direct efforts at problems stemming from greater use of and increasing levels of radioactive materials. (Space is the limiting factor and is needed to house even the present staff adequately.)

2. Work on viewing systems to emphasize shielded windows, optical periscopes, and television.

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3. Because of increasing emphasis on plutonium and other highly toxic materials work needed in development of shielded facilities.

(One such complete shielded facility vitally needed for the reactor development program of ANL is the proposed Alpha-Gamma facility to be housed in an addition to Building 301.)

(g) Meteorology (an area relatively neglected in last ten years). Seeks to perfect modelling techniques.

(Propose to construct a pilot wind tunnel to test various new and untried features and to follow this with a full-scale tunnel, based on experience with the preliminary device. Costs will run very high but believed warranted.)

(2) Specific Reactor Programs --

(a) Boiling water reactor program (beginning de-emphasis of this program) -- Continuing experimental areas are development of a suitable fuel and fuel cycle, and investigation and evaluation of nuclear superheat for boiling reactors.

(A new BORAX-V is presently under design to permit the evaluation and study of nuclear superheat concepts and to demonstrate nuclear superheating. Another potentially attractive boiling reactor concept is the aqueous homogeneous boiling slurry. This concept appears sufficiently attractive to warrant a "BORAX-I type" experiment to establish preliminary feasibility.)

(b) Fast Reactor program -- Late in 1959 a Pu loading will be installed in EBR-I and it is possible that EBR-I will then be used for a ceramic loading. Sometime within the next few years, the fast thermal coupled reactor concept

will be investigated in EBR-II. The technology of fast reactors is still in its early stages; a major effort of ANL will be required for perhaps a full ten years.

(c) Research reactor program --

1. Maintain continuing program of theoretical and experimental investigation of various concepts of potential value for research or test reactors.
2. Emphasis exemplified by types currently being worked on -- high-flux reactors, relatively low flux special-purpose reactors and pulsed reactors.
3. Design reactor to achieve fluxes above 10^{16}.
4. For those programs which do not need or cannot use high fluxes there is being developed the Juggernaut and the Janus. The TREAT type reactor appears worthy of further study with a view toward other applications.

(d) Advanced reactor programs --

1. Gradually shift efforts from boiling water to the study of various advanced reactor concepts. (Relatively simple and inexpensive BORAX-type experiments should be carried out whenever possible prior to serious consideration of a prototype.)

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2. An extensive development program will be required to extend experience in sodium systems to applicable engineering technology (and other liquid metals).

3. A major Laboratory objective has been the development of very concentrated nuclear power sources; a natural extension is even higher power densities at much higher temperatures. (Process heat, space vehicle propulsion by an ion or plasma jet, or for base power on a satellite or planet, small reactors for remote locations, the direct generation of electricity, and pulsed directly into high pressure waves - shocks.)

4. Investigate two types of reactors which represent advanced development of current Laboratory studies, the evolutionary extension of the EBR-II type to higher and higher design temperatures, and the feasibility of the boiling slurry reactor concept (possible boiling of sodium slurry).

5. Possibly develop dry particle fueled reactors (direct fluidized bed concept or the dust fueled approach, alternatively).

d. EDUCATION AND TRAINING

Security and classification climate much improved. Plan to raise the admission requirements for the International School as engineering schools are now offering basic training in nuclear engineering. Continue and increase cooperation with schools and universities.

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e. SUPPORTING SCIENTIFIC AND TECHNICAL SERVICES

Service functions should be substantially improved and associated research and developmental work should be increased.

(1) Applied Mathematics and Computers -- Lack of space prevents further expansion of computer facilities. Present digital computers are: GEORGE and an IBM-704.

(Needs require growth that can be accommodated only by new construction; a third machine, comparable to present ones, will be required. A group should be established for continuing research, and design of computing devices.)

(2) Electronics and Instrumentation -- Work falls into three principal areas: general electronic instrumentation, development of assorted detectors of radiation, and improvement of computers (particularly additions to GEORGE -- all of which should continue and grow).

(A three-fold increase in personnel is proposed for the next five years, dependent upon space.)

(3) Analytical Chemistry --

(Workload expected to increase by fifty percent; available space and personnel is inadequate at present.)

(4) Reactor Operation -- Present small staff expected to increase with responsibility for additional reactors.

(At present, there are two operating reactors (CP-5 and EBWR); in 1960, three additional reactors (JANUS, JUGGERNAUT, and a Fuel Assay Reactor); by 1963-65 a high flux research reactor and a solid state fast flux reactor.)

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(5) Scientific and Technical Information -- Effectiveness of staff depends upon convenience of information and adequate library facilities.

(Central library required.)

(6) Supporting Personnel --

(Number of machinists must be proportionately increased; radiation protection personnel increase, other support people will increase but not in proportion to programmatic increases.)

SUMMARY OF LONG RANGE PROGRAM
SUBMITTED BY BROOKHAVEN NATIONAL LABORATORY

(Section I of this summary sets forth highlights of the program as projected by the Laboratory, including tabular summaries of facility and personnel requirements and the Laboratory's view of future operating costs. Section II presents a more comprehensive summary of the program in outline form.)

SECTION I - HIGHLIGHTS

1. PHYSICAL SCIENCES account for a little over half of the BNL research effort largely in basic investigations of various aspects of nuclear physics, chemistry, and metallurgy. The program has been built around major research machines, with nuclear physics and nuclear chemistry predominant; smaller efforts are involved with other chemistry research, solid state physics, metallurgy, and applied mathematics. Expansion of approximately seventy-five percent is proposed for the next half dozen years, of which nearly half is in the high-energy program as a result of the new accelerator and of improved facilities at the Cosmotron; additional emphasis will also be placed on the solid state physics and metallurgy programs and in radiation chemistry.

2. LIFE SCIENCES research constitutes about one-fourth of the Laboratory program as measured in sicentific effort, though relatively less in cost since it does not make major use of the large machines; of this effort approximately forty percent is in biology, slightly more than fifty percent in medicine, and a little less than ten percent in environmental research. Expansion of the total program ~~of~~ by approximately fifty percent is proposed for the next five or six years, with relative distributions remaining constant.

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3. REACTOR DEVELOPMENT AND NUCLEAR TECHNOLOGY includes reactor physics, metallurgy, and materials, liquid metal and fused salt technology, fuel cycle development, heat transfer, and reactor evaluations based on present principal scientific and engineering strengths in physics, chemistry and chemical engineering. Expansion will emphasize materials and metallurgy; the effort in reactor physics, metallurgy, liquid metal and fused salt technology and fuel cycle development will remain roughly of equal magnitude and the work in reactor evaluation and heat transfer together about half of that magnitude.

4. EDUCATIONAL FUNCTIONS include participation in the research programs by thesis students and Research Associates, a competitive summer student program, organized "courses" and seminars (presently very few in number), and the annual ten-week summer laboratory program for AEC Radiological Fellows. Expansion of each of these educational processes is proposed.

5. FACILITIES AND PERSONNEL

   a. Facilities expansions, totalling about $60 million can be grouped in three categories as follows:

      (1) Specialized research and development facilities, including such items as additions to facilities including the AGS and maintenance and improvements to these facilities.

      (2) Laboratory and office space.

      (3) General service facilities.

   b. Personnel strength is proposed to be expanded from the present 2110 to 3100 by 1965.

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Table I
PERSONNEL SUMMARY

	1959				1965			
	Staff Sci.	Res Asso	Vis Sci	Other Staff	Staff Sci	Res Asso	Vis Sci	Other Staff
Physical Sciences								
Cosmotron	27	8	21	66	22	10	15	55
AGS	See Dev. of Devices				38	15	20	90
High Energy Research	27	8	21	66	60	25	35	145
Nuclear Structure	22	11	15	35	30	17	20	58
Solid State Physics & Metallurgy	11	1	12	18	25	7	20	47
Chemistry	45	19	13	39	75	33	25	70
Applied Mathematics	4	1	3	1	10	3	5	8
Total	109	40	64	159	200	85	105	328
Reactor Development and Nuclear Technology								
Reactor Physics (1)	13	2	2	21	19	1	3	26
Reactor Evaluation	2	-	1	4	4	-	1	5
Heat Transfer (1)	3	-	1	4	4	-	2	7
Materials & Metallurgy (1)	6	-	2	38	15	2	2	32
Liq. Metal Fuel Chem. & Tech. (1)	17	-	2	45	14	2	3	30
Fuel Cycle Development	11	-	1	21	18	-	4	37
Radioisotope & Rad. Source Dev.	3	-	-	4	7	-	3	20
Total	55	2	9	137	81	5	18	157
Life Sciences								
Biological Research	20	9	15	57	25	20	25	90
Medical Research	26	17	10	122	35	20	20	175
Health Physics Met.Res. & Servs.	17	-	-	51	19	-	2	70
Total	63	26	25	230	79	40	47	335
Development & Operation of Devices & Equipment								
Accelerator Development	5	-	1	2	10	-	3	10
Reactor Development	3	1	-	5	5	-	2	9
Instrumentation Dev.&Svs.	9	-	1	42	27	-	-	64
Mechanical Engr.&Design	9	-	-	38	25	-	-	72
Computer Operations	6	-	1	17	20	-	-	30
60" Cyclotron Operations	-	-	-	9	-	-	-	9
Cosmotron Operations	10	-	-	61	17	-	-	75
AGS	34	(construct.)		100	24	(operation)		90
Graphite Reactor Operations	11	-	-	55)	12	-	-	71
High Flux Beam Reactor Oper.	-	-	-	-)				
Total	87	1	3	329	140	-	5	430
Shared Tech. & Skilled Svs.	3	-	1	216	5	-	-	310
General Admin. & Plant Oper.	-	-	-	577	-	-	-	725
Laboratory - Total	317	69	102	1648	505	130	175	2285

(1) LMFR proj. effort 31 Staff Scientists, 2 Res Assoc., 7 Vis. Scientist man-years & 96 Other Staff in '59 has been dist. among act. noted. These do not include mech. engr. and design effort included under Development of Devices and Equipment.

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Table II
BUILDINGS AND FACILITIES

	Facility	BNL Program Interest	AEC Program Interest	Estimated Cost (in millions) Specific Facil.	Accel. & React. Addn.	Gen. Plant
1960	High Level Rad. Dev. Lab.	Nuc.Engr.	Istop.Dev.	$ 1.4	$	$
	Volatility Studies Lab.	Nuc.Engr.	Research	.26		
	Sites Util. (Steam, Elect.)	Laboratory-wide	Spon.Div.	1.7		
	Total - FY 1960			3.36	1.95	1.0
1961	Chemistry Laboratory	Chemistry	Research	5.0		
	Metallurgy Addition	Nuc.Engr.	Res. (RD)	.4		
	80" Bubble Chamber House	Physics	Research	.4		
	Contained Critical Facil.	Nuc. Engr.	Reactor Dev.	1.0		
	Plutonium Laboratory	Nuc.Engr.	Reactor Dev.	1.5		
	Pathogen Free Animal Lab	Biology	Bio-Med	.5		
	Qtrs - Vis. Scientists (I)	Laboratory-wide	Spon. Div.	.9		
	Lib.& Tech. Info.(Mod.)	Laboratory-wide	Spon. Div.	.5		
	Total - FY 1961			10.2	2.3	1.0
1962	AGS - Particle Sep.System	Physics	Research	3.0		
	AGS - Exp.Area (Forward)	Physics	Research	3.0		
	AGS - Electric Substation	Physics	Research	.5		
	Chemistry Hot Cells	Nuc. Engr.	Reactor Dev.	2.0		
	Nuclear Engr.Bldg.Addn.	Nuc. Engr.	RD (Research)	2.0		
	Instrumentation, Health Physics, ADD	Laboratory-wide	Spon.Div.	3.0		
	Admin., Lect.Hall,Cafeteria	Laboratory-wide	Spon.Div.	2.6		
	Total - FY 1962			16.1	1.8	1.0
1963	AGS - Exp. Area (Side)	Physics	Research	3.0		
	AGS - Power House Addn.	Physics	Research	.4		
	Shops and Engr. Bldg.	Laboratory-wide	Spon. Div.	3.5		
	Total - FY 1963			6.9	1.4	1.0
1964	Plant Maintenance Bldg.	Laboratory-wide	Spon. Div.	2.1		
	Site Utilities	Laboratory-wide	Spon. Div.	1.5		
	Total - FY 1964			3.6	2.0	1.0
After 1964-					Annl. Rqmt	Annl. Rqmt
	Fuel Cycle Develop. Lab.	Nuc. Engr.	Reactor Dev.	2.0		
	Biology Additions	Biology	Bio-Med.	1.5		
	General Services Bldg.	Laboratory-wide	Spon. Div.	1.4		
	Qtrs -Vis. Scientists (II)	Laboratory-wide	Spon. Div.	2.2		
	Stock & Whse; Plant Prot.	Laboratory-wide	Spon. Div.	2.0		
	Total - All special facilities			$ 49.3		

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Table III

COST PROJECTION

	Program Costs (In Thousands)	
	1959	1965
Specific Reactor Projects	$ 3,603	$ See Note (1)
Reactor Systems R&D	525	
Fuel Cycle Dev.	445	
Sub-Total	4,573	5,200
Equipment	250	500
Reactor Dev.-Total	4,823	5,700
High Energy Physics	3,465	
Other Physics	2,725	
Chemistry	2,335	
Metallurgy & Solid State Physics	985	
Sub-Total	9,510	19,800
Equip. -Program	1,000	4,600
-Gen.Lab	600	600
Physical Sciences - Total	11,110	25,000
Radiation Effects) B	1,410	
Beneficial Appli-) & cations) M	2,375	
Other	323	
Sub-Total	4,108	5,900
Equipment	250	400
Biology & Med. -Total	4,358	6,300
Radioisotope & Rad. Source Dev.	235	700
Equipment	45	100
Radioisotope & Rad. Source Dev.-Total	280	800
Res. Operations- Sub Total	18,426(2)	31,600
Equipment - Sub total	2,145	6,200
Res. Operations -Total	$20,571(2)	$37,800

Note (1) No specific reactor projects are shown in "1965". Should LMFR or other specific reactor projects require BNL support at that time, the work will be handled by the diversion of scientific and engineering staff and the addition of supporting help.

(2) Does not include costs for personnel assigned to AGS Construction.

