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NRL Report No. 4147  


Scientific Program  
of the  
Naval Research Laboratory

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Declassification Team

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# Scientific Program of the Naval Research Laboratory

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**OPTICS**

N01-OPTICAL PROPERTIES OF MATERIALS	14
N02-GEOMETRICAL OPTICAL DEVICES	14
N03-OPTICS OF THE ATMOSPHERE AND OF THE SEA	14
N04-SPECTROSCOPY	14
N05-PHYSIOLOGICAL OPTICS	15
N06-PHOTOMETRY	15
N07-ULTRAVIOLET AND INFRARED SYSTEMS	15
N08-RADIOMETRY	15
N99-EXPLORATORY RESEARCH	15

**RADIO**

R01-COMMUNICATION	16
R02-DETECTION	16
R03-IDENTIFICATION	17
R04-NAVIGATION	17
R05-CONTROL	17
R06-COUNTERMEASURES	18
R07-SYSTEMS	18
R08-ELECTRON TUBES RESEARCH	18
R09-ANTENNAS	19
R10-CIRCUITS, COMPONENTS, AND INSTRUMENTATION	19
R11-PROPAGATION	19
R12-PRECISION LOCATION	20
R13-RADIO FREQUENCY INTEGRATION	20
R99-EXPLORATORY RESEARCH	20

**SOUND**

S01-TRANSDUCERS	21
S02-PROPAGATION	21
S03-HARBOR, FLEET BASE, COASTLINE DEFENSE	21
S04-HIGH-RESOLUTION SONAR	22
S05-RECORDING AND REPRODUCTION	22
S06-SONAR ELECTRONICS	22
S07-SONAR SYSTEMS	23
S99-EXPLORATORY RESEARCH	23

**GENERAL SCIENCE**

P01-MEDICAL SCIENCES	24
P02-CRYOGENICS	24
P03-CERAMICS	24
P04-HEAT POWER	24
P05-METEOROLOGY	25
P06-UPPER ATMOSPHERE	25
P07-PHOTON AND PARTICLE COUNTERS	25
P08-ELECTRON MICROSCOPY, X-RAY AND ELECTRON DIFFRACTION	26
P09-CRYSTALS	26
P10-APPLIED MATHEMATICS	26
P11-LUMINESCENT MATERIALS	27
P99-EXPLORATORY RESEARCH	27

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**CYBERNETICS**

Y01-SYSTEMS ANALYSIS AND SYNTHESIS	28
Y02-ORGANIZATION OF PERSONNEL IN INFORMATION PROCESSING SYSTEMS	28
Y03-SYSTEMS FUNCTIONAL DESIGN AND ENGINEERING	28
Y04-HUMAN TRANSMISSION PROPERTIES	28
Y05-MACHINE DISPLAYS AND CONTROLS	29
Y06-HUMAN ENGINEERING OF OPERATIONAL EQUIPMENTS	29
Y07-PSYCHOPHYSICS	29
Y99-EXPLORATORY RESEARCH	29

**SPECIAL SERVICE FUNCTIONS**

K01-RDB SHOCK AND VIBRATION CENTRALIZING ACTIVITY	30
K02-HARBOR DEFENSE INFORMATION AGENCY	30

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#### FOREWORD

The mission of the Naval Research Laboratory is to increase the safety, reliability, and efficiency of the Fleet by the application of scientific research and primary, or laboratory, experimentation to Navy problems. The work of the Laboratory includes all fields of scientific research which are important to present and future naval power and national security.

In an activity of the size and complexity of the Naval Research Laboratory, some means of classification is necessary to bring its varied activities together in an orderly and systematic form for purposes of planning, reporting, and over-all management. The NRL Scientific Program serves this function.

The pages which follow contain a statement of the current approved program of research and development of the Naval Research Laboratory. The program is, in effect, a statement of the areas of technology in which the Laboratory is now working, or in which it believes it should work. It is a breakdown of scientific effort into the individual programs specifically identified and systematically catalogued. The sum of the individual programs makes up the Laboratory program.

The program is designed to make the best use of the resources of the Laboratory in research and development to meet the more pressing needs of the material bureaus and operational requirements as defined by the Chief of Naval Operations.

All scientific activities at the Laboratory are classified into eleven fields. Each of these fields is further subdivided into a number of discrete programs designated by a letter indicating the field and a number indicating the sequence of the program in that field. This program is a revision of that issued on 1 December 1949. In order to tie it in with the operational categories in the "Navy Research and Development Plan 1-5" there are included in Appendix A two cross indexes with the numbers of that plan related to the Laboratory program numbers.

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Scientific Program  
of the Naval Research Laboratory

CHEMISTRY

C01-FUELS

Both current and potential fuels are being investigated for naval uses in aircraft and marine propulsion engines. Problems of immediate concern include: (1) the excessive deposition of carbon in jet engines, (2) the potential contamination of aviation gasoline by jet fuels on aircraft carriers, and (3) the deleterious effects of water or ice in current fuels and the formation of sludge in diesel fuel. Fundamental aspects of ignition and combustion of petroleum fuels are being studied with future emphasis being on pure component hydrocarbons. Studies on stability and compatibility of fuels have also been initiated. High-energy fuels such as the boron hydrides and borohydrides are being investigated to determine the best methods of preparation, physical and chemical properties, and storage characteristics of the compounds. The data collected furnish information suitable for pilot plant scale preparation, handling and storage of the compounds. Slow burning solid monofuels are under study to develop specific charges for existing devices (e.g., driving small turbines or pressurizing containers).

C02-LUBRICANTS

Exploratory research is being carried on concerning the physical, colloidal, and chemical properties of liquid, gelled, and solid lubricants. Emphasis is being placed on synthetic lubricants because of the inability of petroleum products to satisfy some military requirements and because of the dearth of information as to the lubricant possibilities of synthetic liquids. Basic research is in progress on the relation of the physical and chemical properties of liquids to their molecular structures; the mechanism of liquid phase oxidation and mode of action of antioxidants; friction and wear properties of liquids and solids; and the study of rheological, physical, and chemical properties of soap and nonsoap gelled greases. Under development are improved turbo-jet oils and high- and low-temperature (-450° to -65° F at present) oils and greases for aeronautical and ordnance applications. Entire lubrication systems are developed for such special purposes as meeting the severe effects of winter conditions in Korea on the functioning of aircraft machine guns.

C03-PROTECTIVE SURFACES

Investigations are being made on the chemical and physical phenomena associated with the deterioration of material by exposure as well as by the accumulation of naturally occurring organisms. Paint systems are under continuous study to improve the deterioration-resistant properties of coated surfaces. Methods of preparation of metal surfaces prior to

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receiving a protective coating are studied. The newer resins and polymers are studied for possible application in organic coatings for metal surfaces, for especially critical areas such as flying boat hulls and acoustical surfaces of sonar gear, and other naval uses. The coating of bulk fuel storage tanks, both concrete and metal, creates new problems with the changing composition of the newer jet fuels. The relationship of biological activity to chemical constitution is studied with a view to developing more potent fungicides. The chemical characterization of creosote, now used extensively for piling, is being determined in order to increase its repellency to the marine borer. Long-term tropical exposures of material, such as electronic equipment, determine the need for coating and type required.

