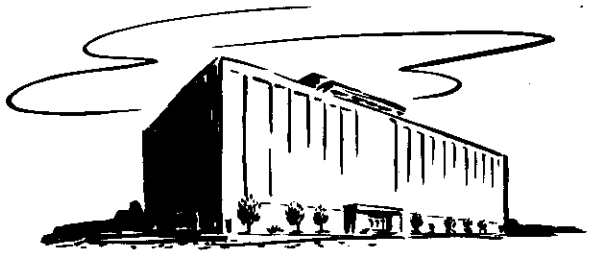
History of



U. S. NAVAL RADIOLOGICAL DEFENSE LABORATORY

1967

This document is designed to serve the dual purpose of Command History and Annual Administrative Report

San Francisco, California 94135

CHAPTER I

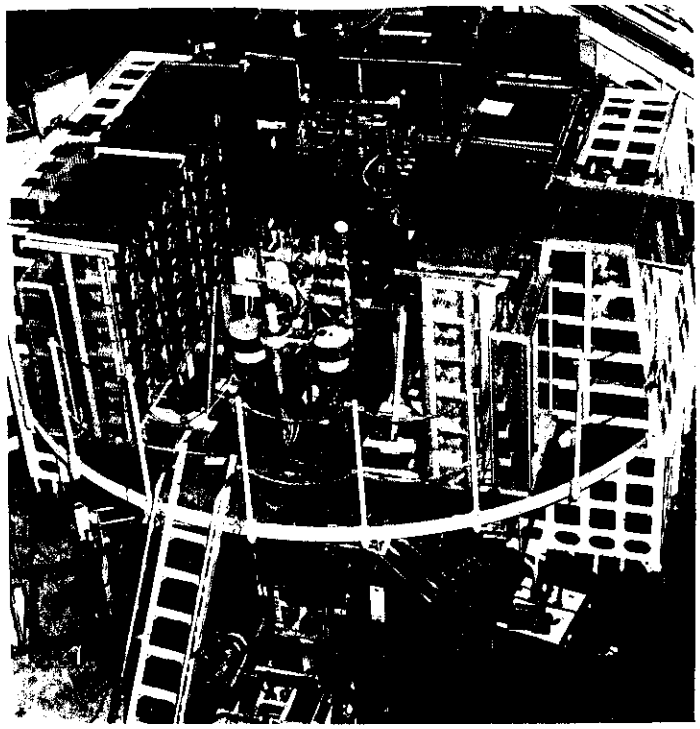
1967: DAILY CHALLENGES MET - FUTURE PROBED

CYCLOTRON BEAM OBTAINED

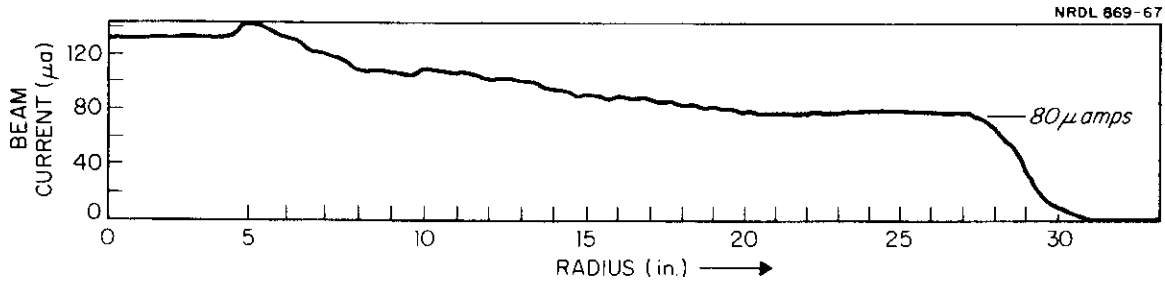
A highlight of 1967 occurred on the evening of 18 December at the NRDL AVF 70-inch Cyclotron - the central beam probes detected the first successfully circulated protons, with an indicated beam current of almost 500μa. The beam was worked out to about five orbits before it became necessary to shut down because of an improperly connected trim coil. However, by the following afternoon, the beam had been circulated out to extraction radius. (The radial profile of the beam, i.e., current vs radius, is shown graphically on the next page.) Obtaining the beam climaxed a period of intense effort in which final assembly of the major machine components was completed and testing initiated. A great deal of excitement was apparent as the Accelerator Branch staff, under the direction of Dr. D. J. Horen, worked to achieve the conditions required in order to produce a beam. The Cyclotron Physics Design and Evaluation Group, under Dr. H. A. Howe, provided the values for initial operating parameters based on extensive computer analysis and determined that favorable conditions could be set up for acceleration of low energy protons. During the latter part of December, additional components were installed and testing continued to measure and evaluate the effects of varying machine parameters on beam properties. Research with the machine should start July 1968.

NRDL'S FUTURE MISSION STUDIED

NRDL's mission remained unchanged during 1967. It reads: "To perform research, development, test and evaluation of the effects of nuclear explosions, natural and controlled nuclear processes, nuclear accidents and incidents, and related fields of science and engineering." This mission is outdated and restatement is essential.



Completely assembled Cyclotron.



FIRST CYCLOTRON BEAM MEASUREMENTS - The graph above shows the proton beam current measured as a function of distance from the center of the machine for the first beam circulated to extraction radius. The source was throttled down in order to give the minimum current obtainable without pulsing. The particle energy was approximately 4 MeV.

MISSION STUDY GROUP shown (left to right) are Dr. Dave C. Jones, Head Physiology-Psychology Branch; the Chairman, Dr. E. P. Cooper, Technical Director; LCDR D. M. Alderson, Jr., USN, Fleet Support Branch; Dr. Aurel Goodwin, Head, Radiation Transport Branch; and Mr. Paul E. Zigman, Head, Technical Management Office. Each member of this group was relieved of his regular duties during the five months period the Mission Study Group was in operation. Their recommendations for three alternative Laboratory roles were reviewed in detail with the Board of Visitors on 19-20 October prior to final completion of the report.

A Mission Study Group, headed by Dr. E. P. Cooper, was organized to study the future direction of NRDL. The group operated on a full time basis from 26 June until mid-November. The Study was generated from the overall reorganization of the Navy Research, Development, Test and Evaluation (RDT&E) structure early in 1967. A three-volume report was produced by the Mission Study Group, presenting three different ways present resources of NRDL can continue to develop to satisfy real Navy needs not otherwise met. A copy of this report was delivered to the Chief of Naval Material, and, on 7 November CAPT D. C. Campbell, USN, C. O. & Director, and Dr. Cooper gave a briefing to RADM A. S. Goodfellow, Jr., USN, DCNM(D), and Dr. G. W. Johnson, DNL/DLP. Details of the report were not yet released at year's end, pending completion of the review underway in Washington.

DR. BATZEL NAMED TO BOARD OF VISITORS

Five members of the NRDL Board of Visitors, appointed when this advisory group was organized in 1966, continued to serve this year. They are pictured on the next page, as is the only new appointee, Dr. Roger E. Batzel, Associate Director for Chemistry and Space Reactors at the U. C. Lawrence Radiation Laboratory in Livermore. As part of a membership rotation policy, in August Dr. Batzel was appointed to succeed Professor Charles Coryell, MIT, as the representative for chemistry disciplines. This distinguished group, representing many disciplines, is concerned with NRDL's overall program, management structure and sponsor relationship.

EXTENSION OF MISSION STUDY

In order to be prepared to implement any new role assigned to NRDL by the Secretary of the Navy, based on the Mission Study report, late in November another working group was established, known as the Interim Planning Group. This group was to do the ground work for establishment of a program planning staff as a part of the regular Laboratory organization and report to top management by 16 February 1968. Members of the Interim Planning Group are Chairman, Dr. W. E. Kreger, Head, Physical Science Division; Mr. R. C. Lilly, Head, Program Office, and Mr. P. E. Zigman, Head, Technical Management Office.

RADIOLOGICAL SAFETY COMMITTEE

A Radiological Safety Committee was established on 3 March 1967 with Dr. E. R. Tompkins designated as Chairman and LCDR T. R. Birdwell, MC, USN, and

U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY

BOARD OF VISITORS

The distinguished scientists pictured below are concerned with USNRDL's overall program, management, structure and [illegible] relationships. They represent many disciplines, thereby providing [illegible] program.

DR. ROBLEY D. EVANS
Chairman, NRDL Board of Visitors
Professor of Physics
Massachusetts Institute of Technology

DR. WILLIAM A. FOWLER
Professor of Physics
Calif. Institute of Tecanology
W. K. Kellogg Radiation Lab.

Dr. NORRIS E. BRADBURY, Director
Los Alamos Scientific Laboratory

DR. ROGER REWOOD BATZEL
Associate Director for Chemistry
and Space Reactors
University of California
Lawrence Radiation Laboratory, Livermore

Mr. A. L. Smith, Alternate Chairmen. Other members are Drs. E. L. Alpen, R. Cole, C. S. Cook, W. E. Kreger, J. D. Teresi, and Messrs. P. Zigman, E. Tochilin, and R. Kennedy.

Two Committees were disestablished on 3 March 1967 - Radiological Policy and Radioisotope.

FUNDING OVER $14 MILLION FOR FY68

Though this history is essentially for the calendar year 1967, since funding is calculated on the fiscal year from 1 July annually, a comparison is made of kind and level of program sponsorship in FY67 and expectations for FY68.

Sponsor	FY 1967 Expenditures (Thousands)	Reporting Units	FY 1968 Funding (Est.)
NAVSHIPS	$ 2,547	(26)	$ 2,432
DLP	1,514	(14)	2,007
NAVELEX	-	-	520
OCD	2,888	(69)	3,000
DASA	1,554	(25)	1,221
BUMED	910	(8)	825
AEC	933	(11)	1,363
MARCORPS	350	(3)	330
USAF	513	(7)	365
ONR	14	(1)	-
ARPA	1,050	(14)	1,045
USA	120	(2)	110
NAVAIR	700	(6)	637
NASA	89	(2)	73
NAVFAC	47	(1)	70
PMR	2	(1)	-
MISC	10	-	-
NASL	40	(1)	134
NADC	11	(1)	-
WESTDOCKS	130	-	-
DTMB	28	(1)	-
	$13,450	193	$14,132

Of the $13,450,000 for the fiscal year which ended 1 July 1967, $10,650,000 was expended in-house and the balance for R&D contractual program. Of former, $5,910,000 was required for salaries, wages, and staff benefits (not including military), remainder for materials, equipment, and facilities.

REORGANIZATION

The only reorganization at NRDL during 1967 took place on 1 July within the Military Evaluations Division as follows:

Code 911 - Weapons Effects Branch, headed by Dr. E. C. Evans III, remained intact.

Code 912 - Biological Response Branch, headed by Dr. J. D. Teresi, was disestablished. Dr. Teresi moved to a staff capacity in the Division Office as a Supervisory Chemist. Other personnel were absorbed by the various Branches.

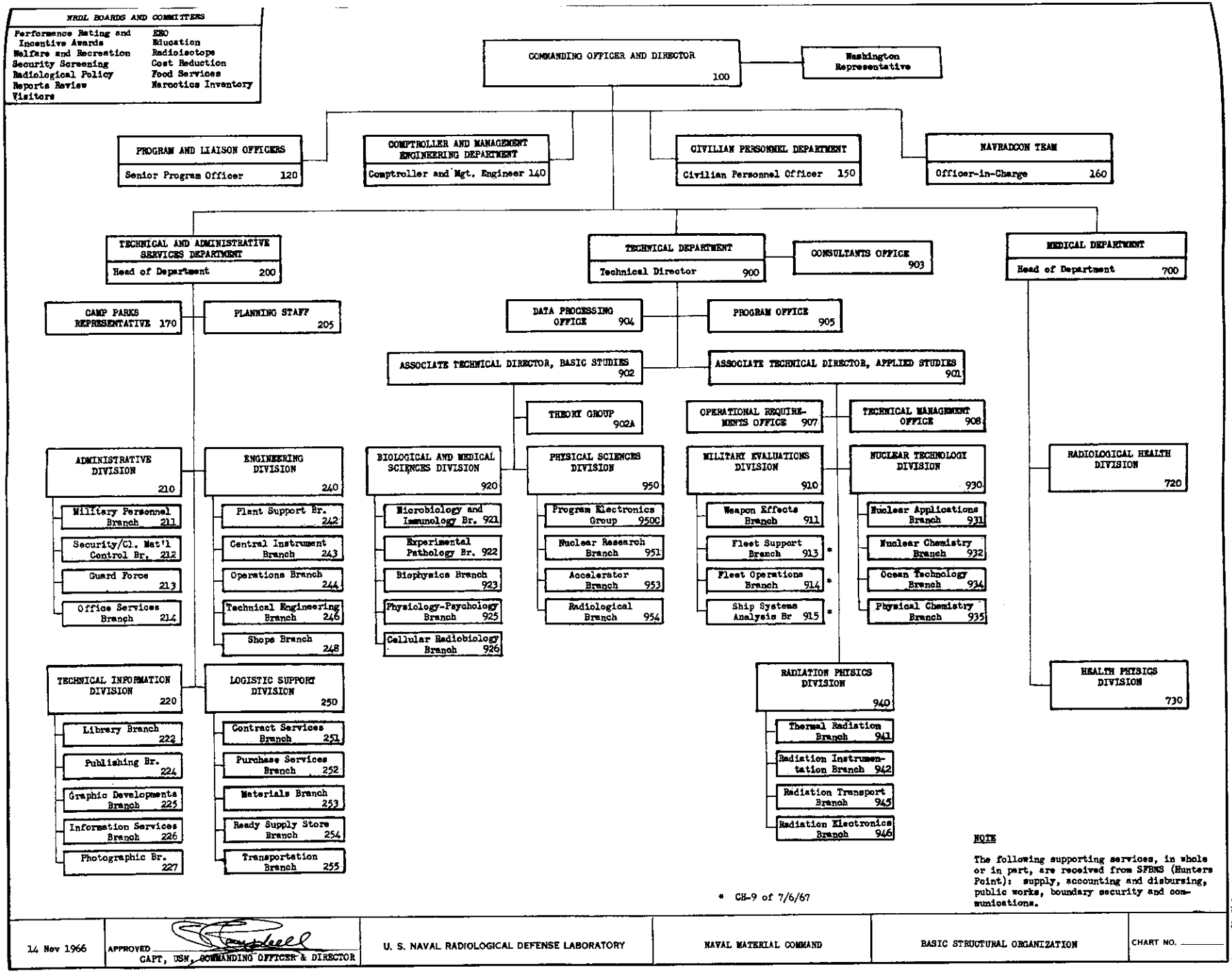
Code 913 - Land-Based Analysis Branch was renamed the Fleet Support Branch to more accurately describe its functions. During February LCDR D. M. Alderson, USN, replaced Miss June Brevdy as head of the Branch, preparatory for her to return to school on a NRDL Fellowship (see page 65). With reassignment of LCDR D. Alderson to the Mission Study Group and subsequent transfer from NRDL (see page 8), Mr. Edward Leahy was selected as Branch Head.

Although Code 914 is still the Fleet Operations Branch, part of the previous functions of the Branch are now carried out in a new Branch named Ship Systems Analysis, Code 915. The former Code 914 Branch Head, Mr. R. A. Sulit, shifted to head Code 915 which comprises three major programs - Ship Concept Formulation, BW/CW Analysis, and SABMIS. Mr. G. W. Gibson now heads Code 914 which also covers three important areas - Fleet Warfare Analysis, USMC Warfare Analysis, and MOESAICS.

A complete organizational chart reflecting these changes appears on the next page.

NRDL TAKES OVER ACCOUNTING FUNCTIONS

On 1 August NRDL took over most of the accounting functions previously done for the Laboratory by the San Francisco Bay Naval Shipyard. Therefore, a new group was established, NRDL Accounting Staff, Code 141B, within the Comptroller and Management Engineering Dept., Code 140. Heading the group is Mrs. Virginia Parker, one of three employees who shifted over from SFBNS. Two others were hired in addition. In-house accounting is expected to be more convenient and to provide quicker and more accurate information. Eventually NRDL expects to process the accounting on its computer, but for the present SFBNS will continue this function.


NRDL BOARDS AND COMMITTEES
Performance Rating and Incentive Awards
Welfare and Recreation
Security Screening
Radiological Policy
Reports Review
Visitors
EEO
Education
Radioisotope
Cost Reduction
Food Services
Narcotics Inventory
COMMANDING OFFICER AND DIRECTOR 100
Washington Representative
PROGRAM AND LIAISON OFFICERS
Senior Program Officer 120
COMPTROLLER AND MANAGEMENT ENGINEERING DEPARTMENT
Comptroller and Mgt. Engineer 140
CIVILIAN PERSONNEL DEPARTMENT
Civilian Personnel Officer 150
NAVRADCON TEAM
Officer-in-Charge 160
TECHNICAL AND ADMINISTRATIVE SERVICES DEPARTMENT
Head of Department 200
TECHNICAL DEPARTMENT
Technical Director 900
CONSULTANTS OFFICE 903
MEDICAL DEPARTMENT
Head of Department 700
CAMP PARKS REPRESENTATIVE 170
PLANNING STAFF 205
DATA PROCESSING OFFICE 904
PROGRAM OFFICE 905
ASSOCIATE TECHNICAL DIRECTOR, BASIC STUDIES 902
ASSOCIATE TECHNICAL DIRECTOR, APPLIED STUDIES 901
THEORY GROUP 902A
OPERATIONAL REQUIREMENTS OFFICE 907
TECHNICAL MANAGEMENT OFFICE 908
ADMINISTRATIVE DIVISION 210
Military Personnel Branch 211
Security/Cl. Mat'l Control Br. 212
Guard Force 213
Office Services Branch 214
ENGINEERING DIVISION 240
Plant Support Br. 242
Central Instrument Branch 243
Operations Branch 244
Technical Engineering Branch 246
Shops Branch 248
BIOLOGICAL AND MEDICAL SCIENCES DIVISION 920
Microbiology and Immunology Br. 921
Experimental Pathology Br. 922
Biophysics Branch 923
Physiology-Psychology Branch 925
Cellular Radiobiology Branch 926
PHYSICAL SCIENCES DIVISION 950
Program Electronics Group 950C
Nuclear Research Branch 951
Accelerator Branch 953
Radiological Branch 954
MILITARY EVALUATIONS DIVISION 910
Weapon Effects Branch 911
Fleet Support Branch 913 *
Fleet Operations Branch 914 *
Ship Systems Analysis Br 915 *
NUCLEAR TECHNOLOGY DIVISION 930
Nuclear Applications Branch 931
Nuclear Chemistry Branch 932
Ocean Technology Branch 934
Physical Chemistry Branch 935
RADIOLOGICAL HEALTH DIVISION 720
TECHNICAL INFORMATION DIVISION 220
Library Branch 222
Publishing Br. 224
Graphic Developments Branch 225
Information Services Branch 226
Photographic Br. 227
LOGISTIC SUPPORT DIVISION 250
Contract Services Branch 251
Purchase Services Branch 252
Materials Branch 253
Ready Supply Store Branch 254
Transportation Branch 255
RADIATION PHYSICS DIVISION 940
Thermal Radiation Branch 941
Radiation Instrumentation Branch 942
Radiation Transport Branch 945
Radiation Electronics Branch 946
HEALTH PHYSICS DIVISION 730
NOTE
The following supporting services, in whole or in part, are received from SFBNS (Hunters Point): supply, accounting and disbursing, public works, boundary security and communications.
* CH-9 of 7/6/67
14 Nov 1966
APPROVED
CAPT, USN, COMMANDING OFFICER & DIRECTOR
U. S. NAVAL RADIOLOGICAL DEFENSE LABORATORY
NAVAL MATERIAL COMMAND
BASIC STRUCTURAL ORGANIZATION
CHART NO.
NRDLINST 5450.3A CH-7

RADIOLOGICAL CONTROL TEAM

The NRDL Radiological Control team, formed to provide, upon request of higher authority, on-the-scene forces at radiological accident sites with "expert" advice and technological assistance, was placed on alert from 2000, 24 March to 0800, 25 March. During this period a full team could have been assembled and equipment made ready for movement within a period of one hour.