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SECTION II
PROGRAM SUMMARY

1. GENERAL

a. THE NATIONAL LABORATORY CONCEPT is emphasized; the "national laboratories" serve as centers in which large machines and other specialized equipment are utilized by scientists from many institutions. The Laboratories must have strong support within the AEC, not only for operating funds but also for the continuing provision of adequate physical plants and technical facilities.

b. BROOKHAVEN'S PRIMARY PURPOSES are:

(1) to seek new knowledge in the nuclear sciences and related fields, with emphasis on programs that require large-scale research tools which are beyond the scope of most individual institutes.

(2) to encourage appropriate use of its facilities by scientists of university, industrial and other laboratories.

(3) to assist the AEC in the solution of specific problems which utilize the Laboratory's unique facilities or the special talents of its staff.

(4) to serve as an important auxiliary in the training of scientists and engineers and otherwise to assist in the dissemination of scientific and technical knowledge.

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c. THE GENERAL CHARACTER OF THE SCIENTIFIC PROGRAM, which covers a wide range of subjects in the physical and biological sciences and in engineering, can be broadly described under five major headings:

(1) fundamental studies of atomic nuclei, the particles which constitute them, and the forces involved in their structure.

(2) the physical, chemical, and biological effects of nuclear radiation.

(3) the use of nuclear tools, such as reactors, charged particles, gamma rays, and isotopic tracers, in all branches of scientific research.

(4) research and development, not necessarily itself of a nuclear nature, directed at the problem of atomic energy development.

(5) the development of specific devices for use as research tools or in practical applications of atomic energy. (These common threads running across the various scientific disciplines lend a coherence and a mutuality of interest that enhance the entire program.)

d. RELATED CONSIDERATIONS

The Laboratory's future role has entailed consideration of many factors,among these the following:

(1) Nature of the scientific program?

(a) Primarily to employ Laboratory facilities and staff skills in pursuit of scientific knowledge.

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(b) The fundamental research programs at Brookhaven are defined only within broad frameworks agreed upon by the AEC and the Laboratory, the detached development being largely determined by the abilities and interests of the staff.

(c) Should be broadly based in many disciplines, exploiting wide applicability of major facilities and benefitting from inter-relationships between scientists in many fields and from many institutions.

(2) Staff consideration?

Facilities and technical information must be available to larger groups of scientists than can be present on its staff at any one time; consequently, flexible appointments are provided for "visiting" scientists and for graduate students pursuing doctoral theses. Continuity in research programs is achieved by continuing staff of senior scientists with "permanent" tenure.

(3) External responsibilities?

Most important educational function performed by the Laboratory is through participation in the research programs by thesis students and research associates and other young scientists; even more deliberately educational is competitive summer student program. (Educational functions should be <u>intensified</u>.)

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While Brookhaven performs many service functions, such as, the irradiation of inert materials, etc., these are largely by-products of the Laboratory's own program; this policy should continue and no appreciable effort should be made to provide facilities or staff purely for such service functions - such might better be provided elsewhere.

(4) Problems of management?

No objective yardstick exists by which to measure effectiveness. Management problems are rendered more acute due to Government-funding.

(Commission can help by minimizing day-to-day monitoring in favor of judgment based on over-all performance.)

(5) Future Laboratory size?

No foreseeable limits on work to be done, but in opinion of Laboratory, there are definite limits on desirable size. At some point a laboratory tends to become unwieldy, management begins to lose touch and the cohesiveness of the laboratory and the invaluable cooperation existing in the smaller institution begins to suffer.

(Optimum size for BNL, to be achieved over the next eight to ten years, would involve an increase in the research effort from seventy-five to one hundred percent; the total "Brookhaven Staff" proper would increase from its present level of slightly less than 2000 to somewhat more than 3000, not counting research associates and visiting scientists. Most of the growth would occur during the next half dozen years, with the 30 BEV accelerator accounting for almost one fourth increase, the new Medical Center for another eight percent, and the remainder of the growth spread across the program.)

2. THE SCIENTIFIC PROGRAM

This program measured in terms of scientific and technical effort, slightly more than half of the work is in the physical sciences; the remainder is about equally divided between reactor development and nuclear technology and life sciences research.

a. PHYSICAL SCIENCES

Of a seventy-five anticipated growth in the next half dozen years, nearly half is proposed in the high energy program as a result of the new accelerator and of improved facilities at the Cosmotron. Additional emphasis will also be placed on the solid state physics and metallurgy programs and in radiation chemistry.

b. NUCLEAR AND PARTICLE PHYSICS

High energy physics constitutes approximately half this effort while nuclear structure research and neutron physics contribute equally to the remainder.

(Scientific staff in high energy physics expected to double; in the nuclear structure and neutron physics program effort to increase by fifty percent. (This program expected to move into new relatively unexplored fields through the acquisition of (1) the high flux Beam research reactor and (2) the planned high intensity, intermediate energy cyclotron.) The high energy accelerator facilities will require expenditures of approximately $10,000,000 over the next four or five years.)

c. CHEMISTRY - BASIC

Now approximately one-fourth of research effort in the physical sciences program (expected to almost double in five to six years).

Radiation chemistry will be given relatively more emphasis.

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d. METALLURGY AND STUDIES OF THE SOLID STATE

(Considerable expansion and diversification of both the metallurgy and solid state physics program are anticipated -- increasing the Brookhaven Staff by threefold while the contributions from research associates and visitors are expected only to double.)

e. MATHEMATICS

New Mathematics program will expand by somewhat more than a factor of two.

f. REACTOR DEVELOPMENT AND NUCLEAR TECHNOLOGY

Reactor development and nuclear technology programs presently constitute one quarter of Brookhaven's research and development effort.

Should LMFR be cancelled or postponed, hardware development will be cut back and greater emphasis placed on more basic aspects of liquid metal fuels.

The effort in reactor physics metallurgy, liquid metal and fused salt technology and fuel cycle development will be roughly of equal magnitude with the work in reactor evaluation and heat transfer together about half of that magnitude.

(In this future prediction, Brookhaven has assumed that the several general nuclear engineering research activities will progress in accordance with the predictions shown in Table I and II which assume no specific reactor projects in 1965. If in the future it should be decided to proceed with large LMFR or other special reactor projects, it would be necessary, because of manpower limitations, to direct scientific personnel from the general research and development effort and temporarily to increase the total Departmental effort in the professional and technician categories.)

g. REACTOR PHYSICS

(1) Metallurgy and materials -- Substantial expansion is expected in reactor metallurgy effort.

(2) Liquid Metal and Fused Salt Chemistry and Technology -- Continue program of research on fundamental chemistry.

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(3) Fuel Cycle Development -- Some expansion of effort.

(4) Heat Transfer -- Extended program to include both experimental and analytical investigations.

(5) Reactor Evaluation -- Continue on present studies and on new proposals for reactors and reactor components.

(6) Radiation Science and Radioisotope Development -- Expand effort, especially in anticipation that design and construction of the High Level Radiation Development Laboratory will be authorized in FY 1960.

(7) Life Sciences -- Constitutes about one-fourth of the Laboratory program; approximately forty percent is in biology, slightly more than fifty percent in medicine, and approximately fifty percent in environmental research. Expected to grow approximately fifty percent, the relative distribution remaining about the same.

3. OPERATIONS AND FACILITIES

a. OPERATIONS

The Laboratory's principal operating cost factor is labor - seventy-five percent, excluding capital equipment and large procurements for special projects such as LMFR. Requirements for capital equipment will continue to be from seven percent to ten percent of operating costs, with exception for equipment costs for the program sponsored by the Research Division where such costs are likely to be as high as twenty-five percent of the operating costs.

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Operating costs proper for the programs projected will increase from $18,500,000 in 1959 to $32,000,000 in 1965, exclusive of capital equipment costs; largest single increase is in the physical research program and due principally to the activation of the high energy research program with the AGS.

Program projections indicate a cost change of about $1,000,000 or slightly less than twenty-five percent for the Reactor Development Division, for the period 1959 to 1965.

Cost change of almost $14,000,000 (125%) predicted for the physical sciences program.

For the Bio-Med Division, the increase is about $2,000,000, or slightly less than fifty percent of present cost.

Work in Radioisotopes and Radiation Source Development is expected to increase several fold.

b. FACILITIES

By adaptation and conversion, Brookhaven has temporarily and partially met the requirements for other general laboratories. The program of visitor participation, basic to the concept of BNL, necessitates provision of permanent housing units to meet both additional demands and need for replacement. Brookhaven places a high priority on this item.

The building program of Brookhaven is also already far behind in meeting the existing needs of the research program.

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SUMMARY OF LONG RANGE PROGRAM

SUBMITTED BY OAK RIDGE NATIONAL LABORATORY 1/

SECTION I - HIGHLIGHTS

1. The BASIC ORIENTATION of ORNL toward chemical technology and reactor development began with its original mission as a pilot plant for the development of plutonium extraction processes for employment at Hanford. Subsequently, the laboratory has grown by absorption of the wartime electromagnetic development laboratory and by assignment of major project responsibilities such as the ANP project and the gas-cooled reactor project. As a result, the laboratory's interests and skills have continually widened until ORNL is now involved in research and development on most of the non-weapon activities of the AEC.

The laboratory's mission is primarily an applied one; approximately three-fourths of the budget is devoted to applied research, development, and production, of which the two largest areas are reactor development and chemical processing. The approach of ORNL in these fields reflects the laboratory's chemical tradition. Thus, in reactors, ORNL is the center for those systems such as fuel thermal breeders which primarily involve chemical engineering techniques. In addition, the laboratory exploits its skills in high-temperature materials, acquired during ANP days, to pursue civilian gas-cooled, maritime and packaged power reactors. The laboratory is the country's central establishment for producing isotopes.

In the near future the laboratory will be a center for the re-processing of spent fuel elements from the power demonstration reactors. Because of

1/ Dated June 3, 1959

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experience in ion physics and electrical engineering with ORNL staff acquired during the development of the Y-12 electromagnetic separation process, the laboratory has engaged heavily in the controlled thermonuclear project.

2. REACTOR DEVELOPMENT - Delineation of the laboratory's mission in reactor development has always been a more severe problem for the laboratory than delineation of its mission in other applied fields. The laboratory believes that a major administrative problem has been solved with the clear statement of ORNL's long-term mission in reactor development, as follows:

   a. THERMAL BREEDING: ORNL has been assigned the responsibility for developing the thermal breeder systems. Although considerable progress has been made in the development of the aqueous homogeneous and the molten salt systems, the solution of several technical problems, demonstration of the degree of operating reliability essential for economic power costs, and actual attainment of breeding, remain. This is therefore the long-range reactor development of the laboratory. ORNL will continue to pursue the two fluid systems - molten salt and aqueous homogeneous - with the hope of building a small prototype of each by the middle 1960's. One type will be selected for construction, planned for FY 1968, of a large prototype; work on the other type will be reduced or stopped.

   b. GAS-COOLED REACTOR: ORNL has major responsibility in the gas-cooled reactor program; the responsibility includes general technical guidance for the 85 MW reactor to be built in Oak Ridge, and continued research aimed at improving the performance of gas-cooled reactors. As part of the short range reactor program, ORNL will concentrate mostly on the gas-cooled systems. The next ten years will very probably see at least one additional, very advanced, gas-cooled reactor built under the laboratory's supervision.

c. TECHNICAL ASSISTANCE: The laboratory provides technical advisory service on specific reactor problems as well as broad questions of concern to the overall reactor development program. The laboratory will continue to serve as a source of reliable and unbiased advice to the Commission in many of its reactor programs.

d. GENERAL REACTOR DEVELOPMENT: This work includes research and development in metallurgy, chemistry, and solid state physics aimed at improving reactor fuel elements and construction materials; in electronics, to improve reactor control and safety systems; and, in engineering, to increase the knowledge of heat transfer and hydrodynamics, and to improve components and evaluate the corrosive behavior of materials under reactor conditions. Work will be continued in these fields and will be oriented partly in direct support of the major ORNL reactor programs, and partly in support of the various projects throughout the Commission.

e. The laboratory management stresses that firm adherence to this mission over the next ten years will, more than any other single action of the Commission, enable the laboratory to steer a sensible and responsible course over the next decade.

3. CHEMICAL PROCESSING activities will be devoted to adaptation of processes to the fuels from specific reactors and to exploration of promising new approaches. The experience which ORNL has acquired in the fabrication of fuel elements for test reactors and fundamental information from metallurgical and radiation effects research will be applied to the problem of producing higher performance fuel elements.

Programs to devise and test safe and economical methods for disposal of radioactive wastes or for utilization of by-product wastes have been initiated and will continue.

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4. CONTROLLED THERMONUCLEAR PROGRAM is based primarily on continuous high-energy injection into a containing magnetic field. The future magnitude and distribution of effort among the major categories in this program should be determined by the imminence of a practical solution of the thermonuclear power program. The laboratory's approach to achieving an ultimate energy source should develop naturally over the next decade. It will probably take about five years to bring the science of plasma to a point where it will be possible to assess realistically the outlook for fusion power. The projections for Sherwood must therefore be considered very tentative and almost sure to be modified as more information is acquired.

5. PHYSICAL SCIENCE RESEARCH:

a. Physics - A large fraction concerns reactions of neutrons, especially those pertinent to reactor development or the utilization of neutrons as tools for research. The laboratory should continue to pursue a broadly-based fundamental program coupled with special emphasis upon neutron physics and fission physics because of their connection with fission power. The laboratory will venture somewhat further into very high-energy physics but will do so carefully to avoid loss of precision.

b. Chemistry - is concerned with the chemistry of the fission process and the fission products; research to determine chemical properties and reactions in aqueous and non-aqueous media has increased, along with the growth of the reactor development program. Work will continue with shifts in emphasis as needed to shore up the applied programs. The addition of the ORIC (Oak Ridge Relativistic Isochronous Cyclotron) and the HFIR (High Flux Isotope Reactor) should stimulate work in heavy element chemistry, and in this field small expansion is likely.

c. Metallurgy and Solid State Physics is concentrated upon obtaining a knowledge or understanding of the fundamental properties and reactions

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of metals, ceramics, semi-conductors, and organic materials, primarily under conditions encountered in reactors.

6. LIFE SCIENCE research problems studied are those principally concerned with the use of nuclear energy, the investigation of the biological effects of radiation and the development of means to alleviate or counteract such effects. Major problems in biophysics include the development of methods to measure radiation dosage accurately, to establish permissible radiation exposure levels, and to determine the biological course of radioactive materials released into the environment. The biological sciences, including health physics, ought to expand significantly over the next ten years.