#### C04-PERSONNEL PROTECTION

The naval program covers defense against CW, BW, and RW agents and measures to ensure safe breathing atmospheres. Current research on defensive CW includes: (1) the mechanism of aerosol filtration, (2) the carbon-oxygen surface complexes, (3) the mechanism of electrostatic precipitation, and (4) the automatic and instantaneous detection of aerosols. This should result in the improvement or development of aerosol filters, gas adsorbent-catalysts, electrostatic precipitators, collective protectors, and aerosol detectors. Current development includes: (1) a new gas mask (Mark V) now being procured for service trials, (2) electrostatic precipitators, one of which is undergoing shipboard trials, with other improved models being studied ashore. Future work will include the study of clothing materials for protection against liquid CW agents. The maintenance of safe-breathing atmospheres in closed spaces, such as in submerged submarines, includes the development of analytical instruments for continuously monitoring the air and a study of methods and chemicals for its revivification. Studies are under way to improve the efficiency of the Navy Oxygen Rebreather Apparatus by the development of new oxides and by changes in design.

#### C05-ELECTROCHEMISTRY

This program is concerned largely with the study of primary and secondary batteries, the Navy's main interest being centered on submarine storage batteries. Basic research is being conducted on the mechanisms involved in electrode reactions, including studies on the thermodynamics of the system and of the physical and chemical conditions which control the kinetics of the reactions. As this type of information becomes available, many specific improvements in the submarine battery are possible, such as longer life, better utilization of the active material, faster methods of charging, and reduced self-discharge and hydrogen evolution. Practical aspects of the program include consultation and liaison with the Navy Bureaus on operational aspects of the submarine battery, including ventilation, control of deleterious gases, evaluation of new types of batteries and participation of personnel in shipboard trials.

#### C06-HIGH POLYMERS

The investigation of high polymers is concerned with two aspects, chemical studies, and the application of polymeric material—with emphasis on the latter. New kinds of polymers are synthesized and examined as chemical substances with the hope of producing new useful materials. Such polymers at present include plasticizers, organophosphorus compounds, potential optical cements, and other components or process chemicals for rubber and plastics. Application of polymers, especially rubber compounds, has been

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pursued for several years and has produced many specialty rubber items from unusual seals to electromagnetic wave absorbers. These application studies will continue to service the Armed Services, particularly for use at both high- and low-temperatures. Special emphasis will be placed on new desirable seals, such as for critical parts for machine guns. Developmental work will continue on electrochemical recording paper, and on extremely fine plastic fibers.

#### **C07-CONTROL OF FIRES**

A basic study of the chemistry and engineering of materials and methods for fire extinguishment in naval air, ship, and shore operations is being carried on. Primary emphasis is placed on the hazards of hydrocarbon fuels and the use of air-water foams on fires in these and similar fuels. Research in vapor phase ignition and its prevention by inert vapors or gases is also being conducted. Early goals for this program included the stationary protection of fuel depots ashore; following this phase the improvement of foam protection of fuel handling areas on shipboard was successfully worked out. Present objectives are concerned with new aircraft crash fire rescue methods using fundamental principles evolved by laboratory research and study.

The focus of future efforts will be along lines dictated by the adoption of new energy sources including the control of damage from nuclear and guided-missile power plants.

#### **C08-COLLOIDS**

This program concerns investigating matter in the colloidal state, including a study of the production, structure, stabilization, and new methods of observing colloids. Particular emphasis is being given the colloidal and physical chemical behavior of oil-soluble soaps and related substances. Earlier work on this project has established the colloidal nature of oil-soluble soaps, their very small molecular solubility, and the unusual rheological properties of their anhydrous solutions. New techniques have been developed for determining the presence and the size of soap micelles in fuels and oils. Exploratory research is in progress on the effects of chemical constitution on the micellar behavior and other colloidal properties of oil-soluble soaps; and on the solublizing power of such soaps, and the mechanisms by which they function as rust inhibitors, oiliness additives, detergents, and gelling agents.

#### **C09-SURFACE CHEMISTRY**

This program comprises investigations of the formation, structure, and properties of boundary films at interfaces, and the naval application of the principles governing interfacial phenomena. In progress are studies of adsorption-desorption equilibria at solid/liquid, solid/air, liquid/liquid, and liquid/air interfaces. These are basic in understanding corrosion-inhibition phenomena, emulsification, foaming, the mechanisms by which oiliness additives in lubricants operate, detergency, and the spreading of liquids on solids. Mechanisms involved in a desensitization of modern high explosives are being investigated. Surface-chemical reaction mechanisms in corrosion inhibition and wear prevention are under study. Applications are being made to certain nonelectronic countermeasures.

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#### C10-RADIOCHEMISTRY

Analytical procedures have been developed for the sequence analysis of complex mixtures containing both radioactive and inactive isotopes. These have been applied to the problem of the radioactivity of the atmosphere. Other special problems of interest to the Navy and the Atomic Energy Commission are now being worked on, and will require the isolation of certain isotopes not in the present analytical scheme.

Radioactive isotopes are being used as tracer elements to follow the course of chemical and physical processes, with present emphasis on the study of liquid metals for heat-transfer media. The solubility of oxygen and iron in sodium and the influence of hydroxide and oxide on the solubility of other components of stainless steel both in the pure and combined states will be determined.

#### C11-PHYSICAL CHEMICAL PROPERTIES

Physical and chemical properties of liquid metal heat-transfer media are under study to collect the data required for design and operation of liquid metal systems. Thermal conductivity, specific heat, viscosity, density, and chemical characteristics have been determined on sodium, potassium, and their alloys, and are scheduled for determination on other alkalis and on sodium hydroxide. The temperature range extends from the melting point to practical high temperatures with 1000°C being the upper limit. In the field of molecular spectroscopy, the absorption spectra of organic compounds are being used to determine their structure and fundamental thermodynamic constants. This research has proved useful in such problems as analysis of rubber and the identification of constituents of organic mixtures. Exploratory research is conducted on the spectra of organophosphorus, organofluorine compounds and on pure hydrocarbons.

#### C99-EXPLORATORY RESEARCH

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## ELECTRICITY

## E01-ELECTRIC POWER SYSTEMS

The instigations embrace the requirements for and the application of electric power systems to naval craft, with emphasis on a study of systems variables which affect design. Techniques of system protection to provide safety and reliability to the electrical system of the vehicles concerned are to be evolved.