On 30 June CDR N. J. Davis, Jr., USN, Senior Program Officer, was assigned collateral duty as Officer-in-Charge of the Radcon team, replacing LCDR B. T. Sansom, USN, when he retired. In July LCDR T. R. Birdwell, MC, USN, replaced CDR M. I. Varon, MC, USN, as Radiological Medical Officer and a member of the Radcon team.

A series of training program lectures and demonstrations, designed to acquaint team members with the functions of others on the team, was initiated by LCDR Birdwell and conducted under the supervision of Mr. A. L. Smith, Head, Health Physics Division.

CONSULTANTS TOTAL 16

Sixteen consultants were under contract to the Laboratory during 1967, representing widely divergent specialties, as follows: Biological Oceanography - Dr. R. W. Brauer, Professor of Physiology and Pharmacology, Duke University. Fire Research - Dr. A. Broido, Chief Scientist, U. S. Forest Service, Pacific Southwest Forest and Range Experiment Station. Lipid Metabolism - Dr. C. Entenman, Director, Institute for Lipid Research. Radiology - Dr. G. E. Hanks, Associate Professor, Stanford Medical School. Radiological Information Systems - Dr. K. K. Harris, Research Scientist, Lockheed. Dosimetry - Dr. H. H. Heckman, Physicist, Lawrence Radiation Laboratory. Hydrodynamics - Dr. M. Holt, Professor of Aeronautical Science, U. C. Nuclear Physics - Dr. H. P. Hotz, Associate Professor of Physics, University of Missouri. Accelerator Physics - Dr. B. D. Kern, Professor of Physics, University of Kentucky. Radiation Biology - Dr. D. J. Kimeldorf, Professor of Radiation Biology, Oregon State University. Immune-biology - Dr. J. J. Miller III, Assistant Professor of Pediatrics, Stanford Medical School. Electron Microscopy - Dr. T. L. Phillips, Associate Professor, U. C. Medical School. Pathology - Dr. V. J. Rosen, Associate Professor, U. S. C. Medical School. Fallout Phenomenology - Dr. I. J. Russell, Associate Professor of Chemistry, Boston College. Kinetics of Reactor Systems - Mr. V. I. Schrock, Associate Professor of Nuclear Engineering, U. C. Probabalistic Modeling - Mr. F. F. Sheehan, Associate Professor of Mathematics, San Francisco State College.

PERSONNEL STATISTICS

CIVILIAN

The permanent staff totalled 552 at the beginning of the year and 548 at the end with an average staffing level of 547. The quit rate was 11.8% and the accession rate 8.2%. Quit rate for professionals was 9% and accession rate 7.8%. The average employee use of sick leave was 59 hours. Average grade level declined slightly during the year from 9.77 to 9.61. Academic degrees hald by the staff now total 154 bachelors, 80 masters and 67 doctorates.

The 1967 Summer Employment Program included seven faculty members, 25 graduate and 10 undergraduate students.

Fourteen young people received Certificates of Completion for participating in the 1967 Youth Opportunity Program at NRDL. This group represents more than 2-1/2% of the on-board civilian employees, or two and one-half times the number requested by the President for his Youth Opportunity Program. Again, most of these young people are still with the Laboratory on a part-time basis during the school year.

OFFICER

In 1967 there was an average of 26 Naval Officers assigned to NRDL with four other service officers assigned. Additionally, there were two clinical clerkships (1915) officer personnel aboard during the year. There were 8 officers transferred, and 9 officers received for duty throughout the year. There was one officer retirement during 1967. There were 3 officer promotions and 3 officer separations.

ENLISTED

Enlisted personnel aboard in 1967 averaged 22. There were 19 enlisted transfers and 24 enlisted receipts. There was one enlisted transfer to the Fleet Reserve during 1967; four enlisted men were separated; three reenlisted; four agreed to extend their enlistments; and one was discharged.

MAJOR PERSONNEL CHANGES

CIVILIAN

A top management staff change took place when the Comptroller and Management Engineer, Mr. James E. Carroll, retired on 31 October (see next page) and was replaced by Mr. Richard Wilson, Head of Financial Control Staff. In turn, Mr. Wilson was replaced by Mr. Richard Ursua, who started his Government career in 1942 and for the past two years was Budget Analyst-Funds Resource Specialist at Western Division Navy Facility Engineering Command, San Bruno.

Promoted to Chief of the 11-man Guard Force was Sergeant Claudius Smith, who had alternated with the other Sergeant since the job became open in September 1966.

One of NRDL plank owners, Dr. D. J. Kimeldorf, left NRDL on 15 September to become Professor of Radiation Biology at Oregon State University. He was replaced as Head of the Physiology-Psychology Branch by Dr. D. C. Jones. Other new Branch Heads include Mr. Raymond Taylor (Radiation Instrumentation) and Dr. D. J. Horen (Accelerator). Mrs. Ofelia Wilkinson became Head of the Applied Programming Staff.

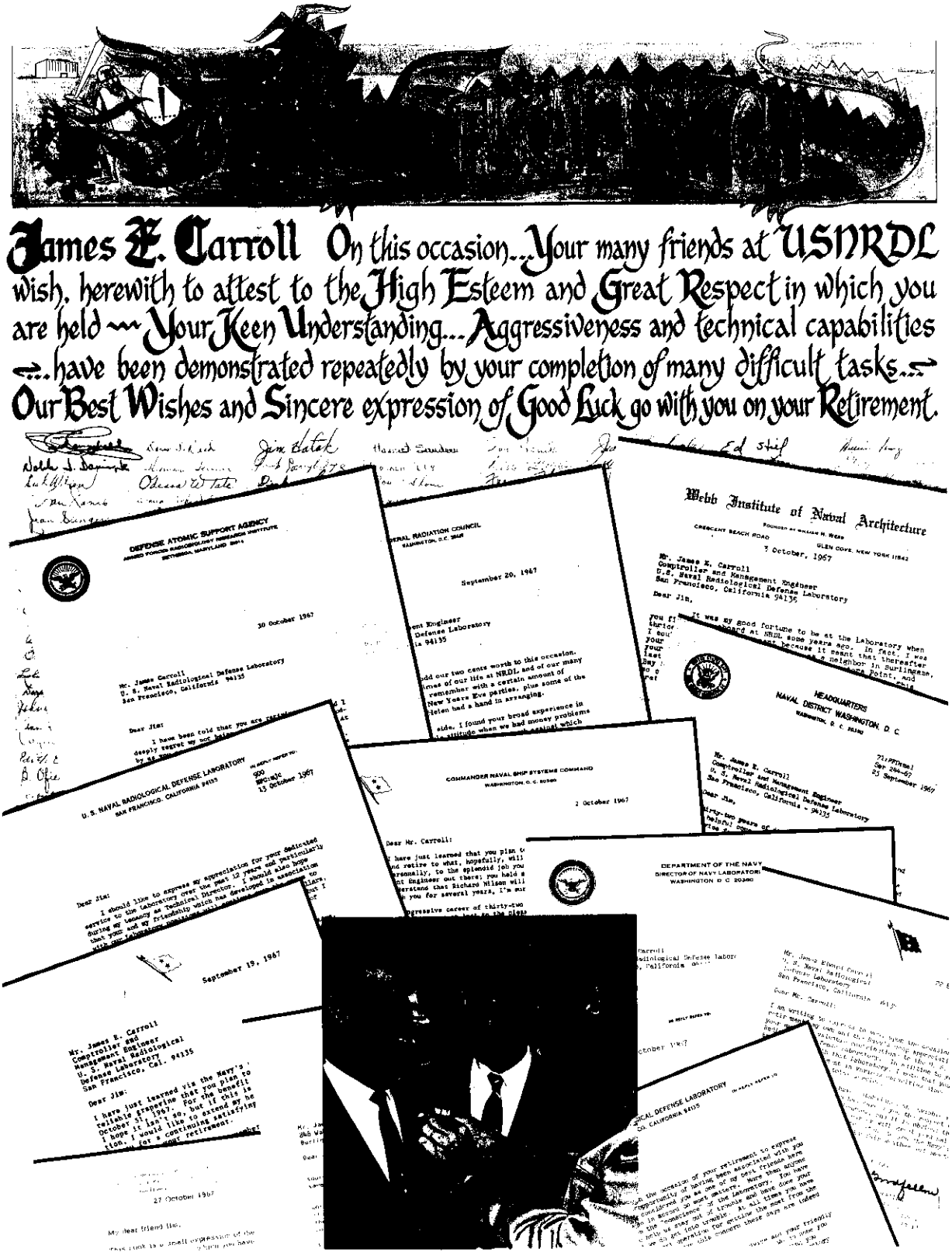
MILITARY

On 30 June LCDR B. T. Sansom, USN, Technical and Administrative Services Director, retired. Acting Head of T&AS for the balance of 1967 was Mr. Val Franz, also Head of the Engineering Division.

In July CDR M. I. Varon, MC, USN, Radiological Medical Director and Head of the Radiological Health Division, was transferred to AFRRI. LCDR T. R. Birdwell, MC, USN, took over as Radiological Medical Director, and LT P. C. Block, MC, USNR, assumed duties as Head of the Radiological Health Division. Both continued also as research investigators.

Also detached during July was LCDR John A. Zimmeht, Jr., MSC, USN, Head of the Administrative Division, who went to Port Hueneme. He was replaced by LT Sue C. Hallett, USN, who also retained her position as Security Officer. LCDR J. J. Miller, MC, USNR, Bio-Med investigator, was released from active duty. He went to the staff of the Stanford Medical Center.

CDR William E. Campbell, Jr., USN, reported aboard in July. For the past three years he was in Seattle with the Supervisor of Shipbuilding.



JAMES E. CARROLL, NRDL Comptroller and Management Engineer since 1953, is presented a retirement pin by the C. O. & Director, CAPT D. C. Campbell, USN. Looking on is Richard Wilson, selected from 80 applicants to succeed Carroll, 70, who completed 32 years of Government Service on 31 October. A scroll and numerous letters attesting to Mr. Carroll's outstanding career were also presented to him. A World War I Navy Veteran, Mr. Carroll earned two degrees at Columbia University (B.S., 1919; Electrical Engineer, 1922). His Government career included work with the Department of Labor, War Manpower Commission, and Bureau of Budget.

CDR Campbell was not given a permanent billet during 1967 because he was sent for indoctrination and systems management schooling October-December.

In August CDR R. K. Voet, MC, USNR, Cellular Radiobiology Branch, went to AFRRI. LCDR S. M. Bailey, Jr., USN, left in October for Headquarters, MACV, Saigon.

Officer changes in December included LCDR D. M. Alderson's departure (see page 4) to assume command of USS COLLETON (ABV-36). Reporting for duty were LCDR F. C. Fehl, Jr., USN, from USS Arnold J. ISBELL (DD869) and LCDR W. E. Trelford, USN, from Staff Headquarters, MACV, Saigon. LCDR Fehl was assigned to Ship Systems Analysis Branch and LCDR Trelford to Radiation Instrumentation Branch.

FACTORS AFFECTING CREATIVITY STUDIED

Early in 1967 NRDL entered into a contract with the Institute for Behavioral Research in Creativity at Salt Lake City, Utah, to undertake a study of factors affecting creativity and productivity of the Technical Department. The director of this study, Professor Calvin W. Taylor, and two of his assistants held a two-day conference here on 13-14 March with supervisory personnel. Later a pilot study was performed. After the behavioral researchers refined these procedures, they returned again and conducted a study of about eight weeks duration during the summer. Information gathered will appear in a report to be prepared by early 1968. Hopefully, this study, oriented chiefly toward first line supervision, will produce results useful for training purposes both at NRDL and elsewhere.

TYPICAL KUDOS

Two examples cited below and the letter on the following page are typical of numerous letters of appreciation received for work performed by this Laboratory: The Chief of Naval Material commended the Naval Air Systems Command for a plan relative to Flak Suppression Weapons Systems. A good portion of this plan was contributed by two NRDLers, Messrs. R. J. Jenkins and G. A. Abbott, Technical Management Office...Dr. E. L. Alpen, Head, Bio-Med Div., was highly commended for his presentation on nuclear dose rates at a meeting at Wright-Patterson Air Force Base on 14 June. "Dr. Alpen's presentation and participation," Major General H. E. Goldsworthy, Commander, Aeronautical Systems Division at Wright-Patterson, wrote to CAPT Campbell, "contributed in an essential manner toward validating concepts and approaches in the establishment of survivability

COMMANDER NAVAL SHIP SYSTEMS COMMAND
WASHINGTON, D. C. 20360

DX/9020
Ser 6115-128

From: Commander, Naval Ship Systems Command
To: Commanding Officer and Director, Naval Radiological Defense Laboratory

Subj: Laboratory Superior Performance in Participation in Evaluation Study of Procurement Practices for DX/DXG Ships; recognition of

Ref: (a) Technical Report, "An Evaluation of the Implicit Risk of Sole-Source Procurement of the DX/DXG in the Event of National or Local Disaster" (U), USNRDL-TR-67-43, dtd 26 Apr 1967

1. On 31 March, NRDL was informally requested to assist a NAVSHIPS DX/DXG Study Committee in evaluating the risks implicit in single source, multiple ship procurement practices. The ensuing report, reference (a), was incorporated in toto with the Committee's findings and presented to the Chairman of the CNM DX/DXG Steering Committee on 1 May 1967. This analysis of the impact of fleet readiness due to natural and man-made causes constitutes a very thorough and informative report and is indicative of the laboratory's outstanding capabilities in operations research.

2. The Naval Radiological Defense Laboratory is commended for its timely response to the NAVSEC urgent request for support of the DX/DXG Study Committee, not only because of the high quality of the report, but also for the enthusiasm and unstinting effort devoted to its preparation.

F. C. Jones

Copy to:
NAVMAT 03L
0331

This results from work during April 1967 by Land-Based Systems Analysis Branch under LCDR D. M. Alderson, Jr., USN.

design goals as they relate to manned systems of concern to this Division."

AEC LICENSE INSPECTION

In early May Messrs. H. S. North and J. R. Metzger from Region V Div. of Compliance, USAEC, inspected NRDL's handling of Special Nuclear Material License and reported no item of noncompliance. They inspected the Laboratory's Byproduct Material and also noted no item of noncompliance. All Laboratory areas at San Francisco and Camp Parks were checked. The last AEC Inspection with similar findings was made January 1965. Special Nuclear Material is Pu, Ur-233, Ur enriched in the isotope 233 or 235 and is possessed in specified quantities up to approximately one kilogram. Byproduct Material is any radioactive material (except Special Nuclear Material) made radioactive by exposure to the radiation incident to the process of producing or utilizing Special Nuclear Material. Quantities possessed by NRDL are specified curie amounts of any Byproduct Material with atomic number 1 to 84 plus certain materials with higher atomic numbers.

ANIMAL COLONY ACCREDITED

At NRDL request, the Animal Colony was site-visited in February by two representatives of the Council on Accreditation of the American Association for Accreditation of Laboratory Animal Care. The site visitors, Dr. M. M. Rabstein and Dr. O. A. Soare, submitted a written report to the Council which in turn reviewed the report to decide whether this Laboratory should be accredited by the Association. Their positive decision is pictured on the next page.

The purpose of the AAALAC is to encourage optimal care for laboratory animals by establishing a program of voluntary accreditation. AAALAC membership consists of national, educational, health and research organizations concerned with the care, study and use of laboratory animals in scientific research. The association uses the Guide for Laboratory Animal Facilities and Care (USPHS Publication 1024) as its primary reference for evaluating laboratory animal care and facilities in determining eligibility for accreditation.

American Association

FOR

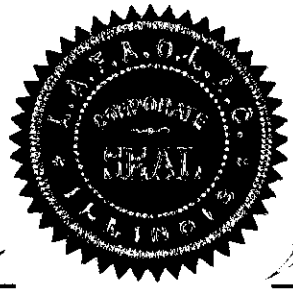
Accreditation of Laboratory Animal Care

Animal Services Branch

Biological and Medical Sciences Division

U.S. Naval Radiological Defense Laboratory, San Francisco

Is hereby accredited for demonstrating its compliance with the Association's standards.



May 5, 1967
DATE

CHAIRMAN
BOARD OF TRUSTEES

FACILITIES

RESEARCH ANIMAL FACILITY

Pictures and a sketch on the following two pages present a comprehensive story of NRDL's new $750,000 Animal Research Facility upon which construction started in February 1966.