7. EDUCATION: Besides making its facilities available to properly qualified faculty members, the laboratory provides training in specialized fields including reactor supervision, nuclear hazards evaluation, health physics, and on-the-job training for technical personnel from private industry. An extension of the educational activities at ORNL can be expected.

8. ISOTOPE RESEARCH AND DEVELOPMENT will be directed primarily by the needs of the isotope production program. Continuing objectives are to increase the purity of all isotope preparations, lower costs, and to develop methods for converting radioisotopes into any desired chemical or physical form. It is expected that the number of personnel will increase in both the radioisotope and stable isotope programs.

9. FACILITIES: All the foregoing plans and activities require facilities. The present building program, when completed, should supply ORNL with most of the general-pupose laboratories it will need, at least over the next decade. Facilities for high-level radiation work are another matter, and additional specialized laboratories of this type will be needed.

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SECTION II - PROGRAM SUMMARY

1. GENERAL DISCUSSION:

The basic orientation of ORNL toward chemical technology and reactor development began with its original mission as a pilot plant for the development of plutonium extraction processes for employment at Hanford. Subsequently, the laboratory has grown by absorption of the wartime electromagnetic development laboratory and by assignment of major project responsibilities such as the ANP project and the gas-cooled reactor project. As a result, the laboratory's interests and skills have continually widened until ORNL is now involved in research and development on most of the non-weapon activities of the AEC.

The laboratory's mission is primarily an applied one; approximately three-fourths of the budget is devoted to applied research, development, and production, of which the two largest areas are reactor development and chemical processing. The approach of ORNL in these fields reflects the laboratory's chemical tradition. Thus, in reactors, ORNL is the center for systems such as fluid fuel thermal breeders which primarily involve chemical engineering techniques. In addition, the laboratory exploits its skills in high-temperature materials, acquired during ANP days, to pursue civilian gas-cooled, maritime and packaged power reactors. The laboratory is the country's central establishment for producing isotopes. In the near future the laboratory will be a center for the re-processing of spent fuel elements from the power demonstration reactors. Because of experience in ion physics and electrical engineering which ORNL staff acquired during the development of the Y-12 electromagnetic separation process, the laboratory has engaged heavily in the controlled thermonuclear project.

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2. PROBLEMS OF ADMINISTRATION:

a. Delineation of ORNL's reactor mission has always been a more severe problem than delineation of its mission in other fields. The laboratory believes that a major administrative problem has been solved with the clear statement of ORNL's long-term mission in reactor development, and that, by comparison, other problems over the next decade will present relatively little difficulty.

b. As to whether ORNL should build and operate prototype reactors the laboratory will continue to insist on its prerogative to build and to operate experimental devices of any size if such are needed to carry out the laboratory's technical responsibilities to the Commission.

c. The laboratory has no desire to expand significantly except in some areas of biology and chemistry. On the other hand, the laboratory has no important objection to expanding at an expected rate of 20% in five years. Such expansion is a rather natural growth which comes with maturation of various projects. The technique of decentralized management is sufficiently well developed at ORNL to allow such expansion to be taken in stride.

d. Maturing of staff is a problem shared by most of the atomic energy laboratories. The modal age of the technical staff at ORNL is now about thirty-four; by 1969 it may be as high as forty-four. It is axiomatic that a research institution cannot maintain its vitality if its staff grows old and the management of ORNL has always been cognizant of this fact and problem. The situation will require serious attention and examination by laboratory management in the future.

e. The general-purpose facilities (laboratory, research reactors, shops, etc.) which are in being, under construction, or which are included in the 1960 budget submission are probably adequate for the next decade with the exceptions listed in the complete report.

3. SCIENTIFIC & TECHNICAL LONG-RANGE PROPOSALS

a. REACTOR DEVELOPMENT

(1) Long-Range Reactor Development: Thorium Utilization. This responsibility is being undertaken in the broadest sense and will involve frequent re-evaluation of the importance of conversion rates, doubling time, and inventory of fissionable and fertile material on the usefulness of reactors in supplying the world's energy requirements from thorium. All types of reactors that have potential utility in this field will be analyzed to determine their relative merits. The most promising types will receive sufficient experimental work to ascertain whether they can attain their theoretical promise. One or more types will be developed through the reactor prototype stage to provide the technology required for further exploitation on an industrial scale. Reactor development activities are presently concerned entirely with the aqueous homogeneous and molten salt reactors. Because both types have exceptional promise, they will be developed concurrently through completion of the reactor experiment stage. At that time one type will be chosen to be pursued through the large prototype stage; work on the other type would then be reduced to some low level or stopped. Beginning of construction is planned for about FY 1968 and operation begun in FY 1971 or sooner. The major ORNL participation in the thorium breeder program will be completed with experimental operation of the prototype.

(2) Short-range Reactor Development. The laboratory's program of short-range reactor development is intended to reflect directly the Government's intent to utilize the development of nuclear power as a vehicle of national policy. The laboratory's role in the shorter range reactor

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program is two-fold: continued responsibility for research leading to high-performance gas-cooled power reactors; and technical advisory service to the AEC on broad questions of concern to the overall program as well as on specific reactor systems. The laboratory expects to build other experimental reactors and reactor cores beyond the GCR with the principal basis being new and improved fuel elements. Other possible areas of interest include the direct conversion of radiation to electricity, use of nuclear power in space exploration, and possible attention to areas of applied research and development associated with nuclear energy.

b. CHEMICAL PROCESSING DEVELOPMENT

ORNL has been strong in radiochemical separations and has become a recognized center for process development. With most of the process development demands for production now satisfied, major programs are being and will continue to be directed to the industrial utilization of nuclear energy and in the industrial utilization of radioisotopes and radiation. ORNL has facilities now available, planned and approved, or proposed, in which to carry out radiochemical separations at the highest activity levels on a significant engineering scale. The objectives of the radiochemical process development and demonstration programs are to develop radiochemical separations techniques which will make it possible to reprocess any power reactor fuel in a single multi-prupose chemical plant. Allied programs that should be sustained as important concern development of effective radiochemical waste treatment procedures and development of safe containment and disposal for high-level and low-level contaminated wastes in gaseous, liquid, or solid forms. To apply existing and new knowledge in the future to the problems of either "commercial" utilization or to very unique applications will require the

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expansion of fundamental knowledge in both process chemistry and engineering. The organization of the chemical development and basic engineering studies needs to be established under longer range programmatic studies rather than supported by projects with limited and sometimes transient objectives. The expansion of fundamental knowledge in process chemistry and in applied reactor chemistry will naturally lead to the establishment of more fundamental and applied research subcontracts with universities and qualified industrial research and development organizations.

c. CONTROLLED THERMONUCLEAR PROGRAM

The ORNL program is based primarily on continuous high-energy injection into a containing magnetic field. To pursue this program there are three major activities: First, the development of experimental machines; second, the system development necessary for these machines; and third, a program of basic research in plasma physics in order to understand the results of the experiments and to discover new avenues of approach to thermonuclear power. These three major activities are at present roughly equally balanced in support. The future magnitude and distribution of effort among these activities should be determined by the imminence of a practical solution to the thermonuclear power problem. The laboratory's approach to achieving an ultimate energy source should develop naturally over the next decade. It will probably take about five years to bring the science of plasma to a point where it will be possible to assess realistically the outlook for fusion power. The projections for Sherwood must therefore be considered very tentative and almost sure to be modified as more information is acquired.

d. PHYSICAL SCIENCE RESEARCH:

(1) Physics, Instrumentation & Mathematics. In the nuclear sciences, the laboratory pursues and should continue to pursue a broadly-based

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fundamental program coupled with special emphasis upon neutron physics and fission physics because of their connection with fission power. Instrumentation and applied mathematics are both laboratory-wide in their import, partly geared as service organizations for the research divisions, but both also encouraging originality in their own right.

(a) Physics - To explore systematically all phases of physics which are related to nuclear technology. As the needs of the research program become apparent in the future, new tools will be required which will make it feasible to extend the basic knowledge in directions indicated by the needs. Future plans for research with the new ORIC (Oak Ridge Relativistic Isochronous Cyclotron) are difficult to predict; however, it is certain that experiments will be extended to higher energies and produce important results concerning our knowledge of the atomic nucleus. In order to really make progress in the understanding of physical phenomena, it was necessary to apply techniques ranging from low-temperature solid state physics to ultra-high-energy particle physics. The ORNL has entered the high energy field only recently. In order to broaden the basis of the investigation of nuclear forces and nuclear structure, it is expected to increase the effort in the field of ultra-high-energy physics in the future. This will prepare the laboratory for efficient utilization of the Southern Regional Accelerator when it becomes available.

(b) Neutron Physics - information basic to an understanding of reactor operation is that dealing with processes of neutron production and absorption and measurement of the basic as well as adjunct parameters. Valid subjects for future study include criticality experiments, detailed neutron transport behavior, and spectral variations in the vicinity of discontinuities in reactors. All the experimental effort is being aimed

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at the possible development of a well-rounded theory for reliable predictions of critical mass, fission distributions, etc., so that one could ultimately dispense with much of the critical experimentation. Hence, analytical approaches to reactor analysis will be pursued and within ten years should be capable of affording a quantitative understanding of most phenomena of neutron production, transport, and absorption.

(c) Instrumentation - since the atomic energy program is so closely linked with instrumentation and control, each of the national laboroatores will always have a large group of scientists and engineers devoted to this activity. The report lists 23 examples of future projects in the field of instrumentation which it hopes to examine during the next ten years. In order to carry out the objectives of such a program, an increase of up to 50 people will be required.

(d) Mathematics - The three broad fields of programming theory, numerical analysis and classical analysis will require increased attention and the staff will increase more rapidly, relatively, than the laboratory has as a whole.

(2) Chemistry. Research is organized into four separate divisions; the work of the Chemical Technology Division was described under Section 3b on Chemical Process Development; this section will be concerned with the remaining divisions which comprise 60 per cent of the scientific staff in chemistry. Basic chemical researches are conducted in six areas:

(a) Radiation Chemistry - where recently increased attention has been given to the radiation chemistry of gases, where new advances seem possible, and to the radiation chemistry of molten salts, of

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organic compounds, and of catalytic changes at solid surfaces.

(b) Nuclear Chemistry - Present studies concern the properties of radioactive nuclei, nuclear reactions, and the applications of these two topics to other fields. New efforts will be made to study the radiations emitted in the decay of the short-lived fission products because of their relevance to the shielding and chemical processing problems characteristic of certain reactors.

(c) Isotope Chemistry - The two principal activities concern the separation of isotopes of the light elements and the use of isotopes for basic work in organic chemistry. This work will continue.

(d) Inorganic Chemistry - The properties of fission products technetium and promethium have been studied because of the possibility of extracting them from radiochemical plant wastes. Both elements are of importance because of high fission yields, long half-lives, and large thermoneutron absorption cross-sections. Work will continue.

(e) Physical Chemistry - Activities include significant efforts in two areas of high-temperature chemistry: molten salts and aqueous solutions. Other investigations include ion exchangers, the chemistry of corrosion and thermochemical measurements on various compounds.

(f) Chemical Physics - Work will continue with the application of neutron x-ray diffraction techniques for the determination of chemical structure, with microwave spectroscopy for measurements of the polarity of chemical bonds and for studies in radiation chemistry and with the use of molecular beams for the elucidation of the kinetics of chemical reactions.

(3) Metallurgy & Solid State.

(a) Metallurgy - The basic research programs in metallurgy and solid

state physics at the laboratory have as a common point of departure the investigation of the relationship between the structures of solids and their mechanical, electrical, thermal, and other important physical properties. In metallurgy, work is conducted with unirradiated metals and ceramics, whereas in solid state physics efforts are devoted to achieving an understanding of the interactions of neutrons, charged particles and ionizing radiations with all types of solids, including metals, semi-conductors, refractories, ionic and co-valently bonded crystals and plastics. The program in metallurgy has been devoted to such items as physical metallurgy, micro strains in crystals, high-temperature reactions, ceramics and metal surface studies. Future efforts will concern ceramics and cermets, basic studies on the oxidation of pure metals in gases, and continued studies supporting development of superior alloys for reactor use.

(b) Solid State Physics - directed almost wholly to the measurement and elucidation of radiation effects in solids and to the effects of radiation on the oxidation of metals. Increased efforts in metallurgy will be directed toward the study of ceramics and cermets; basic studies on the oxidation of pure metals in gases in the presence of radiation fields will continue. The next decade should witness important advances in solid-state physics.

e. LIFE SCIENCE RESEARCH

(1) Biology - Basic mission is the study of radiation effects in biological systems in an effort to design means of protection against radiation damage and counteracting damage after radiation has been absorbed. Work will continue to be concentrated along specific lines of basic genetical and cytological research and will not be dispersed more than is absolutely essential.

The criteria of radiation damage being developed in the Division may well form a basis for trying to find an answer to the question of whether there is a threshold for radiation-induced malignancies (leukemia), for studying the effects of Strontium-90, and other problems. It should be seriously considered at this time whether or not the laboratory should get involved in these studies which may well grow out of investigations going on at ORNL now. Such studies will require a large outlay of funds and should be carried on for at least 20 years for significant results.

Serious consideration should also be given to the need for trained botanists. From the long-range viewpoint, it would be wise to build up a strong ORNL plant science group since many basic problems can be investigated much better on plant material than in animals.

(a) Cytology & Genetics - Emphasis is on basic studies of cellular structure and function, and of the action of radiation on the cell and especially on the genetic apparatus. This program will continue at the present high level.

(b) Mammalian Genetics & Development - Basic questions about the nature of the mutation process require that many new experiments be performed to explore the exact nature of the relation between radiation intensity and mutation rate. Recent developments are significant to consideration of the genetic effects of fallout and occupational exposures. The present level of activity will continue although new projects will be initiated as certain major studies are completed.

(c) Microbial Protection & Recovery - Concerned with understanding the sequence of events - physical, chemical and biochemical - that follow the initial energy absorption process to the irreversible establishment

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of biological damage in material at the cell level. Work will be devoted to the role of protective agents and conditions, repair and other factors which may influence the effect of radiation more or less over the spectrum of linear energy transfer.

(d) Mammalian Recovery - Concerned with treatment of lethal total body radiation exposure. Future projects to include: the possibility of transplanting tissues by way of blood stream and other unusual routes, cell preservation studies aimed at growing functional cells ~~and~~ in tissue culture, studies of the normal histology and anatomy of the lymphatic system, and initiation of work on the problem of treating higher levels of radiation damage.