Studies have been made principally on the electric power systems of submarines and aircraft. They include work dealing with the transient characteristics of both ac and dc electrical systems, with circuit protection, and with the general problem of system coordination. Under the latter problem the factors effecting good system performance (regulation, stability, etc.) are investigated during both transient and steady-state periods of operation. Future work will continue along these lines.

## E02-FEEDBACK CONTROLS

The plan of investigation includes techniques, equipment and complete systems involved in the field of feedback control as applied in naval craft and equipment. The aim is to improve the understanding and the theoretical analysis of generalized control systems.

Automatic controls for submarine propulsion systems have been given careful study. Recently, automatic controls are being developed for control of power systems having extreme frequency stability while subjected to large cyclic loads. In the future, work will continue on electrical control systems and on the development of instrumentation and techniques for evaluation of these systems.

## E03-ELECTRIC POWER EQUIPMENT

The study includes factors affecting the performance and design of major electrical components such as rotating machinery, control equipment, transformers, switch gear and cable concerned with the generation, distribution and utilization of electric power on naval craft.

Present research deals with the derating of blast-cooled electrical equipment and with the rating of self-ventilating equipment. The rating of cables singly or in bundles has been given extensive study. The evaluation of electric generators and regulators is a continuing effort, and has led to the production of a manual to standardize the testing of ac generators and regulators used in naval aircraft. Future work will emphasize a study of cooling of electrical equipment in aircraft.

## E04-ELECTRIC INSTRUMENTATION

The investigations are concerned with electrical instrumentation and equipment for naval craft to cover special purposes such as measurement and computation, control, protection, alarm, interior communication, electrical heating, electromagnetic braking, and electromechanical actuation.

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The development and application of computers and computer circuitry represent a continuing part of this program. For example, completed developments include equipment for the measurement of the thrust being developed by a jet engine under flight test, and a device to control automatically the emergency operation of crash barriers for aircraft landing on a carrier. A study is also being made of the application and development of both proton and electron magnetic resonance techniques. In the immediate future, the possible applications of magnetic resonance techniques to meet naval operational problems will be given serious consideration.

#### E05-MAGNETIC AMPLIFIERS

It is proposed to investigate the circuits and circuit elements of magnetic amplifiers to improve and expand their usefulness in communication, computation, control and power applications.

Extensive work has been conducted on magnetic amplifier circuitry to produce circuit elements such as ring-type modulators, trigger circuits, and coincidence circuits with very short response time. Future work will include emphasis on the development of low-level input amplifiers (less than 10 milliwatts), high-speed amplifiers, and a general study of the expansion of the functional capabilities of magnetic amplifier circuitry to provide such components as lead networks, integrating circuitry, and frequency multipliers. Future work may also include a study of the dielectric amplifier used either in conjunction with a magnetic amplifier or by itself.

#### E06-ELECTRIC AND MAGNETIC PROPERTIES

A program of theoretical and experimental research is conducted in phenomena of the solid state with emphasis on electric and magnetic properties. Investigations include the electric properties at the boundary surfaces of semiconducting and conducting materials; the variations of properties with temperature and magnetic fields; ferromagnetic properties at high frequency; the conductivity phenomena induced in dielectrics by cathode-ray bombardment; and relations between the properties of elementary particles and the macroscopic properties of matter.

The nuclear and paramagnetic properties of matter are being studied through the resonance techniques of radio-frequency spectroscopy which have proven a fruitful tool in the clarification of the internal structure of solids. The possibility of using a resonance method for accurate measurements of the absolute value and anomalies of the earth's magnetic field is being studied. It is expected that the study of liquids will lead to fundamental contributions to the understanding of the nature of crystalline electric fields in solids.

#### E07-ENGINEERING MATERIALS

Theoretical and experimental investigations are conducted on materials used as dielectrics, contacts, semiconductors, rectifiers, etc., in electrical and electronic circuits. The objective is to determine and improve their physical and other characteristics under various conditions of use.

Presently the emphasis is concerned with the study of dielectric materials. Class A and class B insulations have been carefully investigated to determine their life when exposed to higher than normal temperatures, and laboratory investigations are being

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compared with actual life tests in motors. This work will include other classes of insulation in the future and will be considerably expanded to cover an intensive study of the damage produced in dielectrics by radiation. A study will be made of nondestructive techniques for testing dielectrics and also of the effect produced in dielectrics by surges of high voltage. Functional characteristics of dielectric structures under operating conditions will be examined and new materials may be developed.

#### **E08-ATMOSPHERIC ELECTRICITY**

This program consists of a study of atmospheric electrical phenomena particularly in relation to their effects upon the operation of aircraft radio receiving equipment. Emphasis is placed on providing practical methods for the reduction or elimination of undesirable effects on radio communication resulting from electrical charging of missiles and aircraft operating in an atmosphere of snow, fog, rain, or dust as well as from thunderstorm activity. Current effort involves development of prototype antenna fittings which will provide complete coverage of the exposed antenna with a high dielectric material so that all electrical discharge from the antenna is suppressed. Production engineering problems are under study by the production of several thousand typical fittings.

#### **E99-EXPLORATORY RESEARCH**

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MECHANICS

F01-ELASTICITY

Stresses and strains are analyzed by closely linked experimental and mathematical attacks. The principal subjects under present study are stress concentrations and flexibilities of curved tubes. These problems are of importance in piping systems where temperature and pressure changes cause stresses in piping and forces on boilers, turbines, and other terminations. As such, the stresses and forces must be calculated.

After pioneering stress analysis of three-dimensional piping systems having long radius bends, and extension to short radius tube turns, components of piping stresses are being combined so as to determine the maximum effective stress for any magnitude and direction of bending moment and internal pressure. Theoretical and experimental results are being put into forms convenient for practical design work.

F02-EXPERIMENTAL DESIGN

These investigations provide the basic engineering for naval devices and structures which are beyond the range of existing theory. Speed and economy are sought by utilization of empirical methods and reduced scale experiments.

The resistance of nuclear-powered submarine components to underwater explosion shock is being studied by experiments on reduced-scale models and on full-scale components. Failures are studied and design revisions recommended. The measurements made during tests are used to define service conditions more adequately, to derive criteria for future designs, and to test scaling theories. Interpretation of the data will be carried further; application to service specification and design will continue.

Advisory services and cooperative experiments with others directed toward improvement of 20-mm machine gun performance will be continued.

F03-SHOCK AND VIBRATION

Shock and vibration incident to naval service of equipment on ships, planes, and missiles are recorded, analyzed and simulated. Methods are developed for obtaining designs of adequate strength and for the development of suitable protective mounts.

Observations on the SS428 submarine and the Viking rocket continue. These records are analyzed and correlated with those of other service conditions to develop design guides. Supporting investigations determine the complex stress-strain characteristics of real materials, and have application to such basic elements as a wire in tension, shock loaded bolts and cantilevers, and transversely loaded shafting. Ultrasonic pulse techniques and resonance methods are being used to study the changes in internal friction and elastic constant caused by plastic flow, fatigue, and other factors. Shipboard equipment items in the prototype stage are being evaluated at the rate of about fifty per year; weaknesses are identified, and remedies applied or recommended.