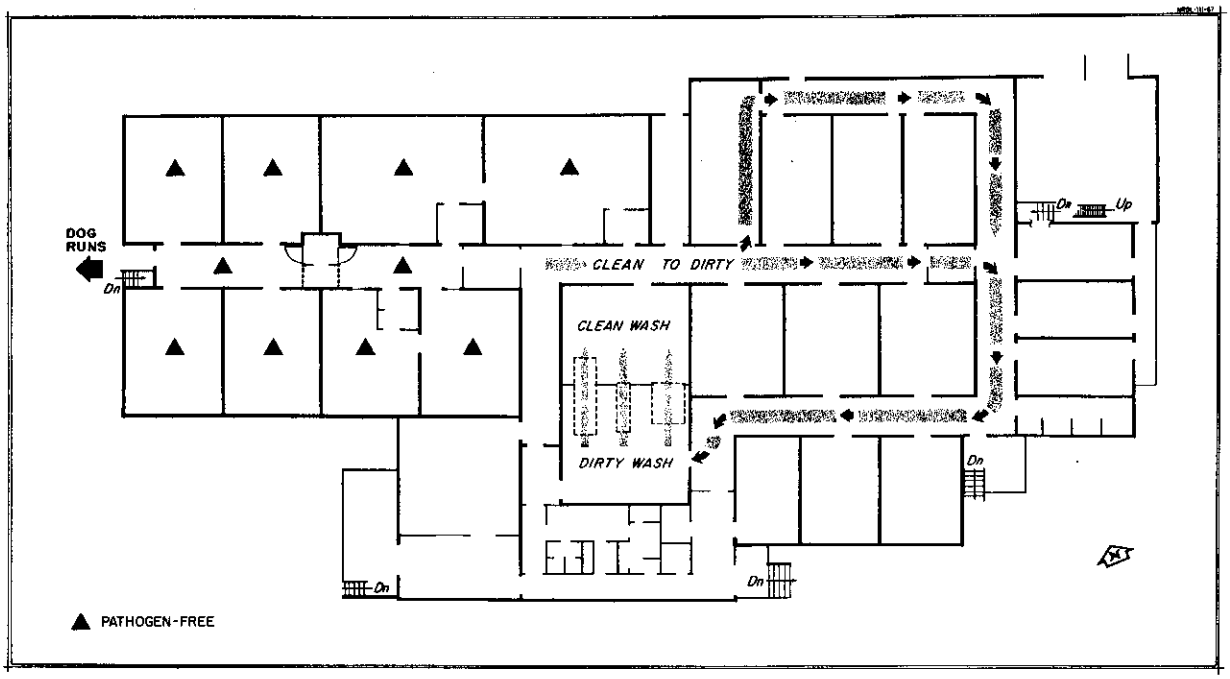
70-INCH AVF CYCLOTRON

News of this major facility warranted presentation as the lead article in the 1967 History. Events earlier in the year which led up to obtaining the first internal proton beam included assembly, pretesting and reworking of the RF system to achieve operation over the required range. The pole tips were assembled and a vacuum pretest completed. Phase 4 magnetic field data was obtained, orbital and extraction calculations performed, the regenerator redesigned, an ion source pulser designed and fabricated and many other components completed and assembled. Final assembly and pump down of the machine proper was carried out during the months of November and early December.

FIRE RESEARCH FACILITY

Modifications to Bldg. 510A were completed about 1 June 1967 for conversion to a Fire Research Facility (pictures on the 3rd page over). This windowless building originally housed X-ray machines so the walls are solid concrete, 3 feet thick. Principal work space has an unobstructed floor area of 600 square feet and a ceiling 40 feet high. A hood, covering about half of the ceiling, was installed over the experimental fire area and a variable speed blower provides a controlled draft to remove gases resulting from combustion. Simulated fuel arrays made with cylindrical electric heaters permit studies of convection and turbulent heat transfer. Wood crib fires up to 6 feet square can be burned with ease and safety. Purpose of current fire experiments is to measure burning rates, gas concentrations, air temperatures above the fuel bed and vertical air velocities in small model fires. Results of these experiments can then be used to scale the larger fires in the continuing Flambeau tests being conducted by Forest Service, DASA and OCD. Results of many large scale fires in carefully arranged fuel arrays in the Flambeau series show that scale modeling in small laboratory fires is required to predict the behavior of mass fires.

ANIMAL RESEARCH FACILITY PARTIALLY OCCUPIED IN 1967 - The Animal Research Facility was substantially completed in March 1967. Some time was then required to install collateral equipment and adjust the mechanical systems. The dog kennel was put into use in June 1967 and about half of the main building was put into use in July. The factor which prevented full use was failure of the sterilization autoclaves to function. At year's end it appeared that legal action may be required against the autoclave suppliers and the new Facility may be without autoclaves for considerable time.

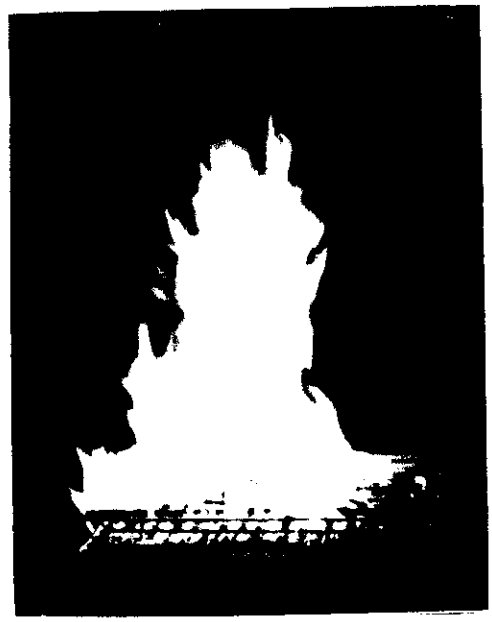


Layout of the 16,000 sq. ft. building, designed for "clean to dirty" traffic flow. A "pass through" barrier separates washrooms from clean areas. The building is a "cast in place" cement structure, so constructed to afford maximum germ control with minimum effort. Air conditioned throughout, each room has individual temperature control. An automatic bedding dispenser will put shavings into the cages, and soiled bedding will be vacuumed directly out of the building. Eight of the rooms are designed specifically for breeding pathogen-free animals. Breeding stock will be established for this pathogen-free colony by taking the young of current Laboratory animals by Caeserian section and having them nursed by germ-free animals purchased elsewhere. A microbiology laboratory for routine checking of all animals will be housed at the Animal Research Facility.

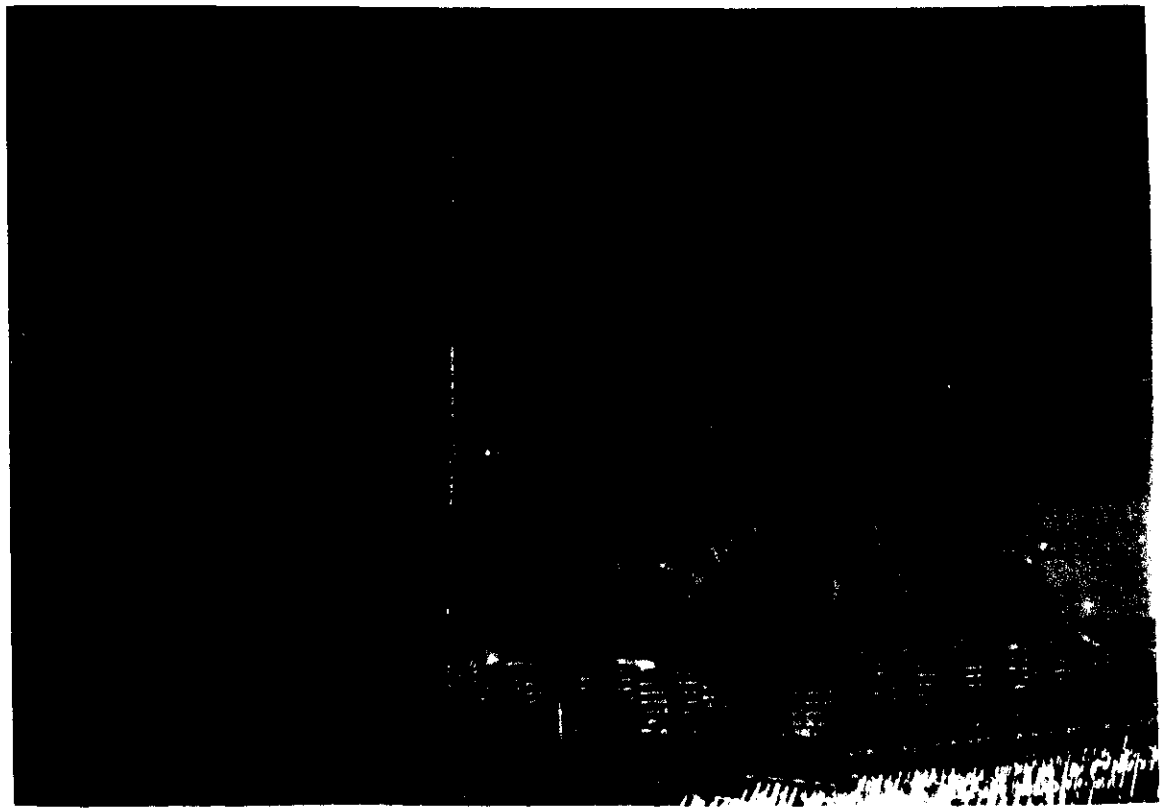
Front door of the Animal Research Facility (left). Close-up of one of the 78 animal runs (right), each equipped with automatic watering LIZIT and a resting board about one foot off the radiant heated concrete slab.

Rear view of the NRDL Animal Research Facility, Bldg. 830, located across the street and slightly west of the main Laboratory, Bldg. 815.

Exterior of fire research Lab



Scales crib fire experiment



Operation Flambeau test crib fire. Four NRDL investigators participated in recent tests (such as the above) and in the main event at Operation Flambeau held near Montgomery Pass, Nevada, where cribbed scrub timber covering a 50-acre area was ignited to simulate a firestorm.

COMPUTER TIE-IN WITH CHINA LAKE

A three-phased test of the use of a UNIVAC 1005 terminal connected to a large UNIVAC 1108 computer located 400 miles away at the Naval Weapons Center, China Lake was scheduled for February-September 1967. Chiefly because of slippage in the development of software by UNIVAC and a delay in installation of high speed transmission lines by the telephone companies involved, Phase I of the test lasted to the end of the year. The addition of the UNIVAC 1005/1108, even though limited, improved NRDL's computer situation although total computer capability remained inadequate.

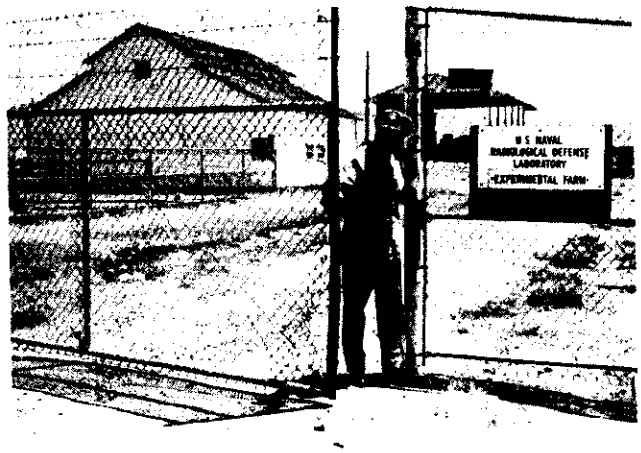
CAMP PARKS

There has been only slight change in NRDL's Camp Parks Facilities this year. The Laboratory has released Bldg 130 and explosive material bunkers 1183 and 1184. Activity at Camp Parks continues at a reduced level.

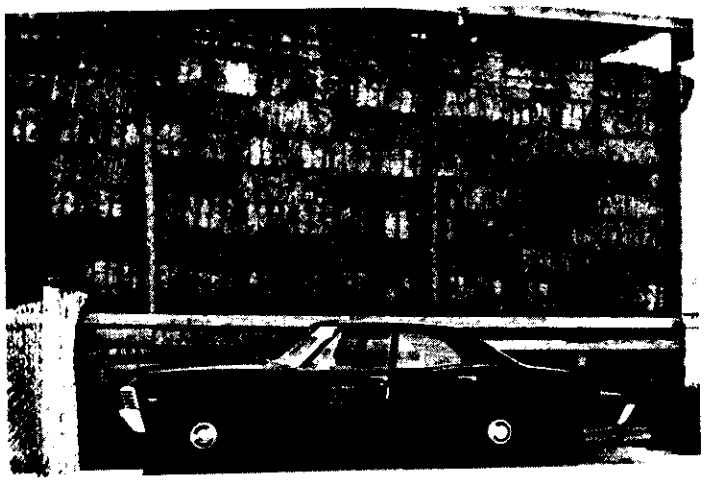
SAN CLEMENTE ISLAND

After an absence of five years, NRDL returned to San Clemente Island to set up a Marine Environment Test Station.

CAPT Campbell's Inspection of NRDL
Animal Facilities at Camp Parks
13 July 1967



Not shown are swine and their facilities under the supervision of the Alameda Sheriff, Santa Rita Rehabilitation Center.



250 tons of baled alfalfa and oat hay are stored in this shed. Approx. 5 tons are consumed weekly.

Angus bull used for breeding purposes on Camp Parks rangeland.

Three month old beagles with barrels and shade platform in background.

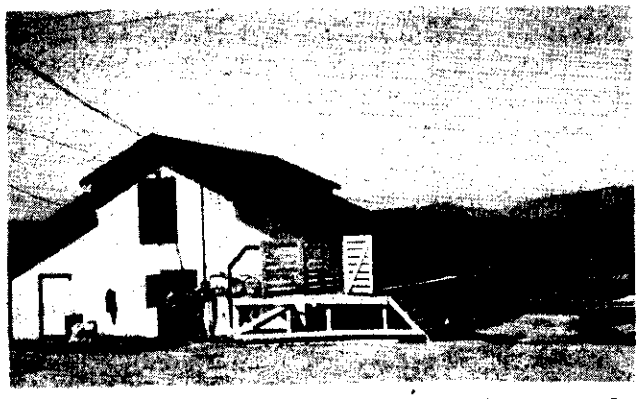
This six week old goose, incubated at the Laboratory, makes friends with beagle and five day old pups.

CAPT Campbell greets ten week old beagle pups at holding pen. 150 beagles are weaned yearly.

Gypsy, Bay, and Boy used for herding the goats, sheep, and burros on the 250 acre Bio-Med Farm.

A herd of Angora goats on one of the seven pastures.

Burros are held in observation corral for 60 days after irradiation. Appearance, appetite and other characteristics are studied, along with changes in blood structure.



Barn and livestock loading ramp with corrals in background.

Experiment sheep held in postirradiation corrals for observation.

Photographer Ray Krenik

CHAPTER II

TECHNICAL PROGRESS AND ACCOMPLISHMENTS

Technical progress and accomplishments at NRDL during 1967 are reviewed in this Chapter, as in the 1966 History, on a cross-sectional basis. Beginning with overall military applications studies reflecting operations/systems analysis type research directly applicable to specific fleet problems, and field test type projects conducted by, or on contract for, the various Technical Department Divisions and Offices, this Chapter also covers highlights of research in the various disciplines of instrumentation and electronics, biology and medicine, chemistry, radiochemistry and nuclear processes, oceanographic and aero-space studies and physics.

Owing to security considerations, some very significant studies performed as 'quick response' to Navy requests are only partially reflected in this History. Indeed, in 1967 these 'quick response' investigations, requiring immediate but thorough literature reviews, systems analysis research, computer oriented studies and state-of-the-art surveys, virtually mushroomed. Increasing requests from a number of Navy and other Department of Defense sponsors were directed to NRDL 'expertise', now virtual authorities in many areas of nuclear science. Many of these studies, however informal, rapidly assumed stature as major end-products of the Laboratory.

CRASH EXERCISE ON DX/DXG - At the request of NAVSHIPS, NRDL made a rapid one month study of risks involved with single source procurement of the DX/DXG advanced escort ship. Because of an extremely short study period it was not possible to make a normal analysis. Heavy reliance was placed on opinions of persons experienced with Navy shipbuilding. The following provided much of this experience: SFBNS-RADM J. H. McQuilkin, USN, CAPT C. L. Fears, USN, CAPT C. M. Hart, USN, CAPT D. T. Homes, USN, CAPT R. A. Porter, SC, USN, CAPT D. C. More, CEC, USN; PSNS-RADM W. F. Petrovic, USN, CAPT H. R. Adrianse, USN, CAPT R. C. Jensen, CEC, USN, CAPT David Keers, SC, USN; SUPSHIP Seattle-CAPT R. E. Harris, USN, Mr. J. L. Mullins, Jr., Mr. J. D. Winston; SUPSHIP SFRAN - CDR G. R. Jones, USN.

AEROSPACE NUCLEAR STUDIES

BETA DOSE TO TISSUE FROM PARTICLE DEBRIS

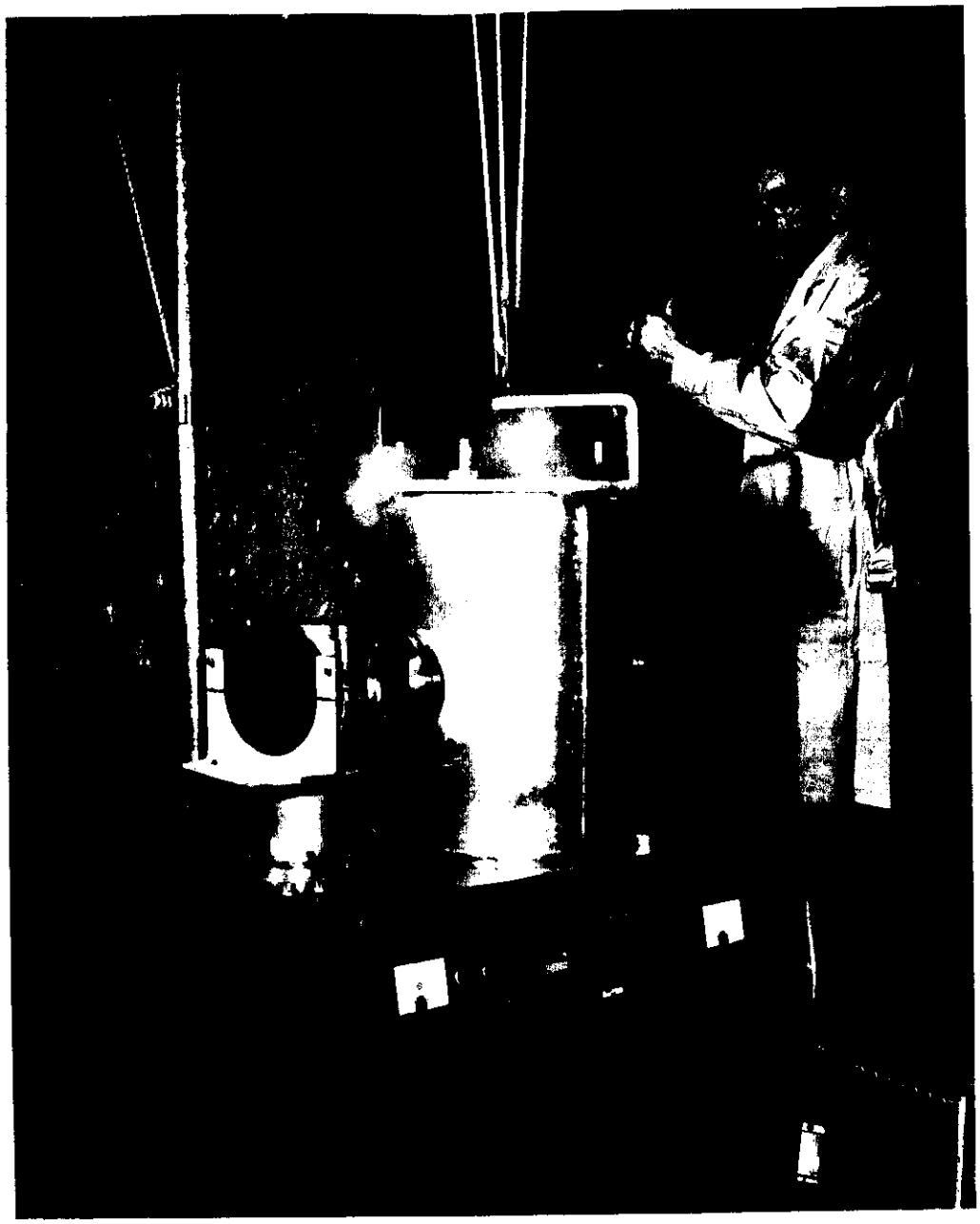
In aerospace nuclear applications beta dose to tissue from particle debris now can be calculated by three mathematical models developed at NRDL during the year. The models calculate beta-dose in tissue from radioactive fragments created by destruct and consequent re-entry of a nuclear-powered aerospace vehicle into earth's atmosphere. Most sophisticated of the three models combined Monte Carlo beta-transport techniques with beta-spectrum degradation and electron-energy-dissipation methods. A comparison of the dose rates in tissue from the three models for typical reactor running conditions, along with expected beta doses from particles created by a hypothetical nuclear-engine destruct, was included.