(e) Pathology - Physiology - These studies have been concerned with the pathogenesis of early and delayed somatic radiation effects in mammals with emphasis on the induction of leukemia and neoplasia. This program will be expanded to encompass the life shortening and carcinogenic effects in mice of chronic low-level radiation.

(f) Cell Physiology - The major objective of this project is the determination of the molecular basis of cell function. The findings will provide a background to facilitate determination of the effects of radiation and other insults on cellular function. No major increase in the program is anticipated.

(g) Biophysics - The biophysics research is concerned with the understanding of the basic primary physical and chemical events which underlie and govern the action of radiation in biological systems. Significant advances have been made by the application of electron spin resonance methods to biological materials. It is anticipated that these studies will be expanded in conjunction with an overall increase in the Commission-supported effort in biophysics and bioenergetics.

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(h) Radiation Immunology - These investigations are concerned with the fundamental immunological aspects of bone marrow and other tissue transplantation, and with fundamental immunological investigations. A modest expansion is planned with emphasis on the immunogenetic aspect of the problem.

(i) Biochemistry - The biochemistry projects at the Oak Ridge National Laboratory have been concerned with three major problems: intermediary metabolism in bacteria and plants, nucleic acid biochemistry, and protein synthesis. Considerable expansion is planned with emphasis on the interrelationships and genetic control of nucleic acid and protein biosynthesis, biochemical studies of gene action, and studies of cellular differentiation at the molecular level.

(2) Health Physics. Health physics must continue to develop as the nuclear technologies grow, particularly in industry. Basic to the science are the processes of the interactions of radiation with matter; work in this field, both theoretical and experimental, must continue. Also basic is good dosimetry; increasing emphasis will be placed on further research and development of these devices.

(3) Waste Disposal. The long-range objectives of the waste disposal and ecological research programs are: (1) to develop better and cheaper methods for the ultimate disposal of liquid and solid wastes in geologic formations isolated from the living environment, (2) to evaluate dilution and concentration factors in the environment which determine the degree of treatment required before low-level wastes are released to the ground or to surface waterways, (3) to develop more efficient methods for the treatment of large volume, low-level wastes, (4) to obtain quantitative information on the movement and rates of biogeochemical cycling of Sr-90, Cs-137, and other fission products in a variety of forest and fresh-water habitats.

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f. EDUCATION:

Besides making its facilities available to properly qualified faculty members, the laboratory provides training in specialized fields including reactor supervision, nuclear hazards evaluation, health physics, and on-the-job training for technical personnel from private industry. An extension of the educational activities at ORNL can be expected.

g. ISOTOPE RESEARCH AND PRODUCTION:

Isotope research and development will be directed primarily by the needs of the isotope production program. Continuing objectives are to increase the purity of all isotope preparations, lower costs, and to develop methods for converting radioisotopes into any desired chemical or physical form. It is expected that the number of personnel will increase in both the radioisotope and stable isotope programs. Private reactor operation and associated radioisotope production will have a great influence on this program during the next ten years. Inasmuch as industry will tend to make only those radioisotopes which can be profitably produced on a large scale, the ORNL radioisotope group will concentrate on making those materials available that others cannot or do not produce.

h. FACILITIES:

All the foregoing plans and activities require facilities. The present building program, when completed, should supply ORNL with most of the general-purpose laboratories it will need, at least over the next decade. Additional facilities which will be required include high-radiation level laboratory space, additional chemical process development hot cells in various locations, a 10 MEV Van de Graaff accelerator to extend the nuclear physics program, a hot laboratory for isotope separation of radioactive nuclides, and additional laboratory space for biology work in the present structure at Y-12 for increased work in radiation protection research, biochemistry, and plant and animal physiology.

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SUMMARY OF LONG RANGE PROGRAM SUBMITTED BY AMES LABORATORY

SECTION I - HIGHLIGHTS

1. PHYSICAL SCIENCE RESEARCH at Ames has, since its inception, been directed toward metallurgy, with primary emphasis on the development of methods for producing high-purity substances and evaluating properties of these materials. No major changes in the overall objectives are envisioned for the next five-year period. The authorized expansion of physical facilities will enhance the Laboratory's ability to produce quantities of highly pure metals and alloys and to evaluate the nuclear properties of solids.
2. EDUCATIONAL OPPORTUNITIES, made possible by the close relationship between Ames Laboratory and Iowa State University, have enabled about 30 metallurgists and about 400 other scientists and engineers to receive advanced graduate training at the Laboratory. Over a hundred of these former students are now employed by the other AEC laboratories and contractors.

SECTION II - INDIVIDUAL AMES LABORATORY PROGRAMS

1. THE PRIMARY PURPOSES of Ames are: 1. to conduct an expanding fundamental research program on atomic energy materials, with emphasis on metallurgy; and 2. to encourage the training of scientists and engineers, particularly in the fields of solid state physics, chemistry, metallurgy and ceramics.

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4. The BIOLOGY AND MEDICINE PROGRAM represents about 15 percent of the scientific effort at Berkeley. This includes the work of a BIO-ORGANIC CHEMISTRY group. The program includes cellular and sub-cellular radiobiology, studies of the hematopoietic system, biomedical studies with cyclotron beams, and other investigations of biomedical interest. A development program of novel and sophisticated instrumentation and techniques is continuing. Some expansion is expected.

5. A small CONTROLLED THERMONUCLEAR RESEARCH PROJECT and various other smaller projects account for the remaining 8 percent of the laboratory's effort.

6. An INORGANIC MATERIALS PROGRAM, to be interdisciplinary in nature, is expected to be launched in the near future. This work is of importance to reactor research, nuclear propulsion, controlled thermonuclear reactions, and space and missile technology. Initially, work will be in high temperature chemistry, physical chemistry of the solid state, metallurgy and ceramics, and general inorganic and physical chemistry. As many as 600 men may ultimately be required on this program.

7. FACILITIES AND PERSONNEL

The size of the Laboratory should be governed by the research programs. It is expected that the Laboratory will double in size during the next ten years. The number of people at Berkeley has increased from 1100 to 2200 in the next ten years.

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Experiments have become more complex, especially in high energy physics. New or enlarged areas of research, such as an Inorganic Materials Program, will add to the size of the Laboratory. The size of the Berkeley campus is expected to increase from 20,000 to 40,000 in the next ten years. The number of graduate students and post doctorals who will work at the Laboratory will probably also double. Operating funds also will have to grow substantially, probably to a level of $2\frac{1}{2}$ to 3 times the present ten years from now. Requirements for equipment and facilities must keep pace with the research program and the size of the staff. Many of the facilities are wartime buildings having outlived their usefulness. Some are in the way of the orderly development of the site. Substantial additional capital investments are anticipated. As a result of recent considerations of the University's master plan, additional building sites will be available to the Laboratory as needed, which will permit the Laboratory to double as necessary.

SECTION II
PROGRAM SUMMARY

1. PHYSICS

The Laboratory is one of the major centers of high energy physics in the world. The two accelerators, the Bevatron and the 184-inch cyclotron, together with their full complement of associated experimental equipment, are among the best in their fields.

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One of the most important of the experimental facilities available to it is the recently completed 72-inch liquid hydrogen bubble chamber. The immediate program is based on increasing the effectiveness and utilization of these machines by increasing the experimental and support facilities and by accelerating the development of detection apparatus and data handling techniques.

For the longer range period (five to ten years), the Laboratory will be engaged in an active experimental program with the modified Bevatron, and will be working on an accelerator development program to open up higher energy and current ranges presently unavailable to high energy physics investigations. Such a program will take a period of five to seven years of development and construction.

2. CHEMISTRY

The Laboratory has a unique standing in the field of nuclear chemistry. Its family of particle accelerators furnishes both the materials for research on radioactive isotopes and the tools to conduct experiments on nuclear reactions and their mechanisms. The 60-inch cyclotron and the heavy ion linear accelerator are the principal machines being utilized. The 184-inch cyclotron and the Bevatron are also being used. The discovery of plutonium and other transuranium elements, the synthesis of a large number of radioactive isotopes (including important tracers), the development of widely-employed methodology, and the training of many of the nation's

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nuclear chemists have been among the products of this research group. To increase the supply of transplutonium isotopes, an intensive production program was started ten years ago with the assistance of other AEC facilities. This program has involved the irradiation of plutonium 239 in the highest flux reactors available, first at Hanford, then at Chalk River, and lately at the MTR at Arco. The transmutation of elements to form new isotopes has always been an important part of the chemistry program. Major emphasis has been placed on the discovery of new elements, extending the periodic system. In the postwar years elements 97 to 102 inclusive have been added.

The future chemistry program will utilize the accelerators to an increasing extent. The 88-inch cyclotron will replace the 60-inch cyclotron as the major tool. The Hilac and the 88-inch cyclotron will have a unique partnership arrangement. For example, the discovery and pioneering studies of some isotopes of particular interest are now being made at the Hilac. The 88-inch cyclotron will then produce the isotopes in sufficient quantity to permit intensive studies. The 184-inch cyclotron and the Bevatron, particularly after the beam intensity improvemesnts, will find increased utilization for nuclear reaction studies.

The scientific programs in general depend on the continuous development of techniques and apparatus as a means of refining and extending the work. New techniques in chemistry, electronic

instrumentation, radiation detection, the handling of radioactive materials (with special problems in the transuranium region), cryogenics, and in computer data processing and evaluation are under constant vigorous development.

3. BIOLOGY AND MEDICINE

The Biology and Medicine Group has utilized, modified, and contributed to the tools and techniques of nuclear physics and chemistry in its approach to research. The Laboratory's accelerators are very important to its work, both as producers of isotopes and as a source of ionizing radiation for many applications. Of the present accelerators the 60-inch cyclotron, the 184-inch cyclotron, and the heavy ion linear accelerator are of primary interest. One of the benefits from a close association with the other divisions of the Laboratory and the many related departments of the University is the utilization by this group of many scientific talents in their approach to research.

The future plans for this group can only be defined in general terms. They will continue the development and use of new experimental and theoretical tools of nuclear physics and chemistry in the investigation of the major unsolved problems in biology and medicine, including the radiation syndrome, cancer, blood disorders, and arteriosclerosis. At the same time, this work will be carefully planned to avoid repetition of the work going on elsewhere.

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As in nuclear physics and chemistry the ability to do biological and medical research also depends heavily on a continued development program of novel and sophisticated instrumentation and techniques.

4. INORGANIC MATERIALS

Within the Chemistry Division there has been a continuing program of modest proportions concerned with the basic physical chemistry of matter, with some emphasis on high-temperature thermodynamics. The establishment of an Inorganic Materials Research program is proposed. In addition to expanding and broadening the scope of the chemistry work done at the Laboratory, this program will increase the knowledge of the properties of matarials, with special emphasis on the high temperature regions.

This work is of primary importance to the national needs, for it has immediate application to advanced problems in reactor research and development, nuclear propulsion, controlled thermonuclear reactions, and space and missile technology. The ability to enter such a program is the result of the University's attracting outstanding faculty members in the fields associated with materials research. Chemists, ceramists, metallurgists, solid state physicists, and mathematicians have been working together to make significant contributions to this field.

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The immediate plan, i.e., through the next five years, is to establish the program and to start the work in the four areas of primary interest: high temperature chemistry; physical chemistry of the solid state; metallurgy and ceramics; and general inorganic and physical chemistry. The longer range program will be to expand the areas of primary interest and to intensify the work on particular subjects which become of major importance.

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LONG RANGE PROGRAM
LAWRENCE RADIATION LABORATORY - LIVERMORE SITE
1959-1969[1]

INTRODUCTION

The Livermore Site of the Lawrence Radiation Laboratory, University of California, has expended since its formation a large portion of its effort in the field of nuclear weapons development. In fact, the weapons program has been and is expected to remain the main purpose of the Laboratory even though other projects will probably be added to the overall Laboratory program. This should not, however, detract from the important work now being done by the Laboratory in other areas of research and development. At the present time, in addition to the weapons program, there are several other programs being pursued vigorously by the Laboratory. Following is a very brief listing of the laboratory program:

1. MILITARY PROGRAMS
   a. Nuclear weapons development.
   b. Nuclear ramjet development (Pluto).
2. NON-MILITARY PROGRAMS
   a. Peaceful applications of nuclear explosives (Plowshare).
   b. High temperature reactor research.
   c. Controlled fusion reaction research (Sherwood).
   d. High speed computing.
   e. Geophysical research.
   f. Basic research.
   g. Educational program.

1/ Full text as submitted by the Laboratory September, 1959.

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In this report much less than a proportional fraction of the discussion is dedicated to the military program. This has three reasons:

Firstly: The question raised by the Joint Congressional Committee seems to be directed primarily toward peaceful applications.

Secondly: The pace of the weapons development is so great that detailed planning for the next ten years surpasses our ability to make predictions. Only the general outline can be forecast with some degree of assurance.

Thirdly: Since this is an unclassified report, the military program cannot be discussed in detail.

1. MILITARY PROGRAMS

a. Nuclear weapons development

The advancement in the field of nuclear explosives has certainly been large during the last ten years. If at the present time the prospects for the next ten years look less impressive than those of the period since 1949, this probably is due to our limited imagination rather than to any objective reason. Surely, important advancements will be forthcoming in the weapons field in the next ten years if the present level of effort in this field is continued. Of course, it must be recognized that the speed of the technical advancement in nuclear weapons depends a great deal on the final outcome of the political deliberations which are now in progress. Certainly, the advancement in nuclear weapons will be slowed if we are not allowed to return to a nuclear testing scheme which will allow full-scale detonations. Even in the event of a complete nuclear test ban, some progress is still possible along several lines.

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It should be pointed out that personnel of the Laboratory are dedicated to the idea that the Laboratory can best serve the purposes of a stable peace by contributing to the national state of preparedness. In case our work on weapons is slowed down by a moratorium, continued vigorous support of the weapons effort will be necessary. This support will be sufficient to ensure some progress and to ensure the continued availability of a highly capable group who will make essential contributions to the safety of the country. On the other hand, if a substantial diversion of the Laboratory's effort were made from the weapons program it will change the nature of the Laboratory in a basic way. Such a change might considerably impair the overall effectiveness of the Laboratory.

The Lawrence Radiation Laboratory has been developing a capability for the past several years which will enable us to engineer into weapons some of those nuclear devices which we have developed. A major portion of the Laboratory's effort in the weapons program is now committed to the weaponization projects that we are presently undertaking. We expect that the percentage of the overall weapon program effort being devoted to this weaponization engineering will decrease some after the next two or three years, but even then it will continue to be a considerable portion of the overall weapons program at the Laboratory.