F04-STRENGTH OF SOLIDS

Increasingly severe operational requirements often make it necessary to load materials beyond the elastic range. Experimentally this program emphasizes study of the

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progressive development of initially localized plastic flowing and fracturing, and observation over a wide range of straining speeds. Suitable techniques are developed for plastic fibers, aircraft glazing, ship plate, armor and other materials of naval interest.

The physical origins of penetration resistance of the armor alloys of iron, aluminum, titanium and magnesium-lithium are being identified. Instability criteria are being developed and applied to rate the toughness of aircraft glazing and structural materials. Studies of yield strength under dynamic loading, as by shock or ballistic impact, are directed toward disclosure of the basic mechanisms and relative evaluation of various metals. Observations are made under cyclic stressing from frequencies of ten million in the elastic range to less than one per second in the plastic range.

A monograph will be drafted to collect the results of almost a decade of study covering the mechanics of fracturing. To permit investigation of flow and fracture in larger specimens, a three million pound push-pull loading device of unique design will be installed.

#### F05-PENETRATION BALLISTICS

As the variety of weapons, the complexity of tactics and the magnitude of ordnance production increase, straining national resources, the need increases for well correlated data and rational analyses as guides toward increased military effectiveness and decreased consumption of materials and manpower. This program utilizes laboratory penetration ballistics techniques with the object of extending their usefulness and of exploring unknown characteristics of armor penetration and gunfire damage.

A discussion and summary of missile penetration relations supported by physical reasoning are being prepared. Measurements are in progress to permit extension of penetration relations to include both shape and form factor of fragments attacking armor at various obliquities as well as at normal incidence. Momentum loss data has been obtained for variously scaled models of a 2.75-inch rocket piercing aircraft sheet materials. An objective technique for estimation of the vulnerability of structural components is being developed.

Investigation of incandescent and incendiary effects associated with very high velocity impacts will continue, spectrograms of typical impact flashes obtained at this Laboratory being analyzed at JHU/APL. The test for rating incendiary hazards of impact flash will be extended into the high velocity range, and additional means for flash suppression will be sought.

#### F06-AERODYNAMIC BALLISTICS

Aerodynamic forces on objects moving at ballistic speeds are investigated by laboratory methods providing or simulating free flight. A short trajectory momentum trap technique for measuring longitudinal drag has been used. Extension to other air force components and further development of the theory are under consideration.

This program has been inactive since July 1952.

#### F99-EXPLORATORY RESEARCH

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METALLURGY

M01-PHYSICAL METALLURGY

To study effects of composition, structure, and processing on physical, chemical and mechanical properties of metals and alloys is the mission of the program. It also seeks to investigate underlying solid-state factors, and to develop alloys for specific purposes.

Investigations of iron base alloys have shown ineffectiveness of the usual alloying elements to increase notch toughness. Microstructure and trace elements are now being studied. A comprehensive survey of refractory materials for containing molten titanium has been carried out, and one is being started of deoxidation. Studies are being conducted of flow and fracture as influenced by temperature, of electric and magnetic properties, of crystal and Brillouin zone structures, and of contact transients.

M02-MELTING AND CASTING

The objective of the program is to evolve fundamental information and to develop new techniques and procedures required for the solution of casting problems of naval importance.

The major effort is concerned with the reliability of castings for critical military use. Methods and procedures have been evolved to insure production of reliable castings and to reduce rejection losses. Test methods have been developed to evaluate casting performance under severe service conditions, such as explosion loading, so as to provide data for engineering design purposes.

M03-WELDING

The mission is to evolve fundamental information and to develop new techniques and procedures required for the solution of welding problems of naval importance.

The major effort is being directed to the evaluation of factors which determine performance of weldments for ship hull structures. Mild steels, armor, and aluminum alloy weldments are under investigation. The remaining effort is aimed at developing fundamental information required to improve performance of weld joints. The modifications of the metal structure resulting from welding and the properties of the weld are being investigated for armor steels, for high-temperature alloys for steam piping systems of ship propulsion units, for super alloys for jet engines, and for aluminum alloys for ship superstructures.

M99-EXPLORATORY RESEARCH

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## NUCLEONICS AND ATOMIC WEAPONS

### H01-NUCLEAR CONSTITUENTS

It is intended to continue the program which serves to increase our knowledge of the particles of which atomic nuclei are made up, and of the way in which particles interact with other particles and with various fields.

Theoretical studies are concerned with elementary particles, field theory, nuclear structure, and nuclear reactions. Specific investigations are being made of the structure of elementary particles, the angular correlation of successive nuclear radiations, and orbits of particles in a synchrotron.

Studies of high-energy cosmic-ray phenomena using thick nuclear emulsion techniques are being conducted. These include the devising of new and improved emulsion techniques, and investigations of: the nucleonic component in dense materials in the stratosphere; the ionization loss of charged particles at relativistic velocities; high-energy heavy primary nuclei; multiple production of mesons, and in particular of heavier-than-pi mesons; and the soft component of cosmic rays at high altitudes.

Low-energy interactions of heavy particles are being investigated with the aid of 2 Mev and 5 Mev Van de Graaff accelerators. Basic nuclear data are being collected on reactions initiated by proton and deuteron bombardment. A program of neutron cross-section measurements which will be useful in the development of nuclear power plants is planned.

### H02-NUCLEAR STRUCTURE

Basic studies of the radiations from radioactive nuclides are being conducted to bring about a better knowledge of the structure of the nucleus. Such knowledge is essential in seeking new ways to obtain nuclear energy and to improve on current methods.

Two beta-ray spectrographs, with associated automatic counting equipment are functioning. Measurements of beta and gamma-ray energies are being made to a high precision on fission product radiations and on positron annihilation radiation.

The 20-Mev betatron has been modified to the point where very good stability is obtained and its output is monitored precisely. Studies completed or in process include the determination of thresholds for gamma induced activities of various kinds.

Satisfactory progress is being made in the development of two novel electron accelerators, namely the electron cyclotron, a compact accelerator of small dimension, and a small-aperture air-core electron synchrotron.

The relative abundance of isotopes, including cases in which the abundance ratio is very large, are being studied using Nier type magnetic mass spectrometers. The non-magnetic type mass spectrometer is being developed and applied to problems of negative ion-forming processes and the measurement of multiple ionization potentials.

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### H03-NUCLEAR MOTIVE POWER

This program includes surveys, theoretical, and experimental work on problems associated with the adaptation of nuclear reactors for power applications.

The properties of reactors, reactor components, materials, and instrumentation are studied. Specific investigations have been made of: the technology of zirconium; and the feasibility of using  $\text{Li}^7$  as a reactor coolant.