INHALATION HAZARDS FROM SPACE VEHICLE LAUNCHES

Launching of space units containing toxic or radioactive materials presents a potential inhalation hazard to populated areas in event of a vehicle abort or destruct. As wind and temperature-inversion data are used to determine rate and direction of cloud spread, a knowledge of meteorological conditions at specific launching points was needed to determine most favorable times for launching vehicles containing these materials. Launching area wind and inversion data were summarized for the 4-year period July 1959 to June 1963. Daily and monthly averages for both daytime and nighttime climatological conditions, inversion data including base height, thickness, temperature difference, and temperature increase as a function of height, and wind data for surface as well as 1000-, 2000-, 3000-, 4000-, and 5000-foot altitudes above sea level were included. Values of concentration from Sutton's instantaneous-release, point-source diffusion equation were tabulated for several release heights so that magnitude of inhalation hazards can be estimated. Isotropic and nonisotropic cloud spread for both inversion and lapse conditions were considered and an indication of the correction required for clouds of initial finite size included.

SNAP PROGRAM RADIOACTIVITY RELEASE STUDY

In the event a plutonium-dioxide-fueled SNAP device is accidentally placed in an ocean environment seawater may gain entry into the hot fuel capsule and expose the fuel to hot seawater. For delineation of consequences to plutonium dioxide under these conditions, a study was



OUTER-SPACE SIMULATION CHAMBER for use in 1967 experiments concerned with stability of thermal-control coatings in the hostile space environment. Temperature of a space satellite surface depends both on optical properties of its coating and on heat exchanges with the interior. These changes can be measured in the laboratory in a simulated space environment provided by a vacuum chamber equipped with an inner liquid nitrogen cooled shroud. (In photo Frank Laughridge is filling shrouds with liquid nitrogen). The satellite orbit is simulated by irradiating the test specimen inside the chamber with a tungsten lamp with intensity controlled by a venetian blind shutter. Opening and closing of the shutter is programmed so that the time-temperature history of each sensor corresponds to an identical sensor on the satellite. Two orbits, each 93 minutes, are programmed to assure that each sensor and its supports are responding in the same way as in space.

made to determine solubility rate of plutonium dioxide in high temperature seawater. Results showed long-term solubility rate of plutonium dioxide at high temperatures to be lower than the rate at room temperature. Lowering of the solubility rate was attributed to formation of a calcium sulfate coating on plutonium dioxide beads at high temperatures. Observed rates at room temperature, 120° and 190°, were 4×10^{-3}, 1.3×10^{-4} and 6×10^{-4} μg/mg/day, respectively.

(Post-Ocean Exposure Check) In addition to controlled Laboratory experiments, a test plan for in situ ocean exposure of uncontaminated radioisotope field material was implemented along with a plan for post-exposure examination of fuel material - ocean bottom material system following recovery of exposure chamber. Procedures were devised for determining whether the fuel remains on top or migrates towards the bottom of an exposure chamber.

(Search Recovery Factors) Estimates were made of location error for a downed SNAP unit involved in an early flight missile launch abort, and navigation error of search vessels also estimated. Effect of these errors on size of area to be searched an on probability that the unit is within that area was studied and sensors, usable in such a search, considered. It was noted that either a newly devised mechanism or modification of existing mechanisms would be desirable for salvage of the unit.

EXPOSURE TO AEROSPACE VEHICLE NUCLEAR DEBRIS PARTICLES

Problems of exposure of man's skin, lungs, and gastrointestinal tract to radioactive-debris particles (1 to 1000μ in diameter) from nuclear-powered aerospace vehicles as a result of reentry burnup or self-destruct were researched and mathematical models developed for analysis of exposure (1) of skin through particle impaction and settling; (2) of lungs through particle suspension, resuspension, and impaction inhalation; and (3) of GI tract through swallowing previously inhaled particles. Description of lung exposure and gastrointestinal exposure following inhalation is based on theoretical and experimental work leading to passage and retention-fraction equations for an assumed respiratory system of three regions: nose and mouth, middle region (pharynx to terminal bronchioles inclusive) and deep lung. A computer program incorporates these equations and an equation for gastrointestinal exposure from ingestion was developed but not yet computerized. These models are used to perform sensitivity analyses of a number of parameters for each of the three kinds of exposure, using a hypothetical nuclear-rocket run with a self-destruct to provide particle-deposition input data. Models are presented in an implementing FORTRAN II computer program along with

tabulated and graphic sensitivity results. For each of the three kinds of exposures and retentions: skin, inhalation, and ingestion, particles/person (p/p) findings vary through several orders of magnitude depending greatly on values of input parameters; particle mass density and size, and deposition density in particles/m^2. Skin retentions depend additionally on area of body uncovered and range from 8.5×10^{-2} to 2.2×10^{-6} p/p. Lung retentions range from 2.0×10^{3} to 0 p/p and gastrointestinal retentions from 3.7×10^{3} to 6.4×10^{-10} p/p, both depending additionally upon values of several breathing parameters.

AEROSPACE PHYSICS STUDIES

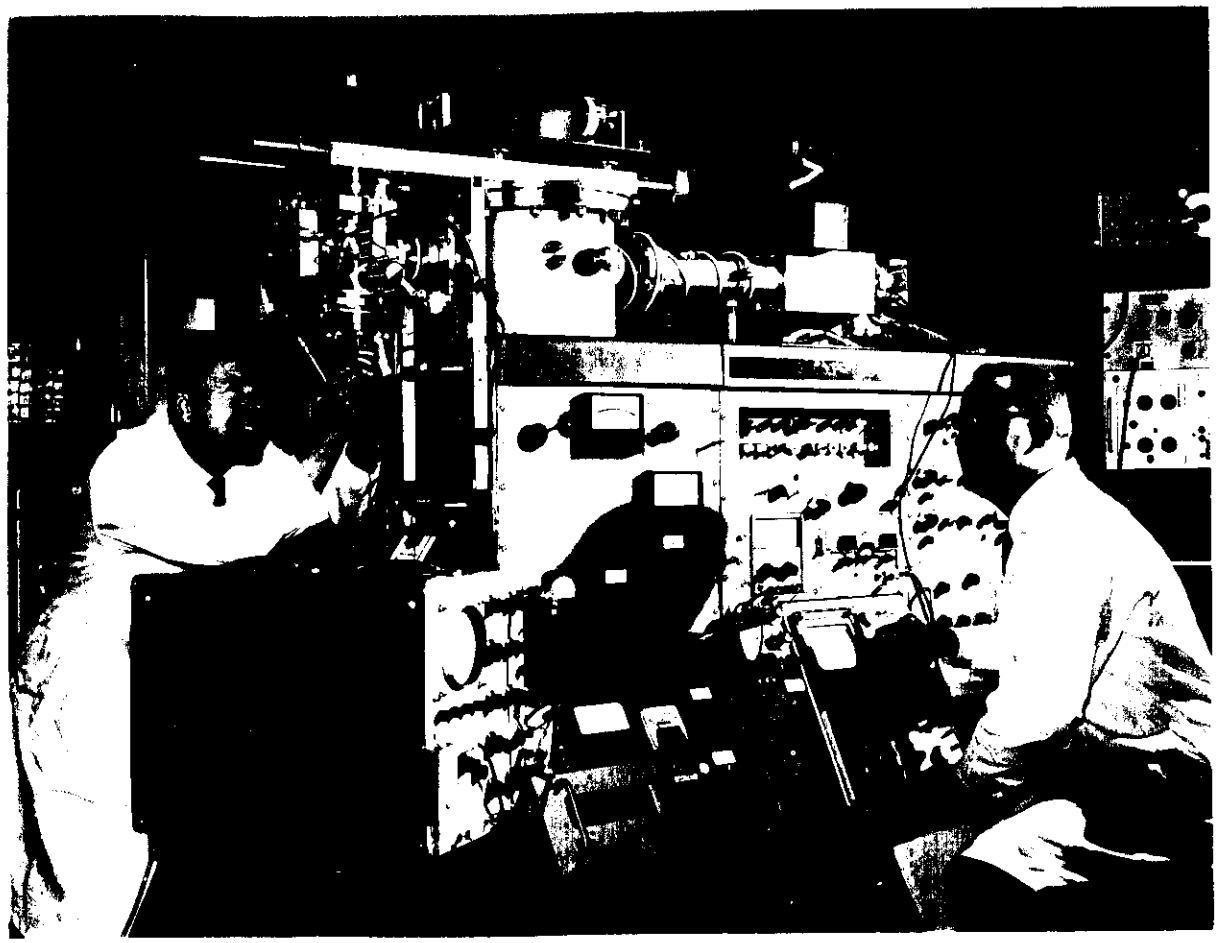
METEOROIDS' TEMPERATURE IN SPACE

Differences in a quantity of primordial gases in some meteorites have been shown to correlate with their optical properties since temperatures of meteoroids depend on these properties and their measurement is necessary before temperature in a given orbit can be calculated. In a NRDL study of these temperatures, it was found that the α/e ratio of chondrites lies between 0.5 and 1.0; of iron between 2.0 and 4.0. Using these values, temperatures of three classes of meteoroids, light chondrites, dark chondrites and irons were calculated for the Mercury orbit. Values varied from 100°C for a light chondrite to 400°C for an iron.

AEROSPACE ELECTRONICS STUDIES

HEAVY PARTICLE DOSIMETRY FOR SPACE FLIGHT

First phase of a NASA sponsored research project seeking a heavy ion dosimeter for measurement of primary cosmic radiation on long range manned space flights was completed. Specifically, a criterion for registration of tracks in polymercharged particle detectors was developed and experimental checks were made of the accuracy of a range-energy computer program for heavy ions in matter using both silicon solid state detectors and direct comparison with track lengths from previous exposures. Encouraging progress was made also on studies of response of polymer track



Dr. Ken Lincoln (left), assisted by Mr. Frank Wodley, inserts a sample of heat shield material into the time-of-flight mass spectrometer. This work is part of an ARPA-sponsored project in which the spectrometer is used to determine the species of gaseous thermal-decomposition products that emanate from the surface of the exposed material as a result of laser-induced heating. The chemical composition of the products is then determined through analyses by means of the mass spectrometer. This research is concerned with the chemistry of wakes of reentry vehicles of interest to the Navy with regard to their future missiles.

detectors to heavy, multicharged particles of energies of MeV/nucleon using data obtained during the Aug. 1966 Fort Churchill balloon flight.

PROTECTION AGAINST NUCLEAR WEAPONS

FLEET ANTI-AIR WARFARE MODEL

An operationally valid anti-air warfare model was prepared for detailed examination of naval operational problems and requirements in a nuclear environment. This model, a computer simulation with conventional and nuclear weapon options, combines operational validity and physical realism in weapons effects, both conventional and nuclear. Labelled SIN or Systems Interaction Nuclear, the model is derived from Systems Interaction Model (SIM), a computer war game designed by APL, Johns Hopkins. SIN model gains computational flexibility and efficiency by being programmed through NRDL General Simulation Routine, which controls input, dynamic storage allocation, and event sequencing for any event-store simulation or war game. Physical realism in its end-game treatment of nuclear weapons effects is incorporated by assessing separate effects of each nuclear burst on each ship in the force. Although only initial effects are explicitly treated, the model is intended to provide realistic space and time distributions of nuclear bursts for subsequent study of delayed and residual effects.

LAND FALLOUT PREDICTION SYSTEM

A computerized physical description of cloud-dynamics and fallout-particle-formation phases for a model of a land-surface nuclear burst was developed comprising two FORTRAN computer program modules, Cloud Rise and Particle Activity. The Cloud Rise Module estimates fallout mass vs particle-size distribution and time-history of temperature and dimensions of a rising and expanding nuclear cloud. The Particle Activity Module estimates fallout particle-size vs fractionated exposure-rate contributions (refractory, mixed, volatile and induced components of total radioactivity). A computer program for a sufficient portion of a Generalized Land Fallout Model was written also to demonstrate utility of modules and to define a method for incorporating modules in other programs. Output data from demonstration runs shows sensitivity of modules to input data, i.e., yield, tropical and midlatitude atmospheres, and burst-point soil-melting temperature.

CLOUD RISE IMPROVED FALLOUT MODEL

Theoretical bases of a land-surface-burst nuclear-cloud-rise model were described and development from a theoretical model of a computer program labelled DELFIC completed in a joint effort by NRDL and a contractor. By use of this dynamic cloud rise model, histories of the rise, growth, temperature, and composition of the cloud are computed throughout virtually the entire period of its rise. Effects on the cloud development of atmospheric structure can be accounted for, and development of a time-temperature history for the cloud allows fractionation of radioactive weapon debris to be approximately accounted for in Particle Activity Module (DASA-1800-V) calculations. DELFIC Cloud-Rise-Transport Interface Module (CRTIM), which can accept particles aloft outputs from either a "parcel" cloud rise model, such as the one currently used by DELFIC, or from a detailed two-dimensional hydrodynamics calculation, has also been developed. The CRTIM corrects particle positions for wind drift during cloud rise time period and prepares the particles aloft inputs for DELFIC Transport Module (DASA-1800-IV).

METHODOLOGY FOR ESTIMATING CASUALTIES

As part of a broad study of operational requirements for nuclear weapon effects information, a procedure was developed for estimating the number of delayed combat ineffectives attributable to initial ionizing radiation as a function of time after burst. This computing procedure for a given analytical representation of the biological response mechanism provides estimates of the fraction of personnel who are immediate casualties due to prompt nuclear effects. It also provides estimates of those who become delayed casualties at later times due to initial ionizing radiation. Taken into account is weapon delivery accuracy and the size of the target area over which the personnel at risk are distributed.

PREDICTING OF INITIAL GAMMA EXPOSURE

From nuclear surface bursts in specified yield ranges prediction of initial gamma exposures were 'methodized' from most recent analysis of test data. Both graphical and analytical formulations were developed in a semi-empirical model for the predictions. Weapon yield, fission-to-total-yield ratio, and ambient air density are required inputs for prediction by the method proposed and either formulation may be used with expected reliability limits of $\pm$ 30% for the exposure.

GAMMA EXPOSURE RATE COMPUTATION MODEL

A Gamma Exposure Rate Computation Model was developed as a research tool to be utilized in the study of radioactive fission product sources (column, base surge, and pool) associated with underwater nuclear explosions. Utilizing the Monte Carlo technique and written in FORTRAN language for IBM 704 computer, the code estimates gamma-ray exposure rates at points in the vicinity of such sources. Sources and their surrounding environment may consist of several media of different composition and/or density. Exposure rates are obtained using either a volume-averaging method of estimating energy absorption at each detector position or a method involving estimation of energy flux at each detector.

ATMOSPHERIC TEST AIR-VAPOR DENSITY TABULATIONS

Ground-zero and burst altitude tabulations, including associated dry-air and water-vapor density data, for atmospheric nuclear tests were completed. Density data for a tropical (15° N Lat.) atmosphere up to 90 kilometers were included plus a method for computing columnar air mass between two points at different altitudes for specific proving ground area. This method can be extended to any set of spatial points within the wide limits provided and can be used for other atmospheres.

AIRBORNE DETECTION SYSTEM RADIATION BACKGROUND

Suitable for monitoring radiation over the ocean, airborne detection system radiation background measurements were developed. Components of background due to isotopic contamination and cosmic rays were separated, pulse height spectra measured, and background suppression techniques compared over large salt ponds simulating a radioactive pool at sea.

NUCLEAR CLOUD PHENOMENA

In a study of nuclear cloud phenomena, specifically on relative motion and coagulation of particles in a turbulent gas, it was found that the theory of turbulent-accelerative particle motion relative to fluid and coagulation may be extended to particles where relaxation times are greater than the period of microscale eddies. Different coagulation mechanisms were compared with the conclusion that the only situation on earth in which turbulent-accelerative coagulation can be more important than gravitational coagulation is in nuclear-explosion clouds. A method of numerical computation of coagulation due to all mechanisms cited also was developed.

DECONTAMINATION PROCEDURE

A decontamination scheduling procedure for resident and other facilities exposed to fallout was developed that permits the user to correlate target analysis results, shelter protection factors, and decontamination data. Feasible decontamination assignments and decontamination schedules may also be obtained and, because the procedure delineates individual exposure doses for all contemplated exposure periods, clear choices of personnel assignments and scheduling options can be effected. Scheduling examples are included as are procedural aids for minimizing decontamination scheduling calculations.

POST-NUCLEAR ATTACK AVAILABILITY OF FOODSTUFFS

Post-nuclear attack availability of foodstuffs for a single city was the objective of an analytical study in which, to support quantitative analysis of a selected, typical city's food distribution system, data were developed depicting location, vulnerability, capacity and inventory of local food producers, processors, wholesalers, retailers, restaurants, institutions, and consumers. Capacity and inventory data were compiled on a commodity-by-commodity basis for eight food groups of meat, milk, eggs, cereals, cereal products, fruits, vegetables, food fats, potatoes, and sugars. These data were summarized in commodity-flow models depicting normal distribution patterns followed by each food group in reaching local consumers.

NUCLEAR ATTACK SHUTDOWN OF STEEL PLANTS

A study was completed of vulnerability of steel-plant operating components to damage from fast shutdown following warning of arrival of fallout from a nuclear attack. Data on expected damage were obtained from personnel of several steel plants in various parts of the United States. Estimates of man-hours and time required for repairs for 1-hr and 5-hr shutdown times and for two situations assumed to represent most pessimistic and most optimistic conditions for each time were obtained. Procedure was devised for estimating the man-hours in time for any integrated steel plant and recommendations were made for actions that can be taken by individual plants and by the steel industry as a whole to minimize damage and expedite resumption of steel production.