The search for new ideas and concepts in the nuclear weapons field will continue to be explored throughout the next ten year period. It is vital that this search continue in this field if the United States is to

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maintain its present position in the world. The following single example is given here to emphasize this point: it is essential that we continue to look for new ways to reduce the weight and size of our nuclear explosives to the maximum extent possible. In the field of missiles a weight reduction by a substantial factor will result in a weight reduction of the missile, a reduction of the size and extent of the launching site, and a reduction of the operational expenditures connected with that launching site. Altogether, such a reduction is likely to result in the saving of billions of dollars. In addition, and by no means of less importance, a weight reduction is likely to be of great help in operational readiness. Thus, expected developments in this area can greatly contribute to our assurance that we shall be able to retaliate even though a heavy surprise attack is launched against the United States. Such assurance in itself would be a powerful guarantee against surprise attacks during the 1960's. This example has been selected because it is the most straightforward and the most predictable provided testing is resumed. Other examples exist which have even greater potentialities for national defense.

It is important to emphasize the uncertain character of our predictions on future developments of nuclear explosives. In the past, further developments have been systematically underestimated. It is proper to remember that in 1950 serious doubts were expressed about the utility of thermonuclear explosions. While the importance of this development had been defended at that time, the overriding argument for the hydrogen bomb was not even mentioned: that is the combination of thermonuclear explosions with intercontinental ballistic missiles, which has given rise to the most menacing aggressive weapon of this decade.

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b. Nuclear ramjet development (Pluto)

For the past few years, the Lawrence Radiation Laboratory has been engaged in the feasibility study and the initial effort connected with the development of a nuclear ramjet engine. The role of the Laboratory at the present time is confined to the proof that a reactor of appropriate properties can be constructed and run on the ground. Presently, facilities are being constructed at the Nevada Test Site for the purpose of operating engineering test reactors. For the future, we believe that the Pluto program should proceed in step-wise fashion. The expenditure of a great amount of money on the ramjet can be postponed until feasibility and nature of the reactor is satisfactorily established. The reactor tests presently planned for Nevada should, however, proceed rapidly in order to avoid later pressure for an uneconomic crash program.

Following the initial phase of this program, the reactor has to be incorporated into a ramjet engine and it must be flight-tested. During this phase, skills will be required which are not available at the Lawrence Radiation Laboratory and could not be developed without a basic change in the nature and purpose of the Laboratory. We, therefore, believe that full responsibility for ramjet engine production certainly cannot be vested in the hands of the Laboratory. At the same time, we believe that it will be necessary during this phase of the development to make certain required modifications of the reactor and that these modifications can best be carried out by the same people who have developed the reactor. Thus, the Laboratory has this important responsibility to fulfill during this phase of the development.

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The next phase in the development is that of production. This, we believe, should be the responsibility of an appropriate selected private company. In this respect, we expect that the same procedures would apply to Pluto as to other contracts between the Air Force and airplane companies.

c. General discussion of the problem of classification

The overriding need for secrecy has set the weapons laboratories aside from other research institutions. In many instances, it has cut us off from valuable discussions with the scientific community. It has been a reason for reluctance of young scientists to join our ranks and it has, in some cases, slowed down the impact of our own results on general scientific progress. These disadvantages are difficult to demonstrate from case to case. They are, nevertheless, real and their cumulative effort is great.

In the past years, declassification has eased these difficulties. The dissemination of knowledge on nuclear reactors has touched our Laboratory to a very small extent. On the other hand, the declassification of Sherwood has allowed us to obtain the advice of some excellent people. The long-range benefits of the exchange of information on Sherwood are likely to become most significant.

Short of declassification, there is the expedient of a proper extension of the group within which full discussion is possible.

The nature and functioning of the Laboratory during the next decade will depend to a very considerable extent on the policy of classification which will be adopted from now on. If it should be found that in an age in which we no longer possess a monopoly on nuclear weapons, classification can be further liberalized; this certainly will contribute to the health and effectiveness of the Laboratory.

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2. NON-MILITARY PROGRAMS

In connection with the work performed throughout the past years in Livermore, there has developed a particular skill, a special set of equipment, and what is most important, a community of people with a unique know-how. We believe that all this capability can be best directed toward the field which is best described as applied science or advanced and inventive engineering.

These words cover a very wide field indeed. Within this wide field, we must select those special activities in which we have a best chance to make an outstanding contribution. In considering the long-range program of the Laboratory, we have, therefore, tried to avoid additional enterprises even though such enterprises may look interesting and challenging, unless we feel that we happen to be specifically equipped for a particular responsibility so that our duties can be performed in the most efficient manner.

a. Peaceful applications of nuclear explosives (Plowshare)

The use of nuclear explosives for peaceful purposes has been considered seriously in Livermore for almost three years. Nevertheless, the total amount of effort so far has been a very small fraction of the work of the Laboratory. Yet we believe that the potentialities of this development are exceedingly great. They can affect water transportation by the digging of harbors and canals. One can greatly increase the usefulness of water resources by the establishment of dams, by breaking up impermeable underground formations and by other means. Several attacks have been discussed on the problem of petroleum supplies, and while the difficulties seem great, the possible reward in the exploitation of tar sands and shales could have consequences beyond any present

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estimates. If one adds to the basic problems of water and oil, the further possibilities of big-scale underground chemical reactions, the creation of underground heat supplies and other proposals which may bear fruit, one can see a real possibility that the development of Plowshare may be of the greatest benefit to our country and, in fact, to people beyond our boundaries.

It is not to be expected that all of these possibilities can be realized and even less that they will come to fruition in the next decade. On the other hand, we are convinced that some very substantial successes will be achieved in the coming decade provided that the Plowshare program is vigorously pursued.

The role of LRL in this program should consist in the development of new tools and new approaches. The new tools include the invention of nuclear explosives which can be used for earth-moving purposes without dissemination of dangerous radioactivity. They further include the development of nuclear explosives of small yield at small cost. At the present time, we are hampered in our plans by the fact that, as a rule, nuclear explosives compete favorably with other methods of blasting only incase the explosion is big.

The investigations of new uses of nuclear explosives are concerned with containment of nuclear explosions, distribution of the radioactivity produced, changes in the rock adjacent to the explosion, and, generally, effects of the intense heat and pressure produced by the explosion.

Beyond the stages of the development of nuclear explosives and of the investigation of desirable effects that these explosives may produce there is a great abundance of challenging tasks in the field of the

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economical applications of Plowshare. The Laboratory does not propose to go deeply into these further developments. Indeed, we expect that these opportunities will greatly surpass in scope anything that the Laboratory could afford to do. We have discussed with Sandia Corporation, with the Corps of Engineers, and with the Bureau of Mines such possible applications, and we hope that these as well as other government organizations will participate in future developments.

Most particularly, we expect that private industry will take full advantage of the opportunities afforded by Plowshare. In addition to numerous expressions of interest, in one special case a substantial enterprise has been started by a private company (The Richfield Company in connection with the Athabasca tar sands).

We hope that private companies will exploit the possibilities which are opened up as soon as this can be done with full effectiveness and with complete safety. We feel that we should limit our efforts to the developmental phase and to such assistance in further tasks which will be required by private industry.

Of course, there may occur applications of such magnitude which no private industry can undertake. If such a situation should arise, we feel that the government should establish the proper methods of handling the situation and we believe that in such a case, the Laboratory will serve by making available those tools and by performing those adaptations which will make the task easier.

b. <u>High-temperature reactor research</u>

In connection with work on the nuclear ramjet, the Laboratory is acquiring special knowledge on high-temperature, gas-cooled reactors. The range of temperatures is very high; in fact, almost twice as high as any now planned for industrial uses.

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Apart from a thermodynamic efficiency, high temperatures have the particular feature that the nuclear fuel and the fission products can diffuse more easily into the material of the moderator. This makes it possible to handle fuel elements in a more flexible and more economic manner. Chemical applications of these high temperatures could also be explored.

In case the reactor for the ramjet proceeds satisfactorily, the Laboratory has the long-range plan to turn its special knowledge gained in this high-temperature field toward peaceful purposes. In particular, the Laboratory should be interested in establishing a small scale prototype of such a reactor. It will have to be seen later whether the Laboratory could do so on its own effort or whether cooperation with private enterprise would be preferable. In any case, we would like to limit our contribution to the establishment of the feasibility of an economical high temperature, gas-cooled nuclear reactor. We hope that in case we succeed, other agencies, and most particularly private industry, will be in a position to exploit the advances which we may have made.

The Laboratory recognizes that in the general field of nuclear reactors our country possesses great and effective research institutions, such as the Argonne National Laboratory, the Oak Ridge National Laboratory, and the Brookhaven National Laboratory, with which, as a general rule, we do not desire to compete. Consequently, we want to limit our contribution to the special field of ultra high-temperature, gas-cooled reactors in which field we are gaining experience due to work in line with present responsibilities.

c. Controlled fusion reaction research (Sherwood)

The Lawrence Radiation Laboratory, in Livermore and in Berkeley, has been among the first who in this country have attacked the problem of controlled fusion. The status of this problem is now, according to general agreement, as follows:

1. Feasibility:

To establish a controlled thermonuclear reaction one has to confine an extremely high-temperature ionized gas (plasma) with the help of a magnetic field.

SUMMARY OF LONG RANGE PROGRAM SUBMITTED BY AMES LABORATORY

SECTION I - HIGHLIGHTS

1. PHYSICAL SCIENCE RESEARCH at Ames has, since its inception, been directed toward metallurgy, with primary emphasis on the development of methods for producing high-purity substances and evaluating properties of these materials. No major changes in the overall objectives are envisioned for the next five-year period. The authorized expansion of physical facilities will enhance the Laboratory's ability to produce quantities of highly pure metals and alloys and to evaluate the nuclear properties of solids.
2. EDUCATIONAL OPPORTUNITIES, made possible by the close relationship between Ames Laboratory and Iowa State University, have enabled about 30 metallurgists and about 400 other scientists and engineers to receive advanced graduate training at the Laboratory. Over a hundred of these former students are now employed by the other AEC laboratories and contractors.

SECTION II - INDIVIDUAL AMES LABORATORY PROGRAMS

1. THE PRIMARY PURPOSES of Ames are: 1. to conduct an expanding fundamental research program on atomic energy materials, with emphasis on metallurgy; and 2. to encourage the training of scientists and engineers, particularly in the fields of solid state physics, chemistry, metallurgy and ceramics.

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2. THE GENERAL CHARACTER OF THE SCIENTIFIC PROGRAM has confined itself to two major areas:

   a. Development of methods for producing uranium, thorium yttrium and the rare earths; and

   b. Evaluation of the chemical, physical, engineering, and nuclear properties of these and other metals and alloys utilized in the atomic energy program.

3. RESEARCH PROGRAMS (1960-65)

   a. Reactor development research programs will concentrate on metals such as thorium and its alloys, yttrium and its alloys, rare-earth metals and their alloys, properties of metals and ceramics at temperatures above 1000°C, effect of non-metallic impurities on metal properties, the measurement of engineering properties such as fatigue and corrosion rate at relatively high temperatures, new pyroprocessing techniques and the measurement of physical properties at high temperatures.

   b. Work in high energy physics will continue to use nuclear emulsions, although it may be supplemented by the use of solid luminescence chambers.

   c. Work in nuclear structure and neutron physics will continue to take advantage of the unique characteristics of the Iowa State Synchrotron.

   d. Chemistry research will consist of fundamental studies on the mechanism of various separation processes such as ion exchange, solvent extraction and sublimation, as well as the development of analytical and spectrochemical analytical methods.

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e. Future work in metallurgy and solid state physics will take advantage of new techniques, such as de Haas-van Alphen effect measurements on single crystals, the use of ionic crystals, the measurement of magneto-accoustic effects on metallic crystals at 1° absolute, high- pressure work and the measurement of fundamental properties that will help determine the real nature of the solid state.

4. ADDITIONAL FACILITIES (1960-1965) - A new Metals Development Building will be available in late 1960 with 47,000 square feet of space. This will alleviate a crowded condition brought about by carrying out production work in an area designed for smaller scale work.

The authorized Ames Laboratory Research Reactor will round out the five-year facility requirements and permit some reassignments to improve the space situation.

5. MANPOWER REQUIREMENTS (1960-1965) - The successful performance of Ames' basic research programs requires that a nucleus of competent and experienced group leaders and specialists in the various fields essential to the atomic energy program be maintained.

The availability of additional facilities will require additional service, maintenance and supervisory personnel.

An orderly growth in personnel by the laboratory as a whole is expected, with personnel being added in those areas that are most productive and whose research efforts are most in line with the AEC's mission in the next few years. It is expected that six new

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research groups will be needed in the next five years. Five would do fundamental basic research and one, applied engineering research related to the reactor or to the pure metals program. The actual number will be dependent upon the availability of qualified personnel and funds.

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SUMMARY OF LONG RANGE PROGRAM
SUBMITTED BY LAWRENCE RADIATION LABORATORY - BERKELEY

SECTION I - HIGHLIGHTS

1. Primarily a BASIC SCIENCE laboratory. Its scientific program covers physics, chemistry, biology and medicine, and miscellaneous smaller projects. It has a close association with a university and is the only major AEC-supported laboratory located on the campus of a large university.

2. The PHYSICS RESEARCH PROGRAM represents about 55 percent of the effort, and concentrates almost entirely on high energy physics. It is one of the major centers of high energy physics in the world. In the future the Laboratory will continue to perform an active experimental program with the modified and improved Bevatron (a 6.2 Bev proton synchrotron) and will be actively working on an accelerator development program. Substantial expansion is envisioned.

3. The CHEMISTRY RESEARCH PROGRAM uses some 22 percent of the laboratory's effort. The laboratory has a unique standing in nuclear chemistry. The particle accelerators furnish research materials as well as the tools with which to work. The heavy ion linear accelerator is the principal machine used in transplutonium element research and isotope studies in general. The future chemistry program will utilize accelerators to an increasing extent. An 88-inch high current cyclotron is being built. Expansion in scope and effort is anticipated.