Proposed problems include a measurement of the diffusion of radioactive iron into stainless steel.

### H04-NUCLEAR TECHNOLOGY

New techniques and instruments are being devised and old ones developed and improved for use in research and development in nuclear physics.

Methods of measuring nuclear radiation are being investigated. Neutron flux and energy measurements in the vicinity of an atomic explosion are being made at the Nevada test site, using threshold indicators. A search is being conducted for a phosphor suitable for use with a photomultiplier tube for counting epithermal neutrons. Improved forms of Geiger and other types of counters are being developed.

Standardization procedures are being established for navy radiac instruments.

Radio-chemical methods are being applied to problems such as the kinetics of ion exchange processes, the solubility of iron in water at high temperatures and pressures, and others.

Unusual vacuum pumping methods are being investigated along two lines. A set of fluorocarbon oils and greases has been developed which facilitates the handling of the halogens in a vacuum system. Preliminary investigations are under way aimed at the design of a novel molecular pump.

### H05-ATOMIC WEAPONS RESEARCH

A program involving both fundamental and applied research is conducted on nuclear physics and nuclear electronics problems associated with the development and testing of fission and thermonuclear weapons. This research is intended to assist in the understanding of the nuclear mechanisms and behavior of these weapons. It is also intended to develop experimental techniques which will enable measurements of the nuclear reactions within the weapons to be performed under the extreme conditions existing during a nuclear explosion.

A study is continuing on the reactions of high-energy neutrons with various elements. This study has already contributed significantly to the understanding of the behavior of thermonuclear reactions.

Experiments performed in the vicinity of a nuclear explosion require very thick shields to obtain good collimation and protection of detectors against undesirable signals. Theoretical and experimental study continues on the interactions of radiation with thick shields.



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#### H06-ATOMIC WEAPONS TESTING

Measurements of nuclear phenomena during and after atomic weapons explosions are being carried out in support of the AEC weapons testing operations at the Nevada and Eniwetok Proving Grounds.

The Radiation Division is acting as a consultant and assisting the Los Alamos Scientific Laboratory in the nuclear measurements program.

#### H07-REACTOR SCIENCE

This program includes fundamental and applied research to investigate and utilize nuclear reactors both as a source of radiation and neutron flux for the study of nuclear reactions and as a source of motive power for the propulsion of vessels and aircraft.

Planning is under way to construct a research reactor at NRL. Design of the reactor and a detailed safety study are in progress. A program is being formulated to utilize the reactor. Power reactor design, neutron diffraction studies, radiation damage effects, and manufacture of short-lived isotopes will be included. Development of apparatus and systems for the control and manipulation of reactors will be undertaken.

The behavior of radiation passing through thick shields is being studied theoretically and experimentally. These studies will contribute to a general understanding of shielding problems. The shielding required for the installation of a reactor in an aircraft carrier is being investigated. Theoretical calculations will be supplemented by measurements on an aircraft carrier.

Members of the group serve as consultants to the Navy on problems connected with the nuclear propulsion of ships and aircraft and give theoretical and experimental assistance on special problems as they arise.

#### H08-RADIATION EFFECTS

Research into the effects produced by irradiation of matter involves two phases: (1) a solid-state study of changes which take place, and (2) investigation of macroscopic effects having bearing on performance, life, and utility of materials in intense radiation fields.

The effects of neutron-induced impurities are studied utilizing both accelerators and piles as neutron sources. Pile irradiation will be facilitated upon the completion of the NRL reactor.

Changes produced by gamma rays, electrons, protons, etc. also are being studied with help of accelerators. An investigation of water corrosion of stainless steel under the influence of electron radiation is under way. This problem arose in connection with the STR submarine reactor currently being developed by BuShips.

#### H99-EXPLORATORY RESEARCH

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## OPTICS

### N01-OPTICAL PROPERTIES OF MATERIALS

Basic studies of miscellaneous optical properties of materials are conducted, including measurements of scattering, reflection, refraction, and radiation of light by optical glass, plastics, crystals, powders, liquids, and dielectric and metallic films, with the view of exploiting new optical properties in naval applications. Completed problems have included measurements of the optical properties in the infrared of new plastics and optical glasses as well as the construction of reflection interference filters for the infrared, for example. Current work is concerned with the development and production of special optical components depending on the optical properties of thin films. Continuation of the exploitation of new optical materials is contemplated.

### N02-GEOMETRICAL OPTICAL DEVICES

Special geometrical optical systems for naval and laboratory use are developed, including such devices as visible-light and infrared sighting devices of large light-gathering power and large field of view. Current work is concerned with the development of an image-motion compensator for use with naval aerial cameras to permit sharp pictures from high-speed aircraft at relatively low altitudes. It will be appreciated that extensive work on optical systems occurs in other programs in connection with rockets and other special situations; also, this program does not embrace work on periscopes, rangefinders, gunsight telescopes, and other standard devices for which the Navy maintains adequate programs elsewhere.

### N03-OPTICS OF THE ATMOSPHERE AND OF THE SEA

Investigations are made of all optical properties of the atmosphere and of the sea, including the attenuation by absorption and scattering of radiations throughout the optical spectrum by clear air, haze, and fog, and the transmission of visible and ultraviolet radiations by sea water. Polarization and brightness measurements of the daylight, twilight, and night skies have been made. Work is in progress on determination of ship or missile position by location of the "infrared" horizon by day or by night; the measurement of the microthermal character of the surface of the sea for infrared detection of submarines; the measurement of visibility along the slant path between aircraft and carrier deck; measurements of the aureole around an ultraviolet source; and the effectiveness of smoke screens in the infrared. Results obtained apply directly to problems of visual and infrared detection, optical communication, night photography, and thermal effects of atomic explosions.

### N04-SPECTROSCOPY

Spectroscopic investigations from the extreme ultraviolet to the infrared are made to study special light sources and the elementary processes occurring within them, the photoelectric effects in solids and gases, and the emission and absorption spectra of flames. Much emphasis is currently placed in the extreme ultraviolet region between 500A and 2000A. New radiation sources are being developed for use below 1000A. The program ties in closely with the upper atmosphere research program in which radiation from the sun in the extreme ultraviolet is being studied with rocket-borne equipment.

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**N05-PHYSIOLOGICAL OPTICS**

The optical properties of the human eye and the physical factors influencing its ability to see, both by day and by night, form the basis of this program. Currently, studies are being made to determine the visibility of stars in the daylight or twilight sky for the purpose of navigation in the Arctic; to improve night vision by the correction of night myopia; and to ascertain the properties of the eye involved in the measurement of very low brightnesses by visual photometry in connection with specifications of self-luminous marker buttons and similar devices. Personnel assigned to the program participate in the scientific working sessions of the Armed Services NRC Vision Committee.