UNDERWATER DETONATION DATA REVIEW

Extensive literature review of the distribution of radioactive debris

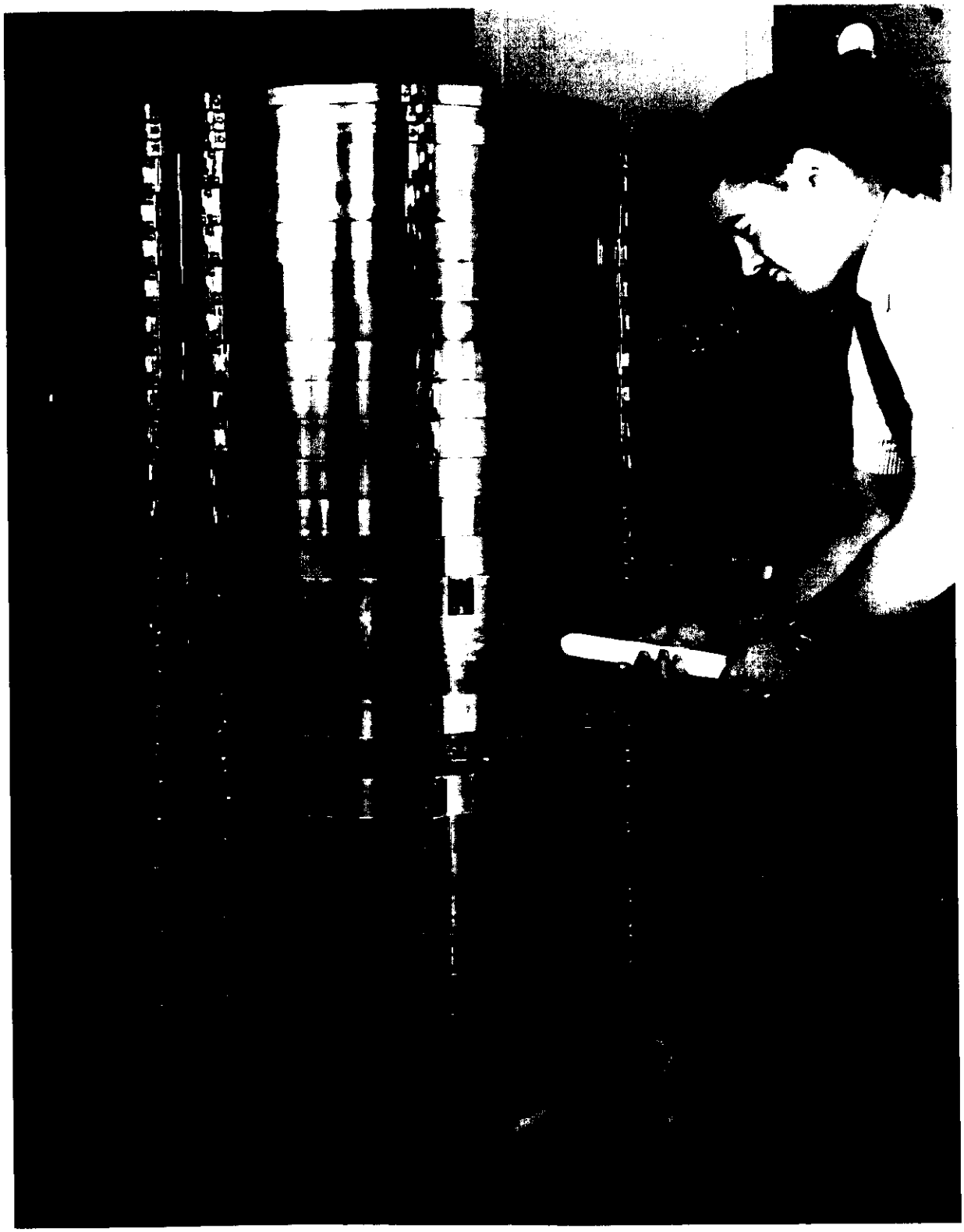
and associated nuclear radiation from underwater nuclear explosions was completed as a contribution to a book being published by DASA on "Underwater Nuclear Explosions". History of the fission products is followed from the time of detonation and free-field gamma radiation phenomena are discussed for various depth ranges by evaluation of three major sources: the early above-surface phenomena, the base surge, and the residual radioactivity in the ocean.

SHIP-SHIELDING CALCULATIONAL METHOD

A new method was devised for gamma-ray ship shielding calculations relatively simple in concept and use and applicable to various types of situations involving either plane or volume sources of radiation. Sufficient in accuracy to satisfy most operational and ships design requirements, the method is graphical in design for hand calculation of ship shielding factors utilizing a piece-by-piece accounting for each slab of shielding material and a time-dependent gamma-ray pseudo-spectrum consisting of five energies.

RADIATION SHIELDING IN A DESTROYER

Radiation exposure reduction factors in a destroyer enveloped in a nuclear cloud during an attack were simulated in Laboratory investigations. Exposure rates recorded at various locations in and on the destroyer during numerous exposures to a movable distant point source of Cobalt-60 gamma rays were synthesized into approximate volume-source exposure rates. Resulting semi-empirical data were used to compute factors by which gamma exposures from an enveloping, radioactive base surge or nuclear cloud would be reduced by the ship's structure. The mathematical process used in conversion from point-source to volume-source data for a given detector station involved: (1) assigning solid-angle elements to each contributing source, (2) accounting for buildup and attenuation of radiation from each element, and (3) combining data from all contributing elements. Results were obtained for fifteen locations and comparisons with weapon-test data showed reasonable agreement, indicating that this method of simulation can be a useful means of obtaining shielding information applicable to nuclear warfare situations from experiments with radioactive sources. Since the method starts with experimental data, results are far less sensitive to inaccuracies in assessing the thickness of shipboard shielding materials than are results from purely calculational methods.



Complete detector and shield assembly for the low-background, Compton suppressed gamma-ray spectrometer, showing Mr. Bruce Euler, Nuclear Chemistry Branch inserting a sample planchet into the detector.

GAMMA-RAY ENERGY SHIELDING FACTOR ON A SHIP

Given the shielding factor gamma rays of energy E_o and for a location in a ship, what is the shielding factor for the same location in the ship for a different gamma ray energy? NRDL personnel devised a simple method of calculation in graphical form for easy prediction. This calculates gamma ray shielding factors for any single gamma ray energy from 0.25 to 2.75 MeV provided the shielding factor for a specific gamma ray energy is given. Data for the graphical method, actually consisting of a single graph, gives a correction factor, k, value for 0.25-to-2.75 MeV gamma-ray energies and for various iron shielding thicknesses in inches. Extrapolation for higher gamma-ray energy is possible; for example, for initial radiation lower gamma ray energies are operationally not significant.

DISTRIBUTION OF GAMMA RAYS STUDY

An important contributor to radiation fields from nuclear weapons is secondary gamma radiation produced by neutron inelastic scattering. In order to calculate this contribution, it is necessary to know cross-sections and angular distributions for interactions producing the gammas. Cross sections for production of these gamma rays at several angles were investigated and defined. These cross sections will be used in calculational methods for determining radiation fields produced by nuclear weapons which influence operation of Navy and other military systems, components and units. They also are used to verify theoretical formulations which provide a broader base for determination of nuclear weapon radiation fields. Theoretical and experimental angular distribution of gamma-rays produced by $(n,n\mu)$ processes in sodium, magnesium, aluminum, chlorine and sulfur have been defined in the NRDL study.

OCEANOGRAPHIC STUDIES

AERIAL SEA-WATER SAMPLER

Development of a system for rapidly sampling surface seawater from the open sea anywhere in the world was completed in October. Specifically, a high-buoyancy, rapid-fill sampler was developed for use with a

fixed wing aircraft. It can be deployed on 800 ft. of special line from an aircraft flying at 150 ft. altitude. The sampler sinks, fills and pops to the surface about 1.5 sec. after water entry, is pulled free of the water by forward motion of the aircraft, and is then recovered by winch.

NEW UNDERWATER 'SHOT' DETECTION APPROACH

Development of a system for on-site inspection for clandestine underwater nuclear explosions requires ability to predict initial distribution of fission products in the ocean from explosions covering a broad range of scaled depths. Of particular interest are those explosion depths below which there is a question as to whether detectable quantities of fission products will reach surface layers or atmosphere. Thus, there is a need to describe hydrodynamic flow and resultant radioactive fission product transport resulting from detonation of a nuclear device far below the sea surface. Qualitatively, what happens is that a bubble of steam is formed which pulsates and rises under gravity. If depth of burst is sufficiently great, the bubble will shortly condense away, and upward flow may or may not be sufficiently persistent to reach the surface.

There is no available simple solution to this problem in a theoretical sense which will provide meaningful answers to pertinent questions. Therefore, NRDL investigators took an approach of returning to basic principles and of solving Navier-Stokes equations for incompressible flow numerically using high-speed digital computers.

Work is not yet complete, and no conclusions can yet be drawn concerning the underwater explosion problem; nevertheless, a first version computer code was developed and tested. A basic computer program was started on the NRDL-NOTS UNIVAC 1005-1108 computing system. This code will solve incompressible, viscous, initial-value two-dimensional, axially symmetric fluid flow problems involving up to two free surfaces with differing pressures on each.

RADIOACTIVE POOL PROBLEM 'COMPUTERIZED'

A FORTRAN IV computer program was developed which uses a modified version of the USNRDL pool model to calculate two estimates of the exposure-rate history and total exposure for an unshielded radiation detector moving in a straight line at constant speed and depth through a stratified radioactive pool which is expanding and being dispersed and distorted by constant ocean currents. The program output consists of

printed tables which include (1) various input parameters, (2) two estimates of total exposure, and (3) pairs of exposure-rate estimates for between 20 and 1000 time positions along the track. Two exposure-rate and exposure values computed represent an upper- and lower-bound estimate consistent with state of knowledge of radioactive pools generated in the ocean by underwater nuclear bursts.

OCEAN AREAS PLOTTED

Data has been developed for assessment of expected frequency for random deposition of nuclear power units on land and in various ranges of ocean depths as related to latitude of impact. Derived as the forerunner of a more general study of problems associated with the deposition of radioisotope-bearing power units in the ocean, data covers geographical distribution of land (of any elevation) and of water-depth zones in the oceans. Average depth or elevation of areas approximating $1^{\circ} \times 1^{\circ}$ squares of earth's surface were processed to yield the fraction of the total area falling into one of seven bathyorographic zones. Values were determined for: latitude bands centered on the equator from X° South to X° North, 10° longitude bands, the entire earth, bands of latitude from 0° to X° North or 0° to X° South and 1° latitude bands. Depth zones used in categorizing these regions included one zone for sea level and higher land areas, five zones for depths from sea level to 2000 meters, and one zone for depths greater than 2000 meters.

SEA WEED STUDY

Numerous marine invertebrates forage on benthonic sea weeds. In culture of ulva lobata and related species, they rendered algal tissues unsuitable for NRDL studies of radio-contamination processes in marine sea weeds by boring holes in and otherwise damaging tissue membranes. A search for a means of controlling predators succeeded in the form of culture of ulva and related marine sea weeds free of contaminant invertebrates by application of pesticide, Lindane (γ-hexachlorocyclohexane), at 1-5 ppm. Continuous maintenance of pesticide at these levels for periods in excess of 90 days indicated no adverse effects to either algal transplants or developing sporelings.

FIELD TEST

MOTECS SUCCESS AT "BLUE LOTUS"

The Mobile Tactical Exercise Control and Evaluation System (MOTECS), a digital data communications, processing and display system developed by NRDL to support operations research programs, was given a preliminary test during Exercise BLUE LOTUS at Camp Pendleton, Calif., 4-9 Dec.

The system, valued at $500,000, is designed to permit real time acquisition, transmission, recording, correlation and display of data and information generated in training exercises. The system makes use of digital message entry devices (DMEDS) employed in conjunction with the normal Troop Exercise Control (TEC) system to gather information as significant activity occurs on the simulated battlefield. The digital messages are spurt transmitted to a van mounted Mobile Tactical Exercise Control and Evaluation Center. The Center contains the equipment necessary to decode, record, process and display data pertinent to operations research problems under investigation.

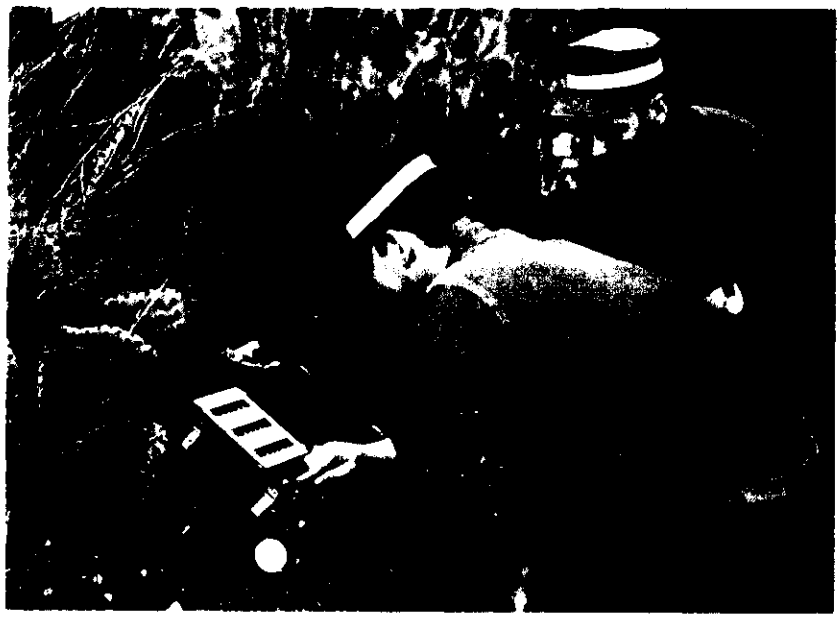
During Exercise BLUE LOTUS, the system was employed by NRDL and Marine Corps personnel, in parallel with the normal TEC reporting system. Its capacity to provide real time displays of unit locations, status, and combat activity (down to platoon level) was successfully demonstrated. The system was enthusiastically received and endorsed by BLUE LOTUS TEC personnel. A continuing development program is planned for MOTECS with its eventual incorporation into the TEC foreseen.

NRDLers participating in the BLUE LOTUS Exercise were G. W. Gibson, Maj. R. F. Milligan, USMC, D. H. Williams, W. M. Waskom, R. E. Hawley, W. E. Shelberg, J. L. Jeung, and Jim Reichardt.

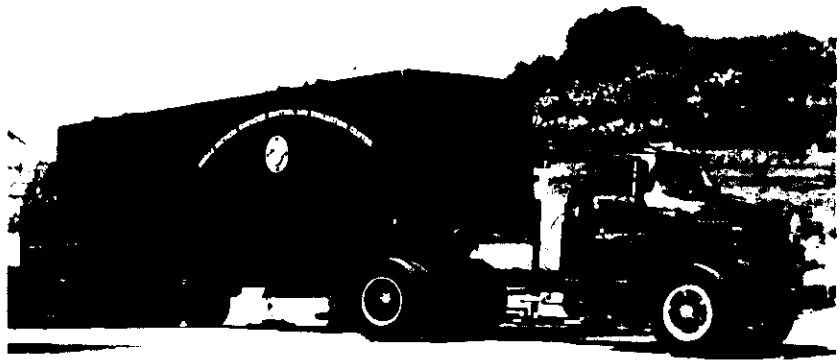
ARMS CONTROL AND DISARMAMENT AGENCY, PROJECT CLOUD GAP

Project Cloud Gap is a joint field exercise with the British Armed Forces. This will be evaluation of arms control verification techniques and equipment. Scheduled for the summer of '68, it will be rendered technical assistance by NRDL. First phase of the NRDL effort, which includes identification, procurement, installation and operation of special test equipment, was completed on 7 December. An NRDL team completed exercise UNIFORM, a preliminary field test for equipment evaluation conducted at Alameda Naval Air Station during the week of 29 October and at

EXERCISE BLUE LOTUS



DMEDS being employed by Marines.



NRDL van with Mobile Tactical Exercise Control and Evaluation Center.

Camp Roberts, California, during the week of 5 November. Sensors were tested against aircraft at Alameda and against wheeled and track vehicles at Camp Roberts. They included acoustical, seismographic, infra-red, inductance and pressure sensors.

SUBSURFACE EXPLOSION TRACING

The CHASE V operation held on 23 May 1966 detonated approximately one KT of unserviceable explosives in Pacific Ocean off the Northern California coast at a depth of 3750 ft. In June 1967 final report was published. The objective of the NRDL part of the experiment was to determine the degree of containment of explosion products below the surface layer, using Rhodamine-B dye tracer with fluorometric measurements both near surface and in subsurface waters. In addition, hydrographic and airborne infrared scanner measurements were made for detection of any significant deep water upwelling resulting from detonation. Results of the surface water fluorometric and infrared scanner surveys established that explosion products were contained below the surface layer. Subsurface measurements did not conclusively locate the subsurface explosion products and a number of operational problems associated with locating underwater and surface explosion debris from a surface ship were encountered.

HMCS YUKON TEST OBSERVED

On invitation of the Royal Canadian Navy, arrangements were made under provisions of IEP ABC-25 for two NRDL observers to attend test trials of a production model of the NBCD filter system installed aboard HMCS YUKON. Messrs. J. S. Dearth and R. N. Anderson, Military Evaluation Division, observed trials conducted off Esquimalt, B. C. during the period 26 March - 5 April. To reciprocate for the courtesies extended NRDL observers by the YUKON personnel, an invitation was extended to the C. O. to visit NRDL when in the San Francisco Area. Direct liaison between the YUKON and NRDL was established during the ship's visit 10-14 May and seven investigators from the Laboratory were given a tour of the ship.

RADIOACTIVE TRACERS FOR BEACH SAND MIGRATION

In an Army Coastal Engineering Research Center sponsored study of seashore transport of beach materials past coastal promontories at Pt. Concepcion, Calif., sand labeled with radioactive nuclides was used.

NRDL investigators developed a water glass technique and tagging procedure several years ago in production of fallout simulant. The technique and procedure had encouraging results on the beach sand project when used for sealing radioactive nuclides Ba^{140}-La^{140} and Cr^{51} into the sand. The NRDL procedure can be extended to beach sands whenever carbonate minerals are absent or removable. Objective of a 1967 NRDL conducted investigation was determining whether outgassing of ^{133}Xe will occur when xenonated sand is subjected to conditions prevailing at the water-sand interface of a marine environment. Experiments were similar to those used previously to test integrity of the NRDL water-glass technique for labeling sand with radioisotopes. Results were: (a) ^{133}Xe is slowly released from xenonated sand in the presence of water; (b) amount of ^{133}Xe lost to the aqueous phase was relatively small (5% maximum), and (c) there was little difference between static-experimental and abrasion-experimental results. The work contributes to the knowledge of conditions created by an atomic attack intended to clear a beach prior to amphibious operations.