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4. The BIOLOGY AND MEDICINE PROGRAM represents about 15 percent of the scientific effort at Berkeley. This includes the work of a BIO-ORGANIC CHEMISTRY group. The program includes cellular and sub-cellular radiobiology, studies of the hematopoietic system, biomedical studies with cyclotron beams, and other investigations of biomedical interest. A development program of novel and sophisticated instrumentation and techniques is continuing. Some expansion is expected.

5. A small CONTROLLED THERMONUCLEAR RESEARCH PROJECT and various other smaller projects account for the remaining 8 percent of the laboratory's effort.

6. An INORGANIC MATERIALS PROGRAM, to be interdisciplinary in nature, is expected to be launched in the near future. This work is of importance to reactor research, nuclear propulsion, controlled thermonuclear reactions, and space and missile technology. Initially, work will be in high temperature chemistry, physical chemistry of the solid state, metallurgy and ceramics, and general inorganic and physical chemistry. As many as 600 men may ultimately be required on this program.

7. FACILITIES AND PERSONNEL

The size of the Laboratory should be governed by the research programs. It is expected that the Laboratory will double in size during the next ten years. The number of people at Berkeley has increased from 1100 to 2200 in the next ten years.

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Experiments have become more complex, especially in high energy physics. New or enlarged areas of research, such as an Inorganic Materials Program, will add to the size of the Laboratory. The size of the Berkeley campus is expected to increase from 20,000 to 40,000 in the next ten years. The number of graduate students and post doctorals who will work at the Laboratory will probably also double. Operating funds also will have to grow substantially, probably to a level of 2½ to 3 times the present ten years from now. Requirements for equipment and facilities must keep pace with the research program and the size of the staff. Many of the facilities are wartime buildings having outlived their usefulness. Some are in the way of the orderly development of the site. Substantial additional capital investments are anticipated. As a result of recent considerations of the University's master plan, additional building sites will be available to the Laboratory as needed, which will permit the Laboratory to double as necessary.

SECTION II
PROGRAM SUMMARY

1. PHYSICS

The Laboratory is one of the major centers of high energy physics in the world. The two accelerators, the Bevatron and the 184-inch cyclotron, together with their full complement of associated experimental equipment, are among the best in their fields.

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One of the most important of the experimental facilities available to it is the recently completed 72-inch liquid hydrogen bubble chamber. The immediate program is based on increasing the effectiveness and utilization of these machines by increasing the experimental and support facilities and by accelerating the development of detection apparatus and data handling techniques.

For the longer range period (five to ten years), the Laboratory will be engaged in an active experimental program with the modified Bevatron, and will be working on an accelerator development program to open up higher energy and current ranges presently unavailable to high energy physics investigations. Such a program will take a period of five to seven years of development and construction.

2. CHEMISTRY

The Laboratory has a unique standing in the field of nuclear chemistry. Its family of particle accelerators furnishes both the materials for research on radioactive isotopes and the tools to conduct experiments on nuclear reactions and their mechanisms. The 60-inch cyclotron and the heavy ion linear accelerator are the principal machines being utilized. The 184-inch cyclotron and the Bevatron are also being used. The discovery of plutonium and other transuranium elements, the synthesis of a large number of radioactive isotopes (including important tracers), the development of widely-employed methodology, and the training of many of the nation's

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nuclear chemists have been among the products of this research group. To increase the supply of transplutonium isotopes, an intensive production program was started ten years ago with the assistance of other AEC facilities. This program has involved the irradiation of plutonium 239 in the highest flux reactors available, first at Hanford, then at Chalk River, and lately at the MTR at Arco. The transmutation of elements to form new isotopes has always been an important part of the chemistry program. Major emphasis has been placed on the discovery of new elements, extending the periodic system. In the postwar years elements 97 to 102 inclusive have been added.

The future chemistry program will utilize the accelerators to an increasing extent. The 88-inch cyclotron will replace the 60-inch cyclotron as the major tool. The Hilac and the 88-inch cyclotron will have a unique partnership arrangement. For example, the discovery and pioneering studies of some isotopes of particular interest are now being made at the Hilac. The 88-inch cyclotron will then produce the isotopes in sufficient quantity to permit intensive studies. The 184-inch cyclotron and the Bevatron, particularly after the beam intensity improvemesnts, will find increased utilization for nuclear reaction studies.

The scientific programs in general depend on the continuous development of techniques and apparatus as a means of refining and extending the work. New techniques in chemistry, electronic

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instrumentation, radiation detection, the handling of radioactive materials (with special problems in the transuranium region), cryogenics, and in computer data processing and evaluation are under constant vigorous development.

3. BIOLOGY AND MEDICINE

The Biology and Medicine Group has utilized, modified, and contributed to the tools and techniques of nuclear physics and chemistry in its approach to research. The Laboratory's accelerators are very important to its work, both as producers of isotopes and as a source of ionizing radiation for many applications. Of the present accelerators the 60-inch cyclotron, the 184-inch cyclotron, and the heavy ion linear accelerator are of primary interest. One of the benefits from a close association with the other divisions of the Laboratory and the many related departments of the University is the utilization by this group of many scientific talents in their approach to research.

The future plans for this group can only be defined in general terms. They will continue the development and use of new experimental and theoretical tools of nuclear physics and chemistry in the investigation of the major unsolved problems in biology and medicine, including the radiation syndrome, cancer, blood disorders, and arteriosclerosis. At the same time, this work will be carefully planned to avoid repetition of the work going on elsewhere.

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As in nuclear physics and chemistry the ability to do biological and medical research also depends heavily on a continued development program of novel and sophisticated instrumentation and techniques.

4. INORGANIC MATERIALS

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LONG RANGE PROGRAM
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b. Nuclear ramjet development (Pluto)

For the past few years, the Lawrence Radiation Laboratory has been engaged in the feasibility study and the initial effort connected with the development of a nuclear ramjet engine. The role of the Laboratory at the present time is confined to the proof that a reactor of appropriate properties can be constructed and run on the ground. Presently, facilities are being constructed at the Nevada Test Site for the purpose of operating engineering test reactors. For the future, we believe that the Pluto program should proceed in step-wise fashion. The expenditure of a great amount of money on the ramjet can be postponed until feasibility and nature of the reactor is satisfactorily established. The reactor tests presently planned for Nevada should, however, proceed rapidly in order to avoid later pressure for an uneconomic crash program.

Following the initial phase of this program, the reactor has to be incorporated into a ramjet engine and it must be flight-tested. During this phase, skills will be required which are not available at the Lawrence Radiation Laboratory and could not be developed without a basic change in the nature and purpose of the Laboratory. We, therefore, believe that full responsibility for ramjet engine production certainly cannot be vested in the hands of the Laboratory. At the same time, we believe that it will be necessary during this phase of the development to make certain required modifications of the reactor and that these modifications can best be carried out by the same people who have developed the reactor. Thus, the Laboratory has this important responsibility to fulfill during this phase of the development.

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The next phase in the development is that of production. This, we believe, should be the responsibility of an appropriate selected private company. In this respect, we expect that the same procedures would apply to Pluto as to other contracts between the Air Force and airplane companies.

c. General discussion of the problem of classification

The overriding need for secrecy has set the weapons laboratories aside from other research institutions. In many instances, it has cut us off from valuable discussions with the scientific community. It has been a reason for reluctance of young scientists to join our ranks and it has, in some cases, slowed down the impact of our own results on general scientific progress. These disadvantages are difficult to demonstrate from case to case. They are, nevertheless, real and their cumulative effort is great.

In the past years, declassification has eased these difficulties. The dissemination of knowledge on nuclear reactors has touched our laboratory to a very small extent. On the other hand, the declassification of Sherwood has allowed us to obtain the advice of some excellent people. The long-range benefits of the exchange of information on Sherwood are likely to become most significant.

Short of declassification, there is the expedient of a proper extension of the group within which full discussion is possible.

The nature and functioning of the Laboratory during the next decade will depend to a very considerable extent on the policy of classification which will be adopted from now on. If it should be found that in an age in which we no longer possess a monopoly on nuclear weapons, classification can be further liberalized; this certainly will contribute to the health and effectiveness of the Laboratory.

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2. NON-MILITARY PROGRAMS

In connection with the work performed throughout the past years in Livermore, there has developed a particular skill, a special set of equipment, and what is most important, a community of people with a unique know-how. We believe that all this capability can be best directed toward the field which is best described as applied science or advanced and inventive engineering.

These words cover a very wide field indeed. Within this wide field, we must select those special activities in which we have a best chance to make an outstanding contribution. In considering the long-range program of the Laboratory, we have, therefore, tried to avoid additional enterprises even though such enterprises may look interesting and challenging, unless we feel that we happen to be specifically equipped for a particular responsibility so that our duties can be performed in the most efficient manner.

a. Peaceful applications of nuclear explosives (Plowshare)

The use of nuclear explosives for peaceful purposes has been considered seriously in Livermore for almost three years. Nevertheless, the total amount of effort so far has been a very small fraction of the work of the Laboratory. Yet we believe that the potentialities of this development are exceedingly great. They can affect water transportation by the digging of harbors and canals. One can greatly increase the usefulness of water resources by the establishment of dams, by breaking up impermeable underground formations and by other means. Several attacks have been discussed on the problem of petroleum supplies, and while the difficulties seem great, the possible reward in the exploitation of tar sands and shales could have consequences beyond any present

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estimates. If one adds to the basic problems of water and oil, the further possibilities of big-scale underground chemical reactions, the creation of underground heat supplies and other proposals which may bear fruit, one can see a real possibility that the development of Plowshare may be of the greatest benefit to our country and, in fact, to people beyond our boundaries.

It is not to be expected that all of these possibilities can be realized and even less that they will come to fruition in the next decade. On the other hand, we are convinced that some very substantial successes will be achieved in the coming decade provided that the Plowshare program is vigorously pursued.

The role of LRL in this program should consist in the development of new tools and new approaches. The new tools include the invention of nuclear explosives which can be used for earth-moving purposes without dissemination of dangerous radioactivity. They further include the development of nuclear explosives of small yield at small cost. At the present time, we are hampered in our plans by the fact that, as a rule, nuclear explosives compete favorably with other methods of blasting only incase the explosion is big.

The investigations of new uses of nuclear explosives are concerned with containment of nuclear explosions, distribution of the radioactivity produced, changes in the rock adjacent to the explosion, and, generally, effects of the intense heat and pressure produced by the explosion.

Beyond the stages of the development of nuclear explosives and of the investigation of desirable effects that these explosives may produce there is a great abundance of challenging tasks in the field of the

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economical applications of Plowshare. The Laboratory does not propose to go deeply into these further developments. Indeed, we expect that these opportunities will greatly surpass in scope anything that the Laboratory could afford to do. We have discussed with Sandia Corporation, with the Corps of Engineers, and with the Bureau of Mines such possible applications, and we hope that these as well as other government organizations will participate in future developments.

Most particularly, we expect that private industry will take full advantage of the opportunities afforded by Plowshare. In addition to numerous expressions of interest, in one special case a substantial enterprise has been started by a private company (The Richfield Company in connection with the Athabasca tar sands).

We hope that private companies will exploit the possibilities which are opened up as soon as this can be done with full effectiveness and with complete safety. We feel that we should limit our efforts to the developmental phase and to such assistance in further tasks which will be required by private industry.

Of course, there may occur applications of such magnitude which no private industry can undertake. If such a situation should arise, we feel that the government should establish the proper methods of handling the situation and we believe that in such a case, the Laboratory will serve by making available those tools and by performing those adaptations which will make the task easier.

b. <u>High-temperature reactor research</u>

In connection with work on the nuclear ramjet, the Laboratory is acquiring special knowledge on high-temperature, gas-cooled reactors. The range of temperatures is very high; in fact, almost twice as high as any now planned for industrial uses.

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Apart from a thermodynamic efficiency, high temperatures have the particular feature that the nuclear fuel and the fission products can diffuse more easily into the material of the moderator. This makes it possible to handle fuel elements in a more flexible and more economic manner. Chemical applications of these high temperatures could also be explored.

In case the reactor for the ramjet proceeds satisfactorily, the Laboratory has the long-range plan to turn its special knowledge gained in this high-temperature field toward peaceful purposes. In particular, the Laboratory should be interested in establishing a small scale prototype of such a reactor. It will have to be seen later whether the Laboratory could do so on its own effort or whether cooperation with private enterprise would be preferable. In any case, we would like to limit our contribution to the establishment of the feasibility of an economical high temperature, gas-cooled nuclear reactor. We hope that in case we succeed, other agencies, and most particularly private industry, will be in a position to exploit the advances which we may have made.

The Laboratory recognizes that in the general field of nuclear reactors our country possesses great and effective research institutions, such as the Argonne National Laboratory, the Oak Ridge National Laboratory, and the Brookhaven National Laboratory, with which, as a general rule, we do not desire to compete. Consequently, we want to limit our contribution to the special field of ultra high-temperature, gas-cooled reactors in which field we are gaining experience due to work in line with present responsibilities.

c. Controlled fusion reaction research (Sherwood)

The Lawrence Radiation Laboratory, in Livermore and in Berkeley, has been among the first who in this country have attacked the problem of controlled fusion. The status of this problem is now, according to general agreement, as follows:

1. Feasibility:

To establish a controlled thermonuclear reaction one has to confine an extremely high-temperature ionized gas (plasma) with the help of a magnetic field.

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The problem of the production and confinement of a sufficiently hot plasma appears to be most difficult. In a broad international effort in which our Laboratory has played a vigorous and reputable part, many reasons for these losses have been discussed and understood. There is expectation that within the next ten years a working model of a controlled thermonuclear reaction can be established. At the same time, it must be pointed out that this is only a hope and not a certainty. In case there should be success, we feel sure that our Laboratory will contribute in an important way to such a success.

However, it must be fully realized that even a successful model of a controlled thermonuclear reaction will not make economical exploitation of controlled thermonuclear power immediately available. Considering the difficulties encountered so far, the Laboratory expects that it will be several decades before Sherwood will produce a plant that can successfully compete in energy production with conventional or nuclear power sources.

2. Advantages:

In case an economical power plant based on Sherwood plans can be established, the following advantages are expected:

(a) Inexpensive and practically inexhaustible fuel.

(b) Better control of by-products. The thermonuclear reaction produces fewer and more easily controlled radioactivities. Generally, the hazards connected with such a reactor are expected to be much smaller than those connected with a fission reactor.

(c) Direct conversion of a substantial part of the thermonuclear power into electricity. The methods now contemplated in confining the hot, ionized gas lend themselves in a simple and natural fashion to the problem of direct conversion. This, in turn, may substantially decrease the expense of auxiliary equipment.