**N06-PHOTOMETRY**

The program is concerned principally with the study of methods of visual and physical photometry and colorimetry at low levels of intensity and of the luminous properties of phosphorescent and fluorescent materials. The study of luminous material has improved night aids to military activities and contributed materially to the development of the use of the radioactive isotope strontium-90 to activate the luminous zinc sulfide phosphor. Emphasis is being placed on the study and development of photoelectric methods of low brightness photometry. Present work will be continued with the view of improving standards and increasing the convenience and accuracy of methods available to naval inspectors and to manufacturers of night aids for the Armed Forces.

**N07-ULTRAVIOLET AND INFRARED SYSTEMS**

Investigations are made of detection, signaling, and control systems utilizing ultraviolet or infrared radiations. The program has included past work on the Stabilized Ship Detector, the Passive Bearing Finder, and other miscellaneous prototype detection and communications systems. Work is in progress on the origin and spectral distribution of infrared radiation from aircraft; optical scanning systems to distinguish this radiation from sky background radiation; on the development of a voice-modulated optical communication system utilizing pulse-time modulation of gaseous discharges excited by RF power; and on the practical use of photoconductors responsive to long wavelength infrared radiation in infrared detection systems.

**N08-RADIOMETRY**

Work in this field includes spectrographic, photoelectric, radiometric, and photographic diagnostic measurements of the optical radiation from explosions.

**N99-EXPLORATORY RESEARCH**

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RADIO

R01-COMMUNICATION

It is the purpose of the program to investigate and develop systems and components to advance short- and long-range communication between subsurface, surface, and supersurface units for all areas, including the polar regions, emphasizing such factors as choice of frequency, spectrum utilization, means for decreasing vulnerability, merits of various types of modulation, and provision for automatic operation. Systems will be studied which utilize audio, graphic visual and electromechanical techniques to improve such factors as traffic handling capacity, intercept and cryptographic security, accuracy, flexibility and reliability. Relay and data transmission systems—for the transfer of information or intelligence to achieve increased speed, accuracy, and the extension of communication ranges within a task force—will also be investigated.

The work in communication is along two main lines: development of new or better communication services, and increase of reliability and utility of present communication services. New services are being developed for the purpose of: (1) conserving spectrum space, (2) improving the reliability and capacity of communication circuits, and (3) making security communication more secure, by new developments in cryptography, limited-range transmission, and limited-angle transmission and reception.

The reliability and utility of existing services are being improved by redesign and modernization of components and circuits, and exploitation of new components and techniques such as transistors and information quantizing.

R02-DETECTION

Investigations are conducted on detection techniques and systems, considering such factors as target handling capacity, spatial coverage, position accuracy, altitude determination, perception of target, presentation of target information, rapid target interpretation and designation, vulnerability to countermeasures, and operation in clutter. The objectives of this program include: (1) the discovery or development of ideas which advance the detection capabilities of the Navy, (2) advisory and consultative services on naval detection problems, and (3) the determination of the plan or design of detection systems based on studies of naval tactical problems and requirements, sound engineering practices, and laboratory-proved techniques and components. Radar principles are usually employed but other types of electromagnetic systems are included.

The detection program is related to three specific applications. (1) Long-range, low-information-rate surveillance of all radar targets above the radio horizon is anticipated by a combination of four new radar systems now under development. This is being augmented by development of long-range airborne radar for low-altitude coverage and auxiliary airborne surveillance. (2) Short-range high-information rate target indication for designation to weapon systems is being attempted in a single radar system development, scanning techniques for which are still under investigation. (3) Submarine detection is receiving much attention in special radar development, as well as in exploration of other techniques which may prove promising, including electric field anomalies created by exhaust trails and ships' wakes.

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### R03-IDENTIFICATION

It is the purpose of the program to analyze operational requirements for electronic recognition and identification systems; evolve techniques and special components applicable to such systems; develop experimental systems and provide consultative services on construction, use, and operation of final equipments.

Current activity is along two lines. The first includes the final engineering and equipment evaluation incident to the present introduction of the Mark X IFF system into military use by Navy, Army, and Air Force. The second is development of cryptographic devices for the Mark X system to provide security against an enemy appearing as a friend.

### R04-NAVIGATION

The program serves to investigate navigation systems with a view to the future program requirements of the Navy. Studies are also conducted to develop specific navigational aids and systems with emphasis on carrier all-weather flying systems enabling aircraft to perform all functions necessary for military missions; short-range navigation systems for small surface or subsurface units providing position or guidance information; long-range systems with provision for security and other military requirements for subsurface, surface, or supersonic units.

Navigational systems are in various stages of development for three types of application. (1) Long-range "fixes" at sea by shore radio installations are being made more accurate at extended ranges. Five-mile accuracy at 2000-mile range now appears to be realizable. (2) Carrier-based, short-range (200 miles) systems for carrier-based aircraft are in early stages of development—the orbiting, approach, and landing phases being studied first. (3) Aircraft navigation by means of integration of ground speed and drift has been proved, and is nearly ready for Bureau procurement. Accuracy of one percent of distance flown has been demonstrated.

Several instruments are being developed with application to navigation, including a radio sextant for locating sun and moon through overcast, and instruments for precisely measuring electric and magnetic fields.

### R05-CONTROL

Factors affecting accurate control are being investigated. The program also serves to develop new and improved systems for automatically controlling or assisting in the control of gunfire, the guidance and control of missiles, and the take-off flight, and landing, of carrier aircraft. This program involves the application of servo theory to tracking, stabilization, launching, landing, and aerodynamic control systems, and combinations thereof. It includes research on recording, computing and other equipment or techniques needed for proving ground instrumentation, and data reduction useful in the development and evaluation of control systems.

The program in automatic control is directed toward three types of application.

(1) Work on control of gunfire from ships consists largely in cooperation with contractors in final stages of development of new systems and operational research on complete systems under laboratory controlled conditions. (2) Missile guidance work is concerned with fundamental measurements on propagation phenomena, development of techniques to overcome propagation limitations, development of instrumentation for research in automatic

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guidance systems for aircraft and missiles, "Viking" guidance development, and consultation with Navy bureaus and Army Ordnance on missile-guidance development and its coordination. (3) Carrier-based control of aircraft for approach is being readied for fully automatic operation, and automatic control of landing is being developed.

#### R06-COUNTERMEASURES

Techniques for exploration of the complete radio spectrum are evolved with primary emphasis on such fields as interception, direction-finding, signal analysis and vulnerability, with work as indicated on jamming and deception techniques which can be applied against all radio and radar systems. The vulnerability of U.S. (and, where possible, foreign) radio and radar equipments for developing countermeasures are being studied. The program also devises jamming methods, techniques, and experimental systems for use against all types of radar and radio systems. Experimental devices and systems, suitable for use in aircraft and ships for providing technical data to evaluate various newly devised techniques, are being developed.