NEW METHOD FOR CALCULATING DOSE RATE ON NEUTRON-INDUCED ACTIVITY ON A BEACH

When a typical tactical nuclear weapon is detonated just high enough so that the fireball does not touch the ground, neutrons induce the major radioactivity hazard, soil activation by neutron capture. Extent of that hazard depends on composition of soil. Calculating neutron-induced activity dose rate on a beach is complicated by inconsistencies of sand composition. In fact, sand is much richer in water and sodium content closer to the water line.

In an investigation of how to describe a beach mathematically to make such a calculation, the beach was conceived of as concentric rings about a detector. Soil activity was calculated in the neighborhood of several sample points. For each ring of sand the average function was constructed from various neighborhood functions. Then the dose rate to detector was summed up from each ring of sand, taking into account inverse square loss and attenuation through the sand. Gamma rays from the neutron-induced nuclides Na^{24}, Mn^{56} and Al^{28} were considered. The method used can consider nonuniform Na, Mn and Al content and neutron thermalization.

A neutron induced activity prediction system for use in amphibious operations was developed. It is designed to predict radiation hazards on beaches exposed to neutron fluence from a nuclear weapon. A new prediction system was devised and a 'cookbook' type of approach developed for describing the systems' operating instructions.

PHOEBUS REACTOR TEST MEASUREMENTS

Beta dose rates, gamma spectra, and decay of effluent particles from the PHOEBUS 1B EP-IV reactor test run at AEC's Nevada Reactor Development Station were measured. The measurements were an extension of beta hazard prediction studies conducted by NRDL for SNPO, thus far consisting of theoretical and empirical calculations for dose rates from unfractionated spherical carbon-coated uranium carbide fuel particles. Empirical calculations of beta dose rates of actual effluent fuel particles, based on calibrated field measurements with simple, rugged instruments will be expected to provide a more direct method of evaluating the hazard in a particular situation.

BIOMEDICAL STUDIES

96 HOUR EXPOSURE EFFECT IN SHEEP

Radiation lethality in sheep, studied with Co^{60} gamma radiation at five exposure rates ranging from 660 to 2.0 R/hr., showed that a decrease in exposure-rate (or protracting the exposure over longer time periods) results in an increase in the LD_{50}. That is, the LD_{50} at 660 R/hr is 237 R, while at 2.0 R/hr it is 637 R. Analysis of these data showed linearity through the range 660 - 30 R/hr. However, between 30 and 3.6 R/hr, a sharp departure from this relationship occurs with the LD_{50}'s at 3.6 and 2.0 R/hr being considerably higher than would be predicted from extrapolation.

In another series of experiments, kinetics of injury accumulation at 3.6 R/hr was studied with the following observations: although injury accumulation data do not preclude possibility of a strictly linear relationship, the best fit to data may be curvilinear. Nature of the curve would indicate that the rate of injury accumulation is decreased as total exposure and time of exposure are increased. Therefore, departure from linearity, which occurs both in studies of injury accumulation and LD_{50}, suggests that at least two "recovery processes" are operative. Speculation is offered relating these results and "recovery" mechanisms described for cell-culture systems. Results have been compared with dose-rate effectiveness expressions derived for rodents and man. They did not support the assumption used in several military and civil defense documents

that for man and livestock, biological effect of an exposure received in 96 hours (termed "brief") is the same as that received within a few minutes. Protracting an exposure in sheep from a few minutes to 96 hours results in a doubling of the LD_{50}.

INJURY ACCUMULATION/RECOVERY IN SHEEP

A modified split-dose technique was used to measure accumulation of injury during protracted exposures of domestic sheep to Cobalt-60 gamma radiation. Initial or conditioning exposure of 165 R was given at 0.5, 0.95, 1.85, and 3.94 R/hr, and the acute exposure $LD_{50/60}$ was determined immediately thereafter. These studies indicate that there is a dose rate threshold for injury accumulation under these conditions of protracted irradiation and that threshold lies between 1.0 and 1.5 R/hr. Recovery from injury accumulated during protracted exposures was studied by determining the $LD_{50/60}$ at various times after protracted exposures. Rapid recovery without a lag period that proceeds to a transient acquired radioresistance 15 days after conclusion of protracted irradiation is indicated.

NEW ANTI-BACTERIAL AGENT FROM BEE VENOM

What may eventually prove to be one of the most significant developments from Laboratory basic research for 1967 emerged from a study on bee venom and its radiation resistant properties. Venom and one of its fractions, melittin, have been shown to generate antibacterial activity against a penicillin-resistant strain of Staphylococcus, one of the most deadly of the bacteria afflicting man. This activity of bee venom and melittin was demonstrated by a method similar to that being used for plate sensitivity tests. Both whole bee venom and its melittin fraction were also able to inhibit growth of 20 of 30 different bacterial organisms tested. More gram-positive organisms (86%) were sensitive to bee venom and to melittin than gram-negatives (46%). Antibacterial activity of bee venom and melittin were of the same magnitude. Zones of inhibition created by bee venom and melittin were compared with those caused by penicillin, and equivalent units of penicillin were computed. Antibiotic potency of a single bee string was also determined. Among gram-positives, antibacterial effect of a 1:10 dilution of whole liquid bee venom was equal to that of penicillin at a concentration of 0.093 to 17.0 units/ml. Same dilution of bee venom, when tested against gram-negative organisms, compared to a higher range of penicillin values - 93 to 1,700 units/ml.

REACTOR DEBRIS PARTICLES ON SKIN

As part of a continuing investigation for SNPO, AEC, a detailed study was made of biological effects to be expected from exposure to debris from a reactor destruct or burnup, that is, from adherence of the small particles to bare skin. Findings were: immediate effect of the radiation on skin is to produce ulcers which may fail to heal. To produce such ulcers, radiation must be supplied in a sufficiently large dose over an area of the skin. If the area of skin irradiation is too small, ulcers will not occur no matter how large the radiation dose. Radiation from reactor debris will consist primarily of beta radiation which will have an intense dose rate, but a restricted field of exposure. Under favorable conditions of particle size and particle activity beta radiation from particles in contact with human skin may present no hazard. Late effect on skin is to produce cancer. Almost nothing is known about relationship between radiation dose and production of cancer. But occurrence of skin cancer is generally associated with large radiation doses and occurrence of serious ulcers during time immediately after radiation. Radiation exposure which does not produce ulcers is unlikely to produce cancer. Recommendations were made for application of findings and evaluation of biological hazard.

INFLUENCE OF AGE ON FAST-NEUTRON IRRADIATION EFFECTS

For rats receiving sublethal (acute) dose or fast neutrons as young adults, there is evidence of metabolic deficit persisting throughout life and of earlier appearance of degenerative and neoplastic processes (as compared with their non-irradiated littermates). Since age at exposure has been shown to be an important variable markedly affecting the magnitude and chronology of other late effects of irradiation, effect of age at exposure upon these specific criteria of residual radiation injury was investigated.

Results showed that food consumption remained markedly decreased after irradiation during juvenile state and, to a lesser extent, after exposure during young or middle-aged adult stages. Body weight was permanently depressed regardless of whether irradiation occurred during the juvenile (1 month of age), or the young (3 months), middle-aged (10, 15 months), or old (21 months) adult stages of life. Magnitude of this metabolic deficit was inversely related to age at exposure. When prorated to metabolic size, an age-associated marked increase in water consumption occurred at an earlier age in animals irradiated as juveniles or as young adults, but not in animals irradiated during middle

age. Excess (above control) incidences of animals with palpable growths were observed after exposure at all but oldest age. In general, then, exposure as a juvenile is most detrimental, while irradiation late in life is least effective. Thus, age at exposure appears to be an important consideration in establishing risk estimates for the induction of metabolic, generative, or neoplastic injury by ionizing radiation.

MIXED LEUCOCYTE REACTION APPLICATION TO INBRED MICE

Development and evaluation of a 'test tube' biological method capable of matching compatible donors and recipients for skin or kidney transplants constitutes one of the many products of NRDL which is of direct practical value to the Armed Forces. That matching transplantation antigens of donors and recipients is critical to success in tissue transplantation has become apparent from recent improvement in survival after kidney grafts from related donors. A method under study in 1967 for matching donor and recipient, is based on the in vitro immunological reactivity of the peripheral blood lymphocytes from pairs of individuals being matched. Under standardized tissue culture conditions higher incorporation of tritiated thymidine into the DNA of these cells in mixed culture indicates greater tissue incompatibility between these individuals. This method was investigated to determine its sensitivity and specificity. It would be advantageous to standardize this test using blood leucocytes of the mouse. Genetic and antigenic basis of tissue graft rejection in mice has been carefully investigated over a period of many years. Such a body of knowledge does not exist for any other animal species, including man. In spite of the evident advantages to be gained from adaptation of the mixed leucocyte reaction to inbred (pure genetic) strains of mice, there are no evidences of any prior work of this kind, and NRDL investigators are believed to have achieved the first successful adaptation of this test to inbred strains of mice.

FOOD RESTRICTION AND RADIATION EFFECTS

A definitive study of electron microscope featuresof glomerulosclerosis, both after unilateral nephrectomy and after food restriction, showed that food restriction retards development for manifestation of what is considered to be a direct radiation effect on the kidney. Experimentation also further confirmed the thesis that a stimulus for growth, combined with direct effects of radiation, accelerates development of glomerulosclerosis. Growth retardation is shown to have a preventive inhibiting effect upon the lesion.

EFFECT OF DOSE/LIMB SHIELDING

Chromosome studies in irradiated mice indicated that, following high sublethal whole-body exposure, regeneration of reticular tissues occurs in a clonal fashion. With increasing doses, from 100 to 700 rads, these organs appeared to be repopulated from fewer and fewer surviving stem cells. In a few instances at the highest dose, progeny of the same cell apparently differentiated to marrow cells at one site and to lymphoid cells in others, suggestive evidence of a totipotent hematopoietic stem cell in adult mouse.

Chromosome studies in mice receiving 900 rads with one limb shielded have indicated repopulation of the thymus and other reticular tissues by undamaged cells from shielded marrow. Such marrow-derived cells, perhaps by restoring immunological competence or by nonimmunological contact inhibition, could account for known effect of limb shielding in reducing incidence of radiation-induced thymic lymphomas.

NEUTRON RADIATION EFFECT ON TUMORS

Large numbers of male rats maintained in duration-of-life experiments, when exposed to neutrons and x-rays, showed a significant increase in both incidence of animals with one tumor and in animals exhibiting more than one tumor. Predominant effect was increase in incidence of malignant tumors, particularly those of epithelial origin. Tumors were found in nearly every organ of the body with skin, kidney, lung and pancreatic islet cells especially sensitive to tumorigenic action of both x-rays and neutrons.

SKIN TUMORS INDUCTION

Another study of tumors induced by radiation had to do with excess number of tumors as a late effect. These tumors appear weeks, months, or, in long-lived species such as man, even years after exposure. Unlike tumors of most organs, skin tumors have attracted recent intensified interest as they can be detected readily in the intact animal and thus provide unique and convenient opportunity for study of time course of tumor development.

Most recent 1967 experiment in this area drew a comparison of male rats irradiated as young adults with their non-irradiated littermates with respect to particular skin tumors developed (malignancy and origin), their location and temporal distribution. Approximately one-fifth of

the nonirradiated controls developed one skin tumor during their lifetime, less than 3% had two, and none had more than two. Over 50% of irradiated animals developed at least one skin tumor, 25% of them had at least two tumors, and about 17% of them had three or more. Although excess of irradiated animals with tumors was significant for both benign and malignant neoplasms of epithelial or non-epithelial origin, effect was the most dramatic for malignant epithelial tumors. Age at initial appearance of tumors was less in irradiated animals, and excess incidences of irradiated animals with tumors were apparent within about 8 months of exposure. Tumors originating in skin appendages (e.g., hair follicles and sebaceous glands) tended to predominate among irradiated animals although there were also significant excesses of tumors of squamous cell, basal cell, and fibrous origin as well. While no control developed tumors of neck or tail regions, tumors were found in these locations in irradiated animals. Tumors developed without evidence of previous destructive changes in skin, as has been reported for less penetrating radiations. There were no apparent consistent relationships between tumor incidence and dose or type of radiation.

BIOCHEMICAL RADIATION DOSIMETER

A striking biochemical effect of exposure to ionizing radiations is early release and breakdown of deoxyribonucleic acid (DNA) in radiosensitive tissues. 'Spilling over' of such DNA-degradation products into the urine is indicated by reports in the literature showing an increased urinary excretion of Dische-positive, deoxyribosyl compounds during the first day following radiation exposure in several mammalian species. Significance of these observations has not been fully explored in terms of implications in relation to use as a biochemical indicator of radiation dose or for studies on biochemical mechanisms involved in radiation injury, and, in a NRDL study, a specific method for measuring urinary excretion of deoxycytidine in X-irradiated rats was employed. Also, effect of age, as well as radiation dose, was assessed.

Rats were subjected to single dose wholebody X-ray exposure at doses from 10 R to 400 R, and urine specimens, collected over a 24-hour period after irradiation, were analyzed for deoxycytidine content using ion exchange and paper chromatographic procedures. 24-hour excretion data revealed a linear dose-response relationship for deoxycytidine excretion at radiation doses from 10 R to 223 R. A significant increase over 'background' levels was noted at doses as low as 10 R. For a given dose of X radiation, excretion of deoxycytidine was considerably lower in rats previously splenectomized; thus at 100 R, the spleen accounted for 83% of the excreted deoxycytidine. An important age factor for

deoxycytidine excretion after irradiation was found: after 100 R exposure 5-week old rats showed a 312% increase in 24-hour deoxycytidine excretion over nonirradiated controls; for 12-week old rats increase was 123%, while in 11-month old rats the increment was only 47%. It was concluded that chemical determination of 24-hour urinary deoxycytidine excretion holds promise as a practical biochemical radiation dosimeter.

ENDOTOXIN EFFECTS ON LEUKOCYTE PATTERNS

Recent NRDL studies have shown that survival is increased in several animal species when bacterial endotoxin is given either before or after midlethal irradiation. Since endotoxins are potent stimulators of the hematopoietic system, and hematopoietic recovery after irradiation appears to be accelerated in endotoxin-treated mice, the mechanism of endotoxin-protection may be closely related to effects on the hematopoietic system.

1967 studies to evaluate the effect of endotoxin on return of leukocyte counts toward normal in irradiated mice and dogs showed that endotoxin-treated animals had higher numbers of circulatory granulocytes than did controls between approximately 7 and 17-21 days after irradiation. Pattern of return of granulocyte counts toward normal in endotoxin-treated animals was characterized by a large rise during the second week which coincided in time with an abortive rise observed in non-treated animals. Also, granulocyte counts in endotoxin-treated animals declined after the period of abortive rise but remained higher than in non-treated animals. Also, granulocyte counts in endotoxin-treated animals declined after the period of abortive rise but remained higher than in non-treated controls and returned to normal earlier than did counts of controls. Influence of endotoxin in postirradiation leukocyte counts was not restricted to granulocytes since during the abortive rise period lymphocyte counts were also increased. These observations gave rise to speculation relating to mechanism by which endotoxin influences post-irradiation leukocyte counts.

RADIATION PROTECTION THROUGH PARABIOSIS

Parabiotic rat pairs with a skin-vascular anastomosis were used to test whether shielding of one member of the pair would protect the irradiated partner against very large exposure doses of x-rays (1200-2400 R). With exception of the lowest dose, all unshielded, irradiated pairs or single irradiated animals died before 5 days had elapsed. In contrast, irradiated rats that had a shielded parabiotic partner survived the 5-day period and many survived beyond 30 days. This is interpreted as

protection against acute intestinal death that normally occurs in the dose range investigated.

RESISTANCE TO DRUGS TESTS

There is a need to find methods to control immunological rejections of organs transplanted from one human to another, i. e., homografts, and to treat autoimmune diseases such as systemic lupus erythematosus. A number of drugs are now being used which control these adverse immunological reactions, but which do not give uniform results and which must be given for long, indefinite periods of time. At least two aspects of immunological processes resist treatment with currently used drugs, namely, ability to mount an anamnestic response and ability to continue established antibody production. Since these functions are probably carried out by long-lived lymphocytes and long-lived plasma cells, respectively, the effect of four representative immunolytic drugs, prednisone, cyclophosphamide, 6-mercaptopurine, and actinomycin D, on long-lived cells in rat popliteal lymph nodes was investigated.

31 days after a course of tritiated thymidine, rats started receiving daily intraperitoneal injections of the drugs to be tested. Each week the dose of drug was doubled until either lymphoid hypoplasia appeared or rats died of drug toxicity. In control untreated rats the percent of persistently labeled small lymphocytes and plasma cells, the long-lived cells, was decreasing at a slow rate. In those rats receiving progressively increasing doses of prednisone or cyclophosphamide, the percent of small lymphocytes labeled increased significantly above control values as lymphoid hypoplasia occurred. Labeled plasma cells continued to be found in prednisone and cyclophosphamide treated rats but were relatively decreased in number after prednisone treatment and relatively increased in number after cyclophosphamide treatment. Rats treated with 6-mercaptopurine or actinomycin D died without having had a marked effect on lymphoid tissue or on the percent of persistently labeled lymphocytes and plasma cells.

Thus, long-lived lymphocytes survived treatment with all four of the immunolytic drugs tested and were specifically resistant to prednisone and cyclophosphamide. At least some long-lived plasma cells were sensitive to prednisone, but they were resistant to the other drugs and specifically so to cyclophosphamide.

NEW LIVER FUNCTION, REGENERATION RESULTS

Radiation injury to liver, an organ considered to be radio-resistant, can be demonstrated by stimulating cell division through partial hepatectomy or hepatoxic agents. In investigations in this area of interest, animals subjected to X-irradiation (200 rad) at one day of age were studied 90 days later with respect to incidence of mitotic abnormalities in parenchymal cells after partial hepatectomy, and to functional competence of liver. X-irradiation of neonatal rats resulted in a similar decrease in both liver and body weights of animals 90 days later. Thus, liver to body weight ratios for both irradiated and non-irradiated controls were the same and regenerative capacity of irradiated animals, i.e., ability to replace hepatic mass as a result of partial hepatectomy, did not appear impaired. Incidence of abnormal mitoses (~45% of total anaphases and telophases) was approximately 3-4 times greater than that of controls. In contrast, bile flow and BSP excretion rate were not affected in animals irradiated at one day of age. Therefore, functional tests of bile flow and BSP excretion rate did not reflect the extensive nuclear damage present in parenchymal cells.

GASTRIC RADIATION INJURY

Several aspects of radiation damage to the gastro-intestinal tract may depend on interaction between it and central nervous or other systems. This has been verified, in some respects, by NRDL studies and suggested also by extensive Russian literature on autonomic imbalance and "hyperacid gastritis". Because of complex physiological relationships, multiple experimental approaches were needed and were employed in 1967 to exclude or define different levels of organization at which gastric irradiation changes occurred.