3. Short-range benefits:

The investigation of controlled fusion has led us into a thorough scientific

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study of the behavior of hot ionized gases of plasmas. These plasmas play an important role in electrical discharges. It is to be expected that before Sherwood will solve the difficult problem of controlled energy release from fusion, it will have led to new and usable techniques in the handling of electrical discharges and connected phenomena.

4. Recommendations and relations to industry:

In the past two years, most effective research teams have been built up dedicated to the solution of the problem of controlled thermonuclear power. In the absence of an expectation of early success we do not intend further to increase our team. On the other hand, we believe that it would be wasteful and inefficient not to encourage this expert group to pursue further the scientific and technical investigations which we have described above. In the last year, the work of this group has been greatly invigorated by the declassification of Sherwood and by wider cooperation with the scientific community and with industry. We believe that the industries and the scientific institutions should be encouraged to take an increasing part in the Sherwood research, particularly, if they do it in fields in which that industrial or scientific institution already possesses some special knowledge. On the other hand, we do not believe that the concentrated high-grade effort represented in the several Sherwood laboratories in this country could be quickly or effectively replaced by industrial teams. The Laboratory, therefore, recommends that the Sherwood effort in the Lawrence Radiation Laboratory should continue at the present level and along established lines.

d. High speed computing

The solution of complicated and difficult physical problems through the aid of high speed computing machines has already become a very important activity within the Laboratory program. It is certain to be even more important in the Laboratory's future activities. Certain problems relative to weapons' design have been the most complex hitherto solved. There are, however, very large numbers of such problems in

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newly developing scientific fields, both applied and fundamental. The Laboratory has an unsurpassed combination of experience in the use of computing machines together with the ability to analyze physical situations mathmatically in a form appropriate to numerical solution of differential equations. We foresee in the next decade that this method will be applied to other problems, ranging from meteorologic to the field theory of elementary particles, and we expect to be in the forefront of this activity. For this purpose it will be necessary to acquire and perhaps also to participate in the design of computing machines of increased memory capacity and increased speed, as components which allow such advances become available. Almost 10% of the Laboratory's operating budget has been spent on computing facilities and operation (including a large staff of programmers) and we fully expect this situation to continue.

e. Geophysics

In considering the long-range program of the Laboratory, we have come to the conclusion that the field of geophysics is one in which we might, under proper circumstances, make a worthwhile contribution during the next decade. Among geophysical topics, we first want to consider meteorology..

In order to perform other duties, the Laboratory must have an excellent set of high-speed computing machines. What is even more important, we must have the ability to solve the problems in physics, mathematics, and computation which are necessary to predict the outcome of involved processes in which hydrodynamics plays an important part. We believe that in this particular field the Laboratory has unique capability.

A small portion of this talent and this equipment could be turned toward the important problem of weather prediction. At present, an exceedingly small effort is devoted to this particular purpose. Our immediate plan in which only two or three people are involved is not to make progress in the field but to evaluate our capability of making real progress if greater effort were to be employed.

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It is obvious that weather prediction in itself is of extremely great importance, both on the national and the international scene. One should further remember that any further possibility of weather modification is closely connected with the question of weather prediction. In fact, without weather prediction, no procedure of weather modification can be reliably judged and evaluated.

Our computing machines and our expert physical and mathematical analysis capability are not our only asset in the field of meteorology. Radioactive materials from nuclear tests have helped to elucidate some important problems of general circulation. In particular, they have made a basic contribution to the understanding of the stratosphere. We believe that use of radioactive materials may be exploited more sensitively and, therefore, more fully. Our radiochemists and more generally our group concerned with bomb diagnostics could make important contributions in this field.

There are other branches of geophysics in which the Laboratory has at present an interest. In connection with the observation, detection, and hiding of nuclear explosions we have acquired some expertness in high atmosphere physics, in electrical phenomena of the atmosphere and in seismology. Future nuclear explosions could give valuable further information, both about seismology and the nature of the upper atmosphere. Part of this work would have to be undertaken as a joint effort with the national satellite program. It would seem to us proper to approach these problems in a thorough scientific spirit and to pursue them as far as possible in full cooperation with the whole scientific community.

f. Basic research

It is necessary for the continued health of a scientific laboratory to devote some of its efforts to pure research. This is of importance for many of the individuals who are at their best if they can participate to some extent in basic scientific work. It is also of importance for the standing of the Laboratory.

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Without significant publications, the Laboratory's reputation cannot be kept at a sufficiently high level and the Laboratory's ability of recruiting and keeping outstanding people will suffer. Finally, the cross fertilization between pure and applied scientific efforts cannot be overestimated.

Among the many possibilities of pure scientific work, the Lawrence Radiation Laboratory at Livermore has concentrated upon those few which are either particularly relevant to our other efforts or for which we are particularly well equipped.

We have paid and we are planning to pay considerable attention to low energy nuclear physics or neutronics. This is a field of great importance in connection with the development of nuclear explosives and of reactors.

A small percentage of our excellent computational equipment has been devoted and is planned in the future to be devoted to purely scientific work. Thus, we have performed calculations about the interior constitution and development of stars and we have also used our equipment to analyze the behavior of elementary particles which topic at present commands top interest among the physicists of the world. These are just two examples and future work might vary to a great extent, being adapted in each case to the particular opportunity to use our machines to the best scientific advantage.

A whole new class of possibilities in pure research is likely to open up in connection with work on Plowshare. Nuclear explosions can be a source of many phenomena whose scientific investigation is of great value. Thus, nuclear explosives may become the best source of sharp neutron pulses and nuclear explosives could be the best means of producing new elements, thereby extending our knowledge of chemistry. Nuclear explosives might also be used to study the earth's interior and the wide region extending from our atmosphere into interplanetary space. These two last topics are on the borderline between pure and applied science and have been already mentioned in the previous section.

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g. Education

One area in which the Lawrence Radiation Laboratory in Livermore can make an increasingly large contribution is in the field of education. The distance between Livermore and the Berkeley campus prevents a really effective association. A close and effective association could serve as a source of fresh minds to the Laboratory, as an opportunity for young men in the Laboratory for further education, and as a chance for some of our more advanced people who want to accept joint appointments to keep up an invigorating interaction with the inquiring minds of students.

At the same time, the unclassified skills developed in our Laboratory are a treasure which should be passed on to the next generation in the most effective manner.

Of course, it should be clearly understood that in any such collaboration a distinct line must be drawn which would permit separation of the classified part of the work at the Laboratory from the necessarily unclassified instruction and research at the educational institution.

It would be premature to suggest in this report in what particular way an effective educational link can be established. Association with a technical institute might be one way. The establishment of such an institution in the Livermore valley has been suggested to the Regents of the University of California. It should be pointed out, however, that a reasonable solution of this problem will have a decisive influence on the health and vigor of the Laboratory during the next decade and in the further future.

Anticipated Growth of the Laboratory and Level of Support Required

The use of the Livermore Laboratory was started in 1952 with a nucleus of approximately 250 people to further weapons research and development. From this modest beginning, it has grown to 3,700 in seven years and added programs in controlled thermonuclear reactions, nuclear propulsion, and peaceful uses of nuclear

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explosions. In addition, a substantial computational group has developed. Here, once again, the size has been dictated by requirements of the various programs.

This rapid increase has not been without problems and we would not like to have the next ten years continue at such a rate. An increase of 5% per year, however, could be readily absorbed but even this should respond to program demands. This could bring our staff to 5,600.

Work at Livermore suffered greatly at first due to lack of adequate plant and equipment. Program demands and people far exceeded available space to take care of requirements. When the present construction program is finished in about one year, good facilities will, for the most part, be available to support only 3,700 people. The exceptions are those activities housed in the old wooden buildings. These should be replaced with modern, efficient structures. Beyond such a point, new facilities should be geared to program increases, specialized units and obsolescence.

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LOS ALAMOS SCIENTIFIC LABORATORY

Comments Concerning the Ensuing Ten Years 1/

The Los Alamos Scientific Laboratory was established under a contract with the University of California in the early part of 1943 to provide a focal point for the previously diversified research directed towards the feasibility of an atomic bomb. Its initial staffing was partly military and partly civilian, although the major technical direction was primarily the latter. It attained its wartime peak strength during the summer of 1945, with about 1500 civilians and 2000 military personnel more or less directly involved in Laboratory activities.

The Laboratory conducted the first nuclear test at Alamogordo on July 16, 1945, and provided the actual bombs and the technical crews associated therewith for the strikes against Japan immediately thereafter.

By the time of the adoption of the Atomic Energy Act of 1946, the technical military staff of the Laboratory had essentially vanished and the civilian staff had decreased to about 1300. Nevertheless, the Laboratory successfully provided the nuclear devices for use in Operation Crossroads at Bikini in 1946 and participated in other technical aspects of this operation. Following the adoption of the Atomic Energy Act of 1946 and the decision by the AEC to continue the Laboratory as a permanent institution under the continuing administration of the University of California, the Laboratory began to increase in size, ultimately reaching approximately its present strength of 3250 by about 1956. Its size has been primarily limited by the availability of local government housing and has remained essentially constant over the last several years.

During the first half dozen years after the war, the Laboratory concentrated almost all of its programmatic attention on problems of atomic weapons develop-

1/ Full text as submitted by the Laboratory September 14, 1959.

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ment climaxed by the successful development of the thermonuclear fusion process in 1951. Since then, the Laboratory has broadened the base of its activities by applying various of the skills and technologies developed in connection with weapon activities to other areas of national interest.

The current missions of the Los Alamos Scientific Laboratory follow:

"General conduct of basic and applied research in the fields of nuclear weapons, thermonuclear and fission power programs, and nuclear rocket propulsion systems. The Laboratory contains research facilities and equipment appropriate to fundamental research in nuclear physics, chemistry, metallurgy, and cryogenics; computational techniques, biophysics, and bio-chemistry. Research is conducted in all of these fields.

The primary mission of the Laboratory is weapons development. In addition, a major mission of the Laboratory is the study of the feasibility of nuclear rocket propulsion. In this field, the Laboratory is responsible for:

A. Theoretical design and system studies of various types of potential uses of nuclear energy for rocket propulsion.

B. Experimental studies of the behavior of materials under the conditions of temperature, radiation, and propellants appropriate to various designs of nuclear rockets.

C. The construction and operational test of prototype and preliminary models of various types of nuclear rocket engine systems in order to evaluate their problems and potential feasibility for actual propulsion use.

D. Participation with NASA and other agencies in system studies potentially utilizing nuclear rocket propulsion.

E. Participating in the nuclear aspects of full-scale nuclear motor or nuclear flight tests in collaboration with NASA.

Another major mission of the Laboratory is the study of the production of power from the fission process. In this field, the Laboratory primarily concerns itself with:

A. Nuclear reactor systems in which the cost of fuel refabrication is minimized through the use of homogeneous or mobile fuels.

B. Systems which burn plutonium particularly under conditions when a breeding cycle is effective.

C. Very high temperature gas-cooled systems whose character, in part, may be related to technologies developed in the nuclear rocket systems.

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D. Systems in which there is a direct conversion of thermal to electrical energy, such as the plasma thermocouple.

Another mission of the Laboratory is the study of the possible production of power from the thermonuclear fusion process. In this field, the Laboratory primarily concerns itself with:

A. The theory and experimental characteristics of the "pinch" effect.

B. The construction, study, and understanding of various Laboratory size devices exploring the containment, stability, temperature, and neutron production of differently generated and contained plasmas.

A final mission of the Laboratory is participation in the scientific life of the United States through basic research and its publication in those areas which are peripheral to and stimulate the more specifically programmatic missions of the Laboratory, through cooperation with education and industrial research institutions, and through participation in programs designed to improve the national level of scientific education and achievement.

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Weapon Research and Development at LASL
Under Various Conditions of Test Moratorium

It should be obvious that the precise character of weapon development a decade hence is as unknown as that which would have been predicted in 1960 from the status of knowledge in 1950! However, with this reservation in mind, there follows some delineation of the areas of investigation which would seem at this time to be the most fruitful and likely for further exploration during the next ten years under one or another condition of testing.

Moratorium "A": All atmospheric testing prohibited. Under these circumstances presumably, testing would have to occur in outer space, underground, or under water. The last situation seems improbable because of oceanographic biosphere problems, and attention will be confined to the first two situations. Testing underground, if legal and requiring only containment, probably would permit the testing of a number of weapon systems. Attempts would also be made to extend the area of applicability of so-called clean weapons. Weapons of greater economy, safety, and yield per pound or per inch of diameter would receive attention, as well as bizarre and exotic systems of producing nuclear yield of potential interest in weapon development.

Outer space testing would presumably be reserved for proof test of those systems with yield so large that underground containment would be impractical.

The general character of a moratorium of this sort would be somewhat slower and more expensive progress than the country has been accustomed to under previous circumstances of testing. It seems unlikely, however, that any promising line of development would be ruled out by this type of moratorium if the country were willing to pursue testing under these circumstances with sufficient vigor and adequate funds.

Moratorium "B": All testing above a few tons prohibited. Under these

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circumstances, weapon development would be limited to further development and refinement of very low yield tactical weapons. Development of new, large yield weapons would be essentially impossible. Further, nuclear weapons would be restricted to systems interpolative between physical situations explored in earlier test series.

Moratorium "C": Limited testing after July, 1960. The progress under these circumstances would be similar to and in the same areas as Moratorium "A" above. Progress would be somewhat easier, cheaper, and faster - particularly in the higher yield areas which might otherwise have to wait for outer space vehicles.

Non-Weapon Activities at LASL Under Various Conditions of Moratorium

Moratorium "A": No atmospheric testing, but testing permitted elsewhere. The non-weapon activities of the LASL would probably increase slightly since it would not seem probable that the rate of testing under these circumstances and the return and analysis of information therefrom would permit quite so large a weapon activity to be effective as heretofore. It is, however, impossible to make a quantitative guess as to this decrease or increase since it depends entirely upon what rate of dollar expenditure the country is willing to put into underground and outer space testing activities.

Moratorium "B": All testing over a few tons prohibited. There are at present a number of essential weapon activities which must be completed, and one may anticipate still further new and interpolative weapon demands which will continue to occupy a substantial portion of the Laboratory's time.

Moratorium "C": Limited atmospheric testing after 1 July 1960. Under these circumstances, it is probable that both weapon and non-weapon activities will remain at about their present level.

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Activities of the LASL and Their Relationship to Universities and Industry

What is the relationship between LASL activities and those of Universities and industry and could any be transferred?