Work is along three main lines. (1) For interception, signal analysis, and direction finding of radio signals, techniques and systems are being developed to cover all frequency ranges and all types of transmission. (2) High-power, wide-band, versatile components are being developed for "jamming" or interfering with enemy radio transmissions. (3) Confusion reflectors for deception jamming and decoys are being further developed. Limited radar-vulnerability studies are being made in support of the jammer development program.

#### R07-SYSTEMS

To develop techniques which increase the effectiveness of combined electronic systems, and to study the factors involved, are the purpose of this program. In particular, attention is concentrated on those systems leading to the rapid and accurate exercise of command. The latter requires techniques and devices for the collection, evaluation, integration, presentation, and distribution of information provided by electronic and associated systems which support the command and control functions. Also under investigation are the techniques and devices required for the determination, suppression and avoidance of interference.

Electronic processes and techniques are being developed and evaluated for collection, classification, communication, storage and presentation of the vast amount of data involved in ship and task-group control. Also being developed, where practicable, are systems for automatic use of information.

#### R08-ELECTRON TUBES RESEARCH

Research is conducted in the field of electron tubes with emphasis on projects applicable to improved naval electronic systems.

Three new types of electronic tubes are under development: (1) Electron storage tubes, having many applications in communication and detection, (2) millimeter-wave oscillator tubes required for limited-range communication systems and ultra-high-resolution radar, and (3) gaseous discharge devices, having promising application to frequency multiplication, modulation and rectification at microwaves, as well as noise

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standards for microwave receiver measurements. The program includes research on basic processes in vacuum-tube manufacture, and on tube design for reliability.

### R09-ANTENNAS

Theoretical and experimental research are directed toward the development of new and improved antennas, antenna components, r-f components closely allied to antennas, and antenna instrumentation.

The work may be classified in three categories: (1) Development of antenna systems for specific radar and communication equipments, (2) development of antenna systems and techniques tailored to specific types of application, such as rapid-scan systems for radar, and antennas with specialized polarization and directivity characteristics for countermeasures, and (3) research in techniques having general antenna application, such as ferrite control of the propagation of microwaves in wave guide. Stress is placed on simplification of shipboard antenna systems by broadband design and multiple use of single antennas, and on drag-free design of aircraft antennas using vertex feed scanners and-slot radiators.

### R10-CIRCUITS, COMPONENTS, AND INSTRUMENTATION

Lumped-constant and distributed-constant circuits and components are investigated, as they may contribute to improved stability, simplicity, compactness and reliability when applied to frequency generation, gain, detection, modulation, synchronization, control, information storage, and economical power and spectrum utilization under a wide range of environmental and abusive conditions. The program also includes research in electronic measurements and seeks to develop techniques and instrumentation needed at the Laboratory to fill specific requirements of the Navy in electronic equipment maintenance. NRL personnel provide consultation and evaluation services to the material bureaus and their contractors for test equipment throughout the preproduction period.

In this work there is a continuing development and refinement of basic components, circuits, and techniques having widespread application in radio. In addition, two major developments are current: (1) time and frequency standards on a decade basis, after many years of effort, are being made practical both for laboratory and for field use; (2) digital techniques for handling and storing of information and for computation are being exploited on a broad front.

### R11-PROPAGATION

The propagation of electromagnetic waves are studied including extraterrestrial, ionospheric, tropospheric, ground-wave, and sea-water propagation. There are investigations also on the attenuation and reflection by propellant gases. Attention is given to reflections from natural and man-made objects and back scattering from and absorption by clouds, rain storms, and the sea surface, with emphasis on quantitative results and the physical characteristics of the reflected waves. Allied to these are means of radar detection of small targets in the presence of sea return. Research is conducted on the absorption of radio waves and studies on available materials (or the devising of new materials) having high permeabilities at high frequencies for use as components in absorbing films.



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Three general types of investigation characterize current work in this field. (1) The propagation of electromagnetic waves through the earth's atmosphere, through sea water, and through rocket and jet exhaust flames, is receiving continuing study directed towards increasing the reliability of radio links and extending radio communication and control services. (2) The reflecting characteristic of radar targets, boundary layers and surface coatings are being studied to aid in control of "radar visibility" and multipath interference effects. (3) Thermal radiation of objects at radio frequencies is being studied for application to passive radio listening as a new method for detection and location of objects.

#### R12-PRECISION LOCATION

Operational requirements are analyzed for precision location systems. The program also seeks to devise new and improved radar systems and components for the resolution, acquisition, and precision tracking of air and surface targets.

The work is devoted primarily to precise analysis of radar echoes from individual targets. It has two principal phases: (1) isolation of individual targets in clutter by high target resolution, and (2) precise tracing of moving targets, as required for weapons control. An objective is target identification by echo "fingerprints."

#### R13-RADIO FREQUENCY INTEGRATION

The application of storage and correlation techniques to radio frequency integration are investigated.

In this program the attempt is being made to exploit the theoretical advantages of cross correlation in radar.

#### R99-EXPLORATORY RESEARCH

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## SOUND

### S01-TRANSDUCERS

The mission of research in this field is to investigate means for generating underwater sound, for converting sound to electrical power, and for realizing desired directional and frequency response characteristics in sound sources and receivers.

Active projects include the study and development of piezoelectric, magnetostriction, and electromagnetic transducers. A large percentage of current effort is in the development of suitable transducing elements for use in large plane arrays for high-level directional radiation at 5 kc. Substantial effort is being directed toward the development of light-weight transducers for experimental helicopter-borne sonar. Electrical beam steering for tactical applications is being studied.

Experimental work is planned on an end-fire line projector for use at frequencies of about 1 kc.

### S02-PROPAGATION

The interaction between sound and the media in which it is propagated is investigated over a wide range of frequency and intensity. The dependence of such interaction on temperature, temperature gradient, salinity, and depth and boundaries of the ocean is determined. Ambient noise in the ocean and ships' self-noise are studied.

Emphasis is currently placed on studies of sound in the frequency range of one to five kilocycles per second in order to obtain information on propagation paths and losses at boundaries that will be directly applicable to systems feasibility studies. Reflection from bottom sediment is being measured. The effect of pressures up to 10,000 psi on sound velocity in sea water is being determined with special interferometers. Laboratory studies of cavitation and absorption in sea water are planned.

The ray theory of sound propagation has been shown to be adequate for the conditions usually encountered in the ocean. Its basic simplicity permits its extension to account for transient spacial distribution and leakage by surface reflection from surface-bounded ducts. Accumulated and new data are being processed, using the new method.

### S03-HARBOR, FLEET BASE, COASTLINE DEFENSE

Application of sonar techniques to the protection of stationary installations is studied. Methods of giving positive warning of the approach of sneak craft and underwater missiles are investigated, with emphasis on the use of bottom-mounted, remotely controlled sonar.