Findings included: two primary, independent functions of gastric epithelium remain unaffected initially by doses of 1 kilorad, namely stimulated acid secretion and electrical activity. Thus, an earlier observation of irradiation effect on resting acid secretion may reflect disturbance in functioning of autonomic nervous system. For electrical changes, new evidence suggests that a subcellular repair process intervenes, preventing manifestation of frank injury. There was no irradiation change in response of cholinergic receptor mechanism, but typical delayed effects could be demonstrated.

ANIMAL RADIOSENSITIVITY AND FOOD IMBALANCE

To determine possible imbalance in a food chain as a result of a nuclear disaster, research was initiated on possibilities of predicting survival in animal members of the chain. Previous work by Sparrow, Schairer and Sparrow (Science 141:163, 1963) indicated a linear relationship between interphase chromosome volume of certain plant species and $LD_{50/30}$ days as a result of gamma and x-radiation exposure. This relationship was studied in invertebrates and mammals. Lining endothelium of intestine as the cellular indicator was selected since it is known to be radiosensitive and shows minimal size variation between cells in a species. Invertebrates were studied and irradiated for LD_{50} at 24 and 48 hours and mammalian cells were counted in the laboratory and survival data taken from the literature. Results indicated a positive correlation with Sparrow's hypothesis in invertebrates and no correlation with mammalian species studied.

DNA RATE/CONTENT OF ERYTHROID CELLS

Many of the effects of radiation result directly from alteration of the cell's ability to replicate itself and thus restore the normal cell number following the injury. Techniques were developed for studying progress of individual cells throughout their cycle from division to division. From data on the normal cycle of cells in bone marrow, the most important single cell system in recovery from radiation injury, it is possible to design experiments on radiation recovery of these cells. Measurements showed that a widely accepted model for replication of DNA leading to cell division was not adequate to delineate the process occurring in the red blood-cell forming tissue of the bone marrow. These cells apparently do not have a post-mitotic pause (G-1 period) following mitosis. The synthetic rate for DNA is essentially constant throughout the synthetic period, but there is a small probability that a cell will be found that is not in active synthesis, regardless of its state of progression through the synthetic interval. It is now evident that DNA synthetic process is intermittent, and that it is dependent upon random sampling periods for individual chromosomes. A model was developed to explain observed data.

RADIATION INJURY RECOVERY

Split-dose technique was used in radiation injury recovery experiments to determine the pattern of recovery from radiation injury in the Syrian hamster. Exposure of animals to 1 Mvp X-rays resulted in a

$LD_{50/30}$ of 941 R (95% confidence interval: 917-967 R). Recovery, defined as a return to normal radiosensitivity after a sublethal exposure, was found to be nonexponential; in fact, a marked transient increase in radiosensitivity was observed during the second week. After exposure to 2/3 $LD_{50/30}$, relatively little recovery was observed on the 3rd day after the conditioning exposure. 94% of the initial injury remained. Between the 3rd and 7th day the hamster recovered at a rapid rate, only 26% of the initial injury remained on day 7. These periods of recovery were followed by regression of animals to a more radiosensitive state. 76% of initial injury was present on day 11. After this time, animals returned toward more nearly normal radiosensitivity with 20% of the initial injury remaining at day 20. These findings showed marked deviation from the exponential recovery pattern usually reported for other rodents.

Hematological studies indicated that extent of recovery, in terms of split-dose radiosensitivity, is not correlated with number of circulating erythrocytes, thrombocytes, granulocytes, or mononuclear cells. Survival time was found inversely related to exposure - the higher the exposure, the shorter the survival time - in all irradiated groups except the group challenged at 3 days. Interpolated survival time at the LD_{50} exposure varied with the day of challenge: 13.7 days at day 0, 11.1 at day 3, 14.1 at day 7, and 17.2 at day 11.

BONE MARROW STUDIES

Bone marrow as a major source of potential immunologically competent cells in the adult mouse was investigated with the following reported: Work at NRDL and other laboratories had suggested that adult bone marrow might be the source of lymphoid precursor cells in the adult mouse. Direct evidence was sought of the presence of lymphoid precursor cells in the bone marrow and of their absence in significant numbers in other lymphoid tissues of the mouse. A significant number of deaths occurred among the secondary hosts only when they had received spleen cells from mice which had been injected with adult bone marrow cells. These results suggest that the bone marrow of the adult mammal is the major or sole source of lymphoid stem cells, i.e., cells destined to carry out the body's immunological functions. Previous work has indicated that the functional maturation of these stem cells to immuno-competence occurs upon their migration to the thymus. These findings have important implications for the problem of recovery after every irradiation and in bone marrow transplantation. They imply that successful transplantation of bone marrow or sufficient shielding of marrow cells in irradiated mammals provides not only the stem cells for hemopoiesis, but also the precursor cells for the immune system.

RADIATION HEAT SHOCK EFFECTS ON CELL DIVISION

Cells are apparently prepared for division along several loosely coupled parallel pathways or chains of chemical and physical processes. Although specific nature of the pathway may no be known, it may be characterized by the agent that inhibits it and by the time in cell cycle at which the agent no longer affects cell division. A study of effects of ionizing radiation on cell division yielded some unusually interesting and rather unexpected findings:

Division of synchronized Tetrahymena pyriformis (strain W), irradiated with low doses of ultraviolet light, is delayed if irradiation is administered during the first 30 minutes after end of synchronizing treatment.

After a short period of transition, relatively high doses of UV have no appreciable effect on division of a majority of cells. Delay induced by a particular low dose administered at any time up to transition to insensitivity is essentially constant. Division of synchronized cells is delayed by heat shocks ($34^{\circ} \pm 0.1\ C^{\circ}$, for 20 minutes), if applied at any time up to approximately 60 minutes after end of synchronizing treatment. After this time, for any single cell in a sample, there is instantaneous transition to heat-shock insensitivity. Delays in cell division induced by heat shocks increase with time from the end of synchronizing treatment, attaining a maximum just before transition to insensitivity.

Two different transition times in responses of synchronized cells to UV and to heat shock are interpreted as representing the completion of two different processes in final preparation of cells for division. Qualitative and quantitative differences between responses to UV and to heat shock suggest that two different substances are involved, one sensitive to UV and one to heat. There is some evidence suggesting that completion of the heat-sensitive process depends upon the UV-sensitive process.

AGE/IRRADIATION EFFECTS ON HEART BEAT

During a long-range study designed to evaluate treadmill exercise performance by the aging irradiated rat appreciable numbers developed cardiac arrhythmias (variations in rhythm of heart beat) with age. Premature beats as well as other arrhythmias were observed. Incidence of animals with arrhythmia was negligible at younger ages but increased markedly late in life. More animals showed arrhythmia at rest than during

the exercise itself. These results appear analogous to effects of age and exercise upon occurrence of cardiac arrhythmia in human subjects and indicate that rats may well prove to be useful experimental animals for the study of naturally occurring arrhythmias. Because irradiation markedly reduced the proportion of animals able to complete the exercise test at ages where appreciable numbers would be expected to show arrhythmia, it was not feasible to evaluate the influence of irradiation on the incidence of arrhythmia.

INSTRUMENTATION - ELECTRONICS

SEMICONDUCTOR DEVICE TRENDS

Semiconductor device trends applicable to Navy electronic system design during the next 3 to 5 years were evaluated during 1967. Results obtained from a survey of technical publications and through individuals representing system contractors, semiconductor manufacturers, naval laboratories and other commands will be used in guiding the NRDL program for development of nuclear radiation response prediction techniques. In particular, current impact of microelectronics necessitated an assessment of this technology and its application to systems of interest.

It was observed that: incorporation of semiconductors in systems under development is inextricably tied to availability of reliable devices and that in 3-5 years at least 25% of all electronic circuits in Navy equipment under development will be microcircuits. Computers and other digital functions are expected to be essentially 100% microcircuitry. Finally, the study indicated that problems associated with adapting SET (Simplified Engineering Techniques) to integrated circuits are formidable.

BOMBARDMENT OF SEMICONDUCTORS STUDY

A number of high-precision determinations of effects of pile bombardment and subsequent thermal treatments on thermoelectric properties of several thermoelectric materials were conducted. These determinations substantiate previous opinions that such effects can be based upon a wide range of mechanisms in different materials and that some materials may be improved by bombardment, while others are worsened and still others

left essentially unchanged. Principal find was that promising materials must be examined as individual materials and not lumped together as a single class when effects of radiation are to be considered.

HIGH RANGE GAMMA RADIAC INSTRUMENT

Low cost silicon diode detectors for use in a high range (1 R/h to 10^4 R/h) gamma radiac were investigated and a computer program developed for processing energy response data. A simple, low cost amplifier using bipolar transistors was designed for use with the diodes. Bipolar transistors were shown to be the best active elements for this purpose by theoretical methods developed during this investigation.

SEMIRAD DETECTION SYSTEM

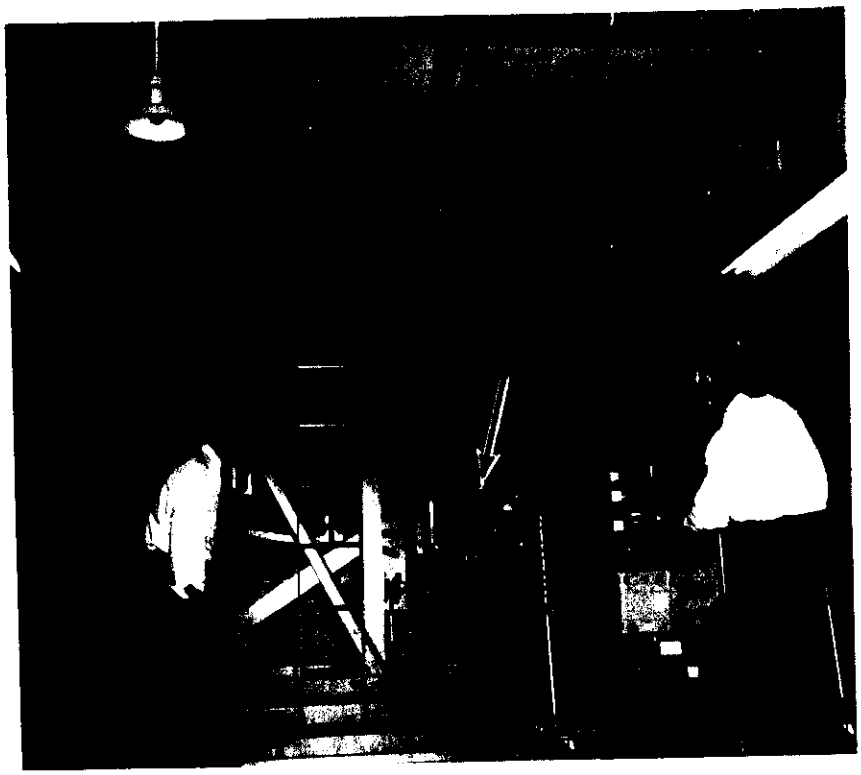
Development, design construction and testing of a semirad detection system for high intensity neutron radiation was completed in November. The neutron sensor has an output which is current-proportional to the neutron dose rate in (tissue) rad/hr. The instrument was subjected to extensive tests at the Fast Burst Reactor, White Sands, New Mexico.

SHIP COMPUTER CIRCUITS RADIATION VULNERABILITY

Circuits, transistors and diodes in shipboard computers and peripheral equipment were examined experimentally for vulnerability to transit radiation. Tests, while limited, provided some valuable results on possibilities of equipment or circuit failure or radiation induced system upset.

RADIO-FREQUENCY RADIATION SIMULATION

Final results were obtained on a study of the feasibility of a system capable of simulating radiation environments using radio-frequency techniques with both nuclear radiation from initial bursts and from subsequent fallout considered. It was determined that a system can be derived which is capable of meeting the simulation objectives and a high degree of reliability can be provided using methods established and proven by hyperbolic navigation systems. Requirements of the simulation allow simplification relative to existing navigation systems.



PREPRODUCTION TESTS AND INSPECTION TESTING OF NAVY RADIACS are performed at NRDL under an assignment from NAVELEX. Approximately 12 different types are tested annually and a recommendation made for acceptance or rejection. Here a Navy Radiac Computer-Indicator Scaler (see arrow) is undergoing shock testing. The operators are Mr. R. A. Nyberg (left) and Mr. A. E. Pasche of the Radiation Instrumentation Branch. The Class HI (high intensity) testing machine for light-weight equipment is used to determine the overall shock resistance of components, equipment, and materials. The machine was designed to simulate those severe shock conditions imposed on equipment in use.

MEGARAD DOSIMETRY DEVELOPMENT

An LiF dosimeter was developed to measure gamma-ray exposures between 10^5 and 2 x 10^9 R. Applicability of the LiF as a megarad dosimeter depends upon the fact that a thermoluminescent glow peak at a temperature at about 450°C has a negligible response to radiation below exposures of 10^5 R. A number of crystal specimens examined were found to have a high temperature glow peak which could be followed as a function of exposure for three to five decades. Similar responses of the high temperature glow peak were found for the dosimeter when exposed to 2-MeV pulsed electrons or thermal neutrons.

WELDED ION CHAMBERS DESIGN

Check-out of the possibility that a welded seal might offer some advantages in a recycling ionization chamber developed as the detector for radiacs AN/PDR-63(XN-1), AN/PDR-65(XN-) and possibly others resulted in design of a welded seal by NRDL. Advantages would include extended temperature range, an alternative technique to be offered contractors, and the possibility of sealing much higher pressures in the future.

THERMAL PHYSICS AND EFFECTS

THERMAL RADIATION STUDIES ON PYROLYSIS OF CELLULOSE

In order to predict fire hazard from nuclear weapons and to invent methods for its control, it is necessary to learn more about the details of the thermal decomposition of cellulose and its variation of temperature. In a study of the thermal degradation of cellulose in an inert atmosphere of the temperature range of 250°C to 350°C, three distinct phases of pyrolysis were observed. After an initial rapid decomposition and weight loss, occurring in a time interval shorter than the shortest pyrolysis period used in the study, the rates of the thermal decomposition of cellulose and of the weight loss were found to be constant. A phase followed where the rate of weight loss only appeared to be proportional to the difficulty between the remaining weight and the residual char. The measured weights of rate loss and cellulose decomposition in the second phase were found to increase about 2.4 fold for every 12°C temperature rise.

MISSILE HEAT SHIELD DECOMPOSITION

A time-of-flight mass spectrometer was used successfully for analysis of blow-off gases produced by thermal decomposition of two different types of R/V materials in connection with studies of decomposition of re-entrant heat shield materials on exposure to nuclear fireball radiation in missile technology. Several thermal sources were evaluated and a pulsed laser was found to be a good high intensity thermal source. Analysis of blow-off gases from carbon phenolic type ablator material indicated that while over eighty different substances were noted, the primary compounds involved were water, acetylene, carbon monoxide, ethylene, and carbon dioxide. Significantly fewer substances were found in blow-off gas from pyrolytic graphite; mainly acetylene, carbon monoxide, and carbon dioxide.

GOLD BLACK COATING ANSWER TO HEAT CAPACITY TESTS

In recent years, considerable effort has been expended in improving the accuracy of total hemispherical emittance and solar absorptance evaluations conducted at NRDL. Since these evaluations are conducted by a transient calorimetric method over a wide temperature range, accuracy of the results depends upon accurate knowledge of the specimen's heat capacity. Although there is published data for most pure metals, heat capacity values for many alloys and insulators are not available. Furthermore, many specimens evaluated consist of a relatively massive coating on a thin metal substrate. In this case combined heat capacity of coating plus substrate must be considered for accurate emittance or absorptance evaluation. In 1967 a method was developed using the heat capacity of pure gold as the primary standard, where if absorption properties of the specimen's front surface are known and the specimen is irradiated by a source of known radiant power, an energy balance equation can be solved for the specimen's heat capacity. However, a front surface coating, both optically suitable and applicable to a wide variety of substrates, remained to be developed. An evaporated gold black coating was employed with excellent results in obtaining the heat capacity of metallic, nonmetallic and even organic substances such as 3M paint. Heat capacity curves obtained by this method for 2024AL, synthetic sapphire and 3M black paint showed accuracy of $\pm$ 5% or better in the temperature region between + 150°C and - 180°C.

PROTECTION AGAINST NUCLEAR WEAPONS AND RADIATION

AIRBORNE FIRES COUNTERMEASURES

In an investigation of countermeasures for extinguishing or controlling airborne mass fires, it was concluded that fire breaks can be effective in cities, provided they are made correctly, rapidly and in adequate width, and provided they are diligently tended by firemen. Probability for controlling an airborne mass fire by creating and maintaining fire breaks and then letting the fire burn out was found to be greater than the possibility of extinguishing the fire, in part or *in toto*. Conceptual countermeasures leading to extinguishment in mass fires resulting from nuclear attack did not seem to be promising.

FUEL ARRAYS IGNITABLE BY NUCLEAR WEAPON THERMAL PULSE

Fuel arrays ignitable by nuclear weapon thermal pulse were surveyed. A determination of densities of occurrence and critical ignition energies of exterior and interior fuel arrays in various land use classes in a city, including residential, light and heavy industrial, other commercial, outside storage, churches, schools, libraries and vacant land was made. Inconclusive results were obtained on a study of the feasibility of aerial photographic methods for estimating exposure of fuel arrays to thermal pulse.

SMOKE SCREEN AS NUCLEAR BURST COUNTERMEASURE

Possibilities of an absorbing smoke screen's properties as a countermeasure in nuclear attack were investigated. Prevention of thermal ignitions by means of a high density smoke screen in both interior and external fuels for radiant exposures corresponding to 5-psi-overpressure level or greater appears feasible. Most promising situation would be where the smoke screen could be used over the central region of the city and where secondary fires caused by blast, etc., could be extinguished quickly. The smoke screen showed some promise for altering nuclear-burst characteristics, decreasing radiant transport through the atmosphere, preventing ignition of kindling fuels, and suppressing fire buildup, coalescence and spread.

SMOKE SCREEN SYSTEMS

Smoke screen systems were developed for protection of large areas from the thermal radiation of nuclear weapon detonations. They include an interim system using solid-fuel smoke generators and a second-generation system using liquid-fuel generators. A solid-fuel system was developed through the prototype design and testing phase while liquid-fuel system was developed through the design feasibility stage. On a pound-for-pound basis, liquid-fuel generators produce smoke which is more effective for attenuation of thermal radiation than smoke from solid-fuel generators, primarily due to higher percentage of carbon present in smoke. Optimum carbon-particle sizes for use in smoke screens were found to be in the range 0.19 to 0.28μ and catalysts could be used to greatly increase smoke production from liquid fuels.

URBAN CONFLAGRATION ASSESSMENT

For the purpose of field testing its methods and procedures, a system for conflagration assessment of urban areas was applied to establish relative conflagration potential of various sections of two metropolitan areas and to delineate probable firebreaks therein.

Both the regular and a simplified version of the conflagration assessment system had been field tested in limited areas of various communities across the country, but validity and practicality of applying them to entire communities had not been tested.