There exists a great similarity between many LASL research activities in non-weapon fields and similar activities carried on in Universities - usually with government funding. In any laboratory with programmatic responsibilities and objectives, a broad basis of research is imperative to provide the best atmosphere for productive scientific activity. Laboratories without such research activities soon cease to have new ideas and become dead. Laboratories like LASL do, indeed, do research like Universities - and it has been one of the important sources of their strength. Take it away or decrease it and the health of the Laboratory will suffer extraordinarily rapidly.

It should also be pointed out that most proposals to transfer activities to Universities or industry always involve government support along with them. It is cheaper and more effective for the government to do its work in its own laboratories than it is to farm it out. Small research contracts are frequently ineffective - the concept of adequate staffing and adequate varieties of intellectual disciplines should be maintained so that government Laboratories always have very much more than a "critical mass" of people.

It should also be pointed out that the existence of strong, ingenious and versatile research groups is an important asset to the government in taking on new and, particularly, classified programmatic objectives in a hurry. As an example, the existence of a strong group of nuclear physicists with appropriate supporting group has been effective at Los Alamos in the past support of testing programs as well as in certain high priority proposals now being made.

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In general, while it is always possible to transfer almost any kind of work away from Los Alamos (except, probably weapon work), it will cost the government more, it will be less well coordinated, and it will seriously and adversely affect the government's chances of getting important work (including weapons work) done rapidly and effectively in its own laboratories.

It may finally be pointed out that the only large scale programs which have been really well done have been done by the government in government laboratories operated by industrial or academic contractors. Radar, the proximity fuze, and the atomic energy program are conspicuous examples. Universities, by themselves, have done nice but uncoordinated research programs. And while it is perhaps an unfortunate example, the U.S. missile program - done by industry - is not always regarded as a shining example of how to get to an objective most rapidly and most effectively!

General Comments on the Future of LASL

It is probable that the overall size of the LASL should show only slow growth over the next decade - a growth permitted primarily by the availability of additional housing as areas such as Barrancas Mesa and White Rock are opened up. There would seem no pressing need for it to expand much more than possibly ten or fifteen percent beyond its present level and then under a philosophy which would suggest the maximum use of its existing facilities.

Perhaps the greatest single question is whether, under a maximum of weapon responsibilities, this will permit adequate progress to be made in areas such as nuclear rocket propulsion, plutonium burning reactors, and similar fields in which the LASL has a unique capability and one which could be duplicated or installed elsewhere only at extraordinarily great expense. This question cannot be answered in a quantitative sense at the present time.

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FUTURE ACTIVITIES OF SANDIA CORPORATION
September 12, 1959

I. Introduction

II. Nuclear Weapons Program of the Future

III. Effect of Test Limitations

IV. "Morale" Problem in a Weapons Laboratory

V. Current Make-up of Sandia

VI. Non-Weapons Activities for the Future

VII. Future Size of Sandia; Facility Requirements

VIII. Sandia's Activities relating to Private Industry

IX. Summary

(The following is the full text of the long range program submitted by the Sandia Corporation.)

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I. INTRODUCTION

Sandia Corporation has been and is today occupied mainly in the field of weapon development. With this almost single purpose for its existence to date, it is only natural to try to start consideration of its future role and activities in relation to possible new weapons of the future. This memorandum will begin with an attempt to assess these possibilities, Sandia's responsibilities in connection with them, and the effect, therefore, of various degrees of test limitation on Sandia's program of the future.

It is important to note, however, that the unique capabilities of Sandia today, in terms of both the size and caliber of its staff and the facilities it has available, permit it to undertake tasks other than weapon development. These capabilities, coupled with the problem of maintaining a competent vigorous staff working solely on weapon development, especially in a period when the whole tenor of the nation is to reduce the emphasis on nuclear armament, make it imperative for Sandia to branch out into new fields of endeavor. The latter part of this memorandum is a discussion of what these fields may be, work on some of which being already underway in a modest way.

II. NUCLEAR WEAPONS PROGRAM OF THE FUTURE

Sandia's traditional role in weapon development is best described by the term "weaponizing", which is intended to convey the notion of taking a nuclear device developed by one of the nuclear laboratories and adapting it by proper encasement and by addition of suitable gadgetry into a useful bomb or warhead meeting specified military characteristics. In this middle position between the nuclear laboratories, on one hand, and the various branches of the DOD, on the other hand, we are in good position to see early the new designs that may be forthcoming from the laboratories and the future needs for new weapons

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by the military services. Yet we are certainly not experts in the design of nuclear explosives, nor can we pretend to understand all facets of the military problem. Thus our picture of the nuclear weapon program of the future should be accepted in terms of this middle ground from which we view the situation.

Within the field of nuclear weapon development, Sandia has a larger role to play in the weaponization of bombs than of missile warheads. Thus, given no change in any other factors in the weapons program, it seems reasonable to assume that there may be some small reduction in workload if missile systems supplant manned aircraft. Also, should a partial or full moratorium slow radically the entry of new models into stockpile, the weaponization load would decrease.

III. EFFECT OF TEST LIMITATIONS

Test limitations affect directly the work of the nuclear laboratories and, except for our direct participation in the tests, affect Sandia's workload only as weaponization may or may not result from the tests. If prognostications on the effect of various kinds of test limitations are vague for the nuclear laboratories, they are even more so in the case of Sandia.

1. No testing in atmosphere, but allowed underground and in outerspace.

Clearly surface testing is the easiest and cheapest to conduct and most immediately productive of results, and so this limitation would be restrictive when compared to the past, but a useful improvement over the present complete ban. However, the nuclear laboratories must obviously put this statement in quantitative form. Sandia, as plans now go, would be heavily involved in instrumentation of the outerspace tests. Our role in underground tests is not yet fully defined.

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It is our estimate that this test condition would stretch out greatly improvements in ICBM's because of the difficulties inherent in outerspace testing. We would guess, however, that after a period of a year or two of learning how best to conduct underground tests, low-yield weapon programs especially for tactical applications, might proceed at a rate almost as high as if surface testing were permitted.

2. Tests prohibited except for yields up to a few tons.

This situation would permit hardly more than "safety" shots or small extrapolations of full-scale tested designs. It is our opinion that the military services will be most reluctant to commit any weapon program to an untested new design, no matter how convincing the results of an IBM 704 calculation. The risks involved in dollars and in military capability would hardly justify, we believe, possible gains in efficiency of 2X's and even more.

Thus we see little difference between this condition and the present one as far as the overall program is concerned or that specifically at Sandia.

3. After July 1960 limited tests up to 2 MT fissionable yield per year.

This condition would obviously permit a sizable test program, yet not completely unlimited. It would require careful determination of what's most important. Such questions will have to be answered as whether a DOD proof test shot is needed or whether "effects" tests or "diagnostics" of new ideas have first priority. Obviously, Sandia's program in weapons will be at the highest rate under this condition.

IV. "MORALE" PROBLEM IN A WEAPONS LABORATORY

It has been stated that it is a strong desire of our government that a vigorous nuclear weapons development program should proceed whether a

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test moratorium, a permanent ban, or a limited ban is in effect. These are pious words to which it is easy to assent, but in fact to inspire and/or harness an able group to work vigorously on nuclear weapons under such conditions is very nigh impossible. Times of war or times of crisis will bring out really intensive effort from dedicated people to work on weapons. But in times when public opinion and apparent government policy is so obviously directed toward doing away with "horror" weapons, the dedication of able and thoughtful people to work along what appears to be a counter direction is most difficult to inspire or command.

What are the alternatives, if indeed it is right that our nation should use some of its effort to pursue "vigorously" the nuclear weapon business? To continue as is, particularly at Sandia where almost our entire effort has been on weapons, will result in the loss of our best people. We can no doubt maintain some kind of staff content to earn a living working on weapons all their career, even under the less exciting conditions we foresee. But this hardly seems to us a best solution.

We believe a far better solution to the problem is to broaden Sandia's responsibilities to encompass other fields of activity. Thus by having part of the laboratory's staff and part of the time of staff members engaged in other challenging technical activities, we can have part of the effort of able people to work on weapons. This can be worth a lot more than 100% of the effort of people with mediocre talent.

V. CURRENT MAKE-UP OF SANDIA

Since its first beginnings as Z Division of LASL in 1945 and especially since it became part of Sandia Corporation in 1949, this laboratory has grown steadily, both in the size and caliber of its staff and in its plant and facilities. Sandia Corporation is today an organization of nearly 8000 people

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with experience and competence in many technical fields. These may be described as physical research, research and development in devices and materials, systems analysis and planning, structural design, development and testing for severe environments, large scale field testing, engineering for manufacture, quality control in manufacture, quality assurance, field engineering, and military training.

This competence has been built up mainly to handle the diverse problems of developing the non-nuclear parts of nuclear weapons. However, its general applicability to other technical problems is obvious. While a major part of Sandia's work may be described as R&D, we have also built up a staff and a competence to follow through with all our designs into manufacture and into use, in order to insure that the military services were given a product that met requirements and held up in use.

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VI. NON-WEAPONS ACTIVITIES FOR THE FUTURE

As stated earlier, it is our considered opinion that Sandia must in the future devote a larger fraction of its effort in areas not strictly concerned with nuclear weapons development. We argue that only in this way will it be possible to maintain a strong staff to do weapons work in a period when public opinion and government policy does not obviously support a vigorous nuclear policy. There is a second reason also, namely, that weapon technology even in its non-nuclear aspects has today so fully exploited the existing art in electronics, materials, and related fields that there is a need for concentrated research in these fields to prepare for the needs of the weapons of tomorrow.

In the topics listed below, we have therefore included areas of increased or new effort for Sandia which we believe will satisfy these two needs.

1. Increased effort in basic research and exploratory development.

Basic research in fields related to the needs of our business is underway and is being increased as scientists of the proper qualifications and interests can be acquired. Areas in which new knowledge is sought include hydromagnetics, high temperature phenomena, solid state physics, physical electronics and combustion processes. Applied research and exploratory development programs seek the application of new knowledge or the new application of old knowledge to provide better weapon components, materials, circuits or systems. Mathematical research seeks new methods or techniques in statistics, numerical analysis or systems studies. In these basic and applied research efforts lie our hope for significant steps forward in the future, both in weapons and non-weapons fields.

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2. Radiation Effects.

It has been recognized that some weapons will have to operate in the presence of nuclear explosions of the enemy. To understand the phenomena of radiation damage, a reactor and related facilities are being installed at Sandia which will make possible a thoroughgoing program in this field covering both the scientific and engineering aspects of the problem. Modest effort is already underway.

3. Detection Systems.

Some work is in progress at Sandia relating to aspects of the detection system that may have to be installed if an international agreement is reached on a test ban.

4. Project Plowshare.

Sandia can, we believe, contribute to Plowshare in at least three ways. First, we are conducting cratering studies with chemical explosives with the purpose of finding how best to arrange nuclear explosives for various kinds of excavations with maximum containment of radioactive products. Second, we are helping LRL plan various projects and assisting in the necessary instrumentation with particular reference to fall-out, shock damage, and other safety problems. Third, at some future date it will probably be desirable to develop nuclear explosives designed specifically to meet the needs of the Plowshare application rather than military requirements. Consideration of economy and how to minimize fission products will probably be paramount, while size and weight will be less important. It seems only natural to expect that Sandia will be heavily involved in such development.

5. Specialized Reactor Design.

Recently Sandia has carried out for LASL considerable planning and design work on the Turret reactor with the expectation of building an experimental

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model of the reactor in Albuquerque. Although this plan was not approved, this effort suggests a role that Sandia can play in the AEC's reactor program. The design capabilities of Sandia coupled with its experience in the field of materials fitted well the Turret problem. The experience gained on this project, as well as other work on Rover, has given us confidence that we are well equipped to handle similar problems in the reactor field. For example, the development of portable reactors for the military could very well be assumed by Sandia.

VII. FUTURE SIZE OF SANDIA: FACILITY REQUIREMENTS

Sandia is today operating with a manpower ceiling of 8000. It is our recommendation that this ceiling be held regardless of test conditions. As pointed out earlier, almost the entire staff is now engaged in weapons programs. We foresee an eventual decrease in weapon activity especially with limited or complete bans on testing. By applying the modest effort now to non-weapon work, we would expect some of these projects to blossom into larger programs for the future.

As a laboratory Sandia is today well equipped with facilities and several new ones are under construction or approved. In terms of buildings the situation is not so favorable, and a large part of the staff is housed in inadequate, costly-to-maintain, wooden structures, some of them buildings built for use by CCC camps in the late 30's. Most urgent is a continued construction program aimed at replacing these worn-out buildings. We foresee, therefore, continued funding requirements of a few million dollars annually to cover some new facilities, replacement of old facilities and the construction of new buildings.

VIII. SANDIA'S ACTIVITIES IN RELATION TO PRIVATE INDUSTRY

Early in Sandia's history atomic weapons were assembled at Sandia and some of the components and auxiliary equipment produced there. As the AEC manufacturing

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complex was built up, and as we developed reliable subcontractors, the production activity of Sandia was reduced.

Sandia has evolved through the years, therefore, into an organization primarily engaged in R&D activity and in certain "engineering for manufacture" functions, but not in manufacturing per se.

On the matter of weapon development, with its special problems of security and safety, there seems to be no question that such activity should be a responsibility of the AEC and hardly one that can be contracted to private industry. In some of the areas of new activity for Sandia proposed early in this memorandum, one might raise this question. Here, too, we believe the role suggested for Sandia is proper. In Project Plowshare, for example, we anticipate that eventually private industry will participate in the planning and preparation activity. However, the AEC will have to retain responsibility for detonation of nuclear explosives and safety matters surrounding the problem. We foresee Sandia serving as the technical arm of the AEC in such matters. Detection systems again should be a closely held activity of the government, and so we believe Sandia's role in this program is proper. In the reactor development field, we believe that there is a proper role for Sandia, even though this is certainly a large area suitable for private enterprise also. Those reactors which involve advanced concepts are, however, high-risk ventures for private industry, unless the work is fully subsidized. In this area of research and development on advanced reactor concepts and in the construction and test of small-scale experimental reactors, we believe that Sandia can make significant contributions and still not pre-emp a field rightfully in the domain of private industry.

Such a diversified program will result in retention and even strengthening of its present staff. It will make possible carrying a weapon program under the adverse conditions of a test ban, as well as undertaking other technical programs of importance to the nation.

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