The major problem encountered was difficulty of estimating densities of construction in each city block, both from Sanborn maps and from aerial photographs but especially from field surveys. Apparent discrepancies were found in calculated ratings for blocks consisting of two-story wood frame apartment buildings, for those where most buildings are concentrated along one side, and for blocks containing many houses with wood shingle roofs. Some difficulty was encountered in measuring distance across firebreaks where fences, rivers or embankments intervened. It was concluded that the system for conflagration assessment of urban areas is capable of being applied to entire urban areas with little modification, that the time required for applying it to all built-up blocks of a metropolitan area is not excessive, that it is capable of being applied by persons with limited knowledge or training in fire protection, and that results obtained conform with current thinking of fire officials and fire protection engineers experienced in estimating fire spread potential in urban areas.

CHEMISTRY - RADIOCHEMISTRY

NEW METHOD ON OXIDE UPTAKE

As part of a program for elucidation of the radioactive fallout formation process, a method was developed for measuring condensation rates of vaporized MoO_3 onto liquid and solid oxide substrates in air at high temperatures. Rate measurements were made from 800 to 1500°C and over MoO_3 partial pressure range of about 10-7 to 4×10^{-5} atm. Substrates of a fused clay loam and a calcium ferrite were used in most of the measurements. Information was obtained concerning the rate-controlling steps in the condensation process.

DECAY CHAIN STUDY

In an exhaustive review of the literature available through February 1967 yielding updated individual radionuclide data the precise descriptions of genetic relationships in fission-product decay chains, as well as half-life values for radionuclides comprising the chains, were compiled as required for calculation of the properties of fission-product mixtures. Accurate knowledge of these properties is required in assessments of consequences of reactor operations, nuclear weapon testing, and nuclear warfare. The information was developed in schematic form together with the literature references.

ANALYSIS OF GAMMA PULSE-HEIGHT DISTRIBUTION

A computer program was developed for analysis of components of a gamma pulse-height distribution composed of a mixture of two or more gamma-emitting radionuclides. The program consists of: (1) identifying the largest gamma photopeak and matching its energy with the largest photopeak of each of the individual radionuclides in the mixture, (2) subtracting enough of the individual radionuclide gamma pulse-height distribution from the mixture so that the photopeak in question is reduced by a certain small percentage, and (3) continuing the incremental subtraction process until photopeaks in the mixture can no longer be identified. The advantage over other similar computer programs is its usefulness in the analyses that are to be made of the large number of low activity mixtures of radionuclides in the program to determine physical-chemical species of the radionuclide debris produced by underwater nuclear explosions.

BETA RADIATION DOSAGE PROGRAM

Computer-type research of more than routine significance included a program for calculating beta radiation dosages incurred from contact with radioactive particles. Prepared for CDC 3600 and IBM 7094; the program is one through which information can be obtained in one package, avoiding execution of a number of programs running sequentially on a digital computer which causes considerable number of awkward input and output problems. It is applicable to particles originating from a nuclear weapon detonation as well as from nuclear reactor destruct. Flexible input/output procedures provide control over selection and arrangement of output parameters. Many tables, functions and parameters, considered input quantities in most programs, were incorporated into this program.

RADIONUCLIDE INHALATION DOSE MEASUREMENT

A FORTRAN computer program system was developed to determine maximum internal dose received by a given body organ as a result of inhalation of specific radionuclides. The program determines effective energy absorbed by the body organ per disintegration of the radionuclide and computes absorbed organ dose for various periods of internal exposure. Dose includes effects from all descendants of the nuclide originally considered to have entered the organ. Tabulated results for 133 radionuclides and their contributions to dose to seven body organs and whole body are presented and input may be modified to yield results for other radionuclides or body organs. The program may also be used to determine (by summing) total absorbed organ dose for a mixture of fission products if the concentration in air of each major contributor at initial intake time is known.

DECAY CHARACTERISTICS STUDY

Data concerning decay characteristics of radioactive isotopes is necessary for their measurement as products of nuclear reactions, for possible use in technological processes, and for their employment as tracers in determination of chemical and physical properties of an element. The latter data is especially important for long-lived radioisotopes of element promethium which has no stable isotopes. A Laboratory experiment measuring half-life and gamma-ray energies of Pm^{146} revealed a half-life of 2020 $\pm$ 18 days (30). Abundant gamma-rays of 453, 736, and 747 kev energy and lower abundance gamma-rays of 146, 589, 634, and 1189 kev were observed.

IRRADIATION OF A REACTION SYSTEM

Irradiation of a reaction system with an external source of radiation using deuterium instead of tritium was investigated. It was found that the hazard to personnel from accidental release from tritium gas is largely due to tritium oxide formed by the self-initiated oxidation of the tritium. An experiment was conducted to complement work involving the study of oxidation of tritium under its own radiation by eliminating the effect of tritium radioactivity and thereby permitting a search for other reaction products, such as peroxide and also providing additional kinetic data for the oxidation reaction. The reaction system chosen that of deuterium-oxygen mixtures exposed to Co^{60} gamma radiation. Under the conditions of the study the rate of deuterium-oxide formation was found to be directly proportional to the deuterium concentration for a given initial deuterium concentration in the region r x 10^{-4} mole $^{-1}$. At a higher initial concentration the rate was independent of deuterium concentration. In a search for other expected stable reaction products, ozone was found but no deuterium peroxide was detected. However, small amounts of an unidentified intermediate reaction, which apparently stabilizes itself on the wall of the reaction vessel, were detected.

FISSION PRODUCT ABUNDANCES PROGRAM

A primary computer program written in FORTRAN II and intended for use on an IBM 704 was developed in a Fission Product Abundances Program. This is a generalized digital computer method for calculating time-dependent abundance of fission products. The times at which the abundances are calculated, the reactor operating history and the fission type (fissile material and fission spectrum) are all input variables. In addition, several different outputs are available. The combination of these features yields a very general program intended to meet the needs of many users.

KIWI-TNT TEST DEBRIS ANALYSIS

Samples of debris from the Nevada Test Station KIWI-TNT event were studied with interest centering on properties relating to biological hazard: particle properties, radiation properties, radiochemical composition and radionuclide solubility. A radiochemical analysis showed that a ground-filter sample was highly enriched in volatively behaving fission products ($Sr^{89,90}$, I^{131}, Te^{132}, Cs^{137}). Cloud samples were somewhat enriched in volatiles but were relatively representative. Fallout samples showed a depletion of volatiles and this depletion increased

as particle size diminished and as particle shape became more spheroidal. Fractionation behavior was quite similar to that observed in weapon debris, as was dependence of fractionation on particle shape. Dependence of fractionation on particle size in the fallout sample, however, was opposite of that observed in weapon debris and indicates the operation of different fractionation mechanisms.

REACTOR SIMULATION OF NUCLEAR 'SHOT'

In an experiment to produce physical-chemical species of fission products as similar as possible to those produced in an underwater nuclear explosion, NRDL investigators resorted to irradiation of a 10 mg foil of enriched U-235 with pulsed thermal neutrons from the KEWB reactor at Atomics International. Motion pictures and temperature measurements of the event showed that complete vaporization was not achieved. However, melting did occur and temperatures in excess of 1300°C were obtained before the thermocouples failed. It was ascertained that use of another type of reactor, such as a TRIGA Mark F which could provide over 3 times the number of calories, should achieve vaporization.

FALLOUT PROPERTIES DOCUMENTATION

One of the most complex and complete literature studies in NRDL annals was finished in June in the form of a 770-page publication on "Local Fallout from Nuclear Test Detonations", Vol. III of "Annotated Compendium of Data on Physical and Chemical Properties of Fallout". This project was undertaken to critically select and compile from published technical reports data all characteristics of nuclear fallout from nuclear weapon tests held through 1958.

RE-ENTRY CHEMISTRY OF STRONTIUM TITANATE

Suitability of Sr^{90} -loaded strontium titanate ($SrTiO_3$) as an aerospace SNAP fuel was investigated with these conclusions: First effect of re-entry would probably be the melting and essentially complete ablation of the stainless steel casing. Concurrent with alloy ablation, the strontium titanate would melt and, finally, the molten titanate would disperse with vaporization. When debris from the device cooled, there would probably remain predominantly strontium titanate with lesser amounts of other strontium-oxygen salts. When these deposited in the ocean they would be much less soluble than would strontium oxide. However, this debris would be in a high state of dispersion, and it appears

likely that the entire debris would be dissolved in a matter of days. Therefore, the advantage of using strontium titanate instead of strontium oxide from the viewpoint of solubility of the resulting debris would be negligible.

ION EXCHANGERS FOR SEA WATER

To be able to concentrate rapidly trace elements from large volumes of seawater, an ion exchanger must not react with major constituents of seawater such as Na, K, Ca, Mg, etc. 1967 research zeroed in on ion exchangers, both organic and inorganic, which meet the requirement. Most methods were found to require very little preparation of seawater solutions prior to adsorption of the element or elements in question.

FACILITIES (RESEARCH DEVELOPED)

LARGE-MEMORY PULSE-HEIGHT ANALYZER

Utilization of coincidence gamma-ray spectrometry offers increased sensitivity and selectivity of measurement for sample radio-nuclide constituent analysis and makes possible studies in nuclear decay that otherwise would be difficult or impossible. To provide suitable instrumentation for this technique on a NRDL project, a large-memory pulse-height analyzer was designed and built. The 16,384 channel analyzer, intended primarily to satisfy requirements for the program involving coincidence spectrometry, includes features which make the instrument useful for a variety of measurement problems in both radiochemical and nuclear physics research and development.

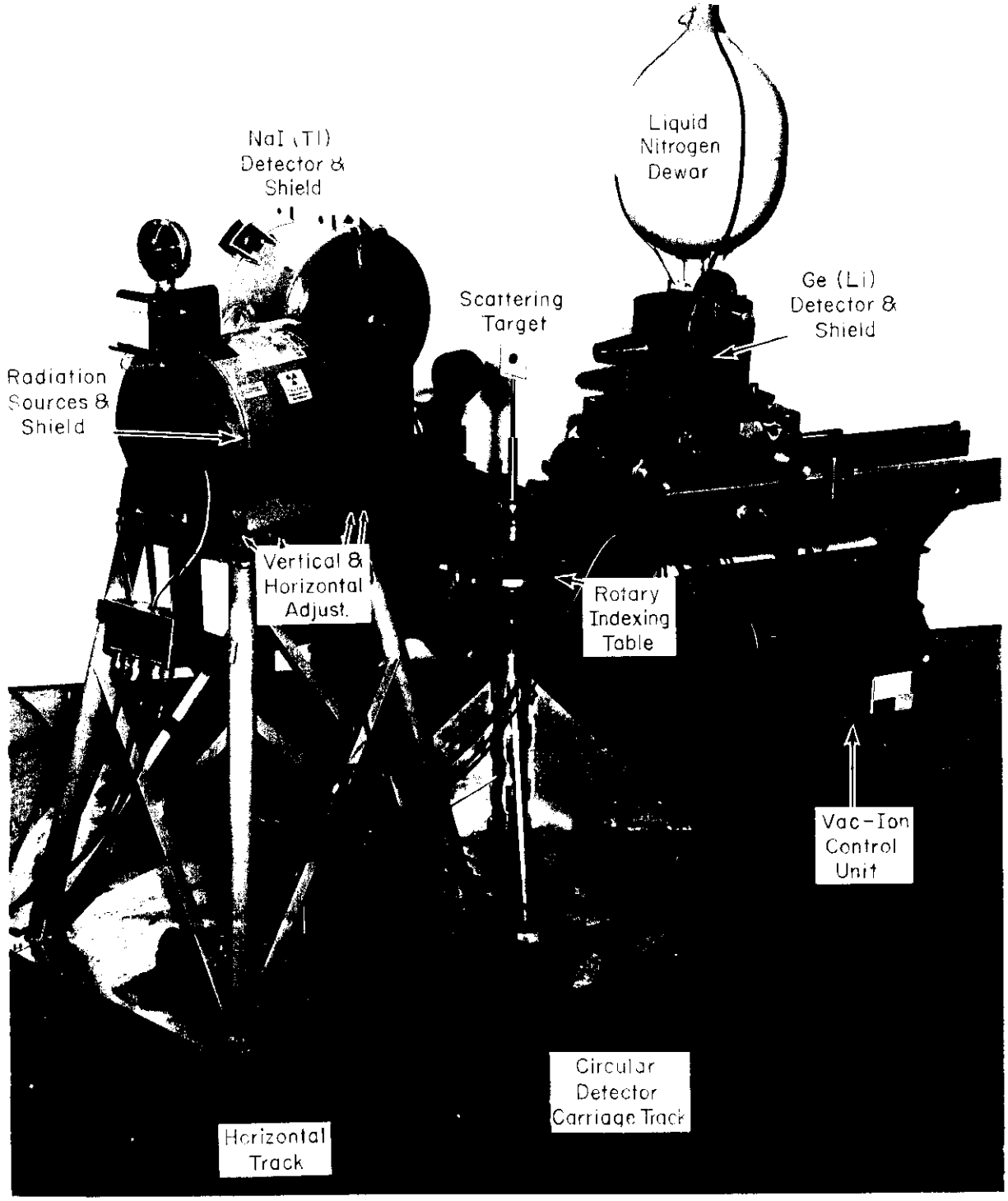
EMP TEST FACILITY

A parallel plate transmission line Electromagnetic Pulse Test Facility was built and placed in operation at NRDL. This facility permits testing of selected structures and electronic specimens in order to determine empirically their response to the EMP. It is capable of generating high, low, and plane wave impedance fields, is free from environmental influence, and is not unduly complex.

GAMMA-/X-RAY SCATTERING FACILITY

Continued shielding studies re-emphasized the fact that use of modern calculational techniques such as the Monte Carlo and the moments methods requires very accurate input parameters. Discrepancies between calculational and experimental data for complex shielding geometries revealed the need for more accurate differential coherent and incoherent gamma-ray scattering cross sections. In particular, this problem is most apparent at very small scattering angles ($<30^{\circ}$).

Construction of a precision gamma-/X-ray scattering facility (see photo on next page) provided a solution to the extent that differential cross sections of coherent and incoherent scattering for Z's from 4 to 92 at primary photon energies of 661.6 keV and at scattering angles from 1.3° to 135° can be determined to within 5 percent. Also, provision was made to vary radiation source for cross section determinations at other energies.



NRDL GAMMA-/X RAY SCATTERING FACILITY - capable of measuring the spectra of scattered radiation at angles from 1.3° to 135° - uses highly shielded and collimated detectors, [NaI (Tl) and Ge(Li)], and a multi-channel pulse height analyzer. Cross sections for differential coherent and incoherent scattering, as well as the photo-electric and the total mass absorption coefficients can be measured using this apparatus.

CHAPTER III - PUBLICATIONS

REPORTS AND MEMORANDA

For the second consecutive year publications production at NRDL was supereminent: 331 documents were issued in 1967, running neck to neck with 1966 at 327. In 1965 the total was 291; 1964, 213; and 1963, a mere 144. A new "monthly high" was achieved in September 1967 with production of 24 fullfledged technical reports, eight letter reports (several of which received commendations from sponsors), two literature review and lecture type publications and several technical papers that found their way into science journals. "Such production in the face of recent transition in the Lab in-house research mission and increasing contract research monitoring/management responsibilities," said CAPT D. C. Campbell, USN, Commanding Officer and Director, "is a tribute to the spirit and drive of both investigator and supervisory personnel in the Technical Department and those in support who handle the load of processing and printing."

A breakdown of 1967 reports by types shows:

U. S. Naval Radiological Defense Laboratory Reports (Formal)	2
Technical Reports (USNRDL-TR)	165
Reviews and Lectures	15
Progress Reports	20
Technical Manuals	3
Technical Memorandums	1
Letter Reports	107
Technical Reports Contractor (TRC)	9
Technical Reports Externally published (TRX)	3
Technical Memorandums Externally published (TMX)	1
Management Reports (MR)	3
Technical Memorandums Contractor (TMC)	1
Letter Reports Contractor (LRC)	1
Total	331

ANOTHER RECORD YEAR - Mrs. Claudia Rushford of the Laboratory Publishing Branch places a report on top of the stack which totaled 331 for 1967, or four more than the previous all-time high established in 1966.

PUBLICATIONS IN THE OPEN LITERATURE

In the open literature, 49 NRDL authors had articles appearing in 23 journals.

BOOKS PUBLISHED

* DR. K. F. SWINGLE, Experimental Pathology Branch, and the Head of the Branch, MR. L. COLE, contributed a key chapter to "Vol. IV: Current Topics in Radiation Research, 1967" at the invitation of the publishers Drs. M. Ebert and A. Howard. Their chapter deals with "Early Effects of Ionizing Radiations on Nucleic Acids." The 800 page book is being published in Amsterdam, Holland.

* DR. W. E. KREGER, Head, Physical Sciences Division, and DR. R. L. MATHER, Radiation Transport Branch, contributed "Chapter 3: Background, Shielding and Collimation" to the book "Scintillation Spectroscopy of Gamma Radiation, Vol. I," edited by Stephen M. Shafroth, Bartol Foundation.

* DR. KLAUS BECKER, NRDL's 11th Scientist-in-Residence, 1965-66, published a new book entitled "Photographic Film Dosimetry." Numerous references are made to the work of MR. E. TOCHILIN, Head, Radiation Physics Branch, and former NRDLer MR. ROBERT GOLDEN.

* DR. C. SHARP COOK, Head, Radiation Physics Division, late in 1967 received a Polish edition of his book "Structure of Atomic Nuclei", published in this country in 1964 by Van Nostrand Press. The book, supplementary reading for students who have had at least one year of college physics, gives an elementary description of models of atomic nuclei. Dr. Cook received word from his publisher that the book is also being translated in Spanish, and a South Asian edition is being printed in New Delhi.

* A book entitled "Ionizing Radiation: Neural Function and Behavior" (1965 Academic Press) written by DR. D. J. KIMELDORF, Head Physiology-Psychology Branch, and MR. E. L. HUNT of the same Branch, is being translated into Russian language, according to Dr. A. B. Tsypin, Institute of Biophysics, Ministry of Public Health, Moscow, USSR.

PATENT ACTIONS DURING 1967

One patent was issued to Mr. W. F. Joseph, "Direct Current Power Supply Having Plural Regulated Outputs," Patent No. 3,337,787.

Patents authorized for filing totaled five: (1) Mr. W. R. Balkwell and Dr. D. A. Kubose, "Surface Contact Sampling Apparatus," (2) Dr. E. L. Alpen, "A New Instrument for Precision Cytophotometry." (3) Mr. R. A. Nyberg, "Mechanically Secure Position Contact Tube Socket." (4) Mr. R. F. Ehat, "Two Terminal Blocking Oscillator." (5) Messrs. R. A. Taylor and R. F. Ehat, "A Temperature-Compensating Signal Transmitter."

There were 14 patent applications pending, and 10 patent disclosures submitted in addition to those authorized for filing.