A system for localizing noise sources and indicating their location on a map concurrently with the sounding of an alarm is being devised. Some applications of the graphic indicator to the problem are being followed.

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#### S04-HIGH-RESOLUTION SONAR

The factors that affect the resolution of small objects are determined and analyzed. These factors include the frequency, pulse length, beamwidth, scanning technique, and manner of data presentation characteristic of the equipment as well as the reflection characteristics of mines and harbor bottoms.

A high-resolution sonar developed at this Laboratory makes use of a sector-scan indicator for scanning within the sound beam. This makes possible a high resolution in azimuth when the mine echo is predominant. Adjustable pulse length is provided in the neighborhood of one millisecond pulses. A wide range of frequency, 16 to 100 kc is available. The use of this equipment for the determination of reverberation levels, echo levels, and penetration of muddy bottoms is planned. Optimum frequency under a variety of conditions may be determined. The effectiveness of the beam-scanning technique utilized will be assessed.

#### S05-RECORDING AND REPRODUCTION

Recording the reproduction of sound are studied with a view to improving fidelity, dynamic range, and frequency limits. Recording processes and media are investigated and recording equipments for special applications developed. High-quality recording facilities support research and equipment development. Auxiliary facilities, for standardizing the measurement of airborne sound and noise, are applied in problems of sound control in compartments.

Emphasis in equipment development is currently placed on the adaptation of special magnetic-tape recorders to signal processing.

#### S06-SONAR ELECTRONICS

Signals and backgrounds encountered in underwater sound work are analyzed. The application of electrical networks to processing these signals, and the presentation of the signals to human operators for interpretation are studied. Information theory, and computer techniques are applied to the detection of targets and to the interpretation of target characteristics and maneuvers.

Work under this program includes the analysis of sonar signals and backgrounds under a variety of conditions to determine what types of electronic processing are most effective for target detection and classification. The effects of data processing and display characteristics on operator performance are determined. Target-detection systems, using visual data presentation, which have provided a significant improvement over existing equipments in both detection range and target information rate, are being further improved.

New analysis techniques using electronic computing equipment are being applied to recorded sonar data; new display techniques for matching the information contained in sonar signals to the human aural and visual senses are being studied and tested; and the results of this research are being used in the design of target-detection equipments both for making optimum use of operators and for automatically indicating the presence of a target.

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**S07-SONAR SYSTEMS**

Systems for all sonar carriers are studied to extend detection range, to improve classification, identification, and target resolution, and to obtain more precise tracking and attack information. Systems are tested at sea to obtain scientific data which are correlated with theory.

Experimental 10-kc equipment has extended maximum range several fold in the past two years. Research at 5 kc, currently under way, is aimed at a significant increase in range and marked improvement in dependability. Use of the acoustic path via the bottom in deep water is sought using a towed transducer.

Target classification is being studied, the approach being to determine distinguishing characteristics of submerged targets and wakes. The graphic indicator, the sector-scan indicator, and the frequency analyzer, all developed at NRL in the past several years, appear to have applications to the problem and are being exploited.

An over-all sonar system for search and attack is embodied in an equipment for small vessels utilizing a small towed body and an automatic alarm. This system is now installed in a ship.

The possibilities of determining range rate with the graphic indicator and target aspect with the SSI are being studied with the objective of improving both the accuracy and immediacy of attack information.

The incorporation of broadband SSI circuitry into listening equipment for added sensitivity and improved display is currently directed toward utilization of a frequency band from one to nine kilocycles.

A preliminary study will investigate the factors involved in utilizing the frequency characteristics of sound attenuation in the sea to obtain range information passively at great distances.

**S99-EXPLORATORY RESEARCH**

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GENERAL SCIENCE

P01-MEDICAL SCIENCES

Adaptations of techniques devised under other elements of the Laboratory program are investigated as they relate to medical studies growing out of continuing work in ultrasonics, radio frequency, microwaves, electronic pulses, vacuum tubes, optics, radioactive tracers, and psychology. The techniques as adapted are concerned with medical diagnosis, therapy, dosage control, and the determination of physical performance characteristics of human beings.

P02-CRYOGENICS

A program of fundamental research on the properties of materials at temperatures approaching absolute zero is being undertaken. The research is planned to increase not only theoretical interpretation and understanding of the physical properties of materials but also to produce handbook data needed in the development of low temperature applications. Applied research in cryogenics primarily concerns study of possible uses in detection and instrumentation of the modified physical properties at low temperatures of metals, dielectrics and semiconductors.

Measurements of thermal and mechanical constants are being conducted with primary interest in the behavior of metals and alloys. Diamagnetism and electrical conductivity phenomena in conductors and semiconductors are being studied in intense magnetic fields and at microwave frequencies. Investigation of the superconducting state continues with special emphasis on the intermediate state where discovery of an anomalous behavior gives promise for better interpretation of the role of free electrons in the thermal conductivity of metals.

P03-CERAMICS

It is the purpose of the program to exploit the properties of ceramic materials for naval use. This includes the study of the preparation, mechanism of formation, and properties of glassy and polycrystalline materials, with emphasis on the fabrication of ceramic bodies for special electrical and magnetic purposes and for heat and corrosion resistance.

Most of the work has been concerned with barium titanate for underwater sound transducers and with ferrites. Greatly improved fabrication techniques have been developed and current efforts are concerned with necessary improvements in the raw material. Electro-mechanical performance characteristics essential to transducer use are being explored.

With titanate work nearing completion other ferroelectric ceramics, nonlinear dielectrics and ferrites will receive additional emphasis as well as work on fundamental solid-state reactions and sintering. Particular attention will be paid to high-temperature applications.

P04-HEAT POWER

Heat power devices are investigated, with particular emphasis on the pulse-jet engine. Experiments are directed at a better understanding of the advantages and disadvantages

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of this type of engine, and at improvement of characteristics such as fuel economy, service life, and thrust-drag ratio.

Engine forms suitable for helicopters and for mounting in multiples are being studied. A new design capable of static operation without an auxiliary air supply and having no moving parts is under development. Small engines of long service life are being adapted to use in smoke generators.

Studies to reduce drag and increase thrust at the higher speeds by such means as phase control in multiple units and by ducting will continue.

#### P05-METEOROLOGY

Under this program, research and development are conducted on new or improved methods and instruments for observing and interpreting phenomena of the lower atmosphere with the objective of reducing meteorological hazards to military operation. The current effort includes work on new methods for measuring, telemetering and recording the meteorological parameters (temperature, humidity, pressure, wind velocity, etc.) as a function of time and position of sensors placed on the ground, in aircraft, aboard ship and on balloons. Emphasis is placed on accuracy and operational simplicity in the measurement and recording of true values of these parameters in any atmosphere and at any subsonic velocity of the sensor. For example, true air temperature is now measured by the vortex thermometer with an accuracy of  $\pm 0.3^{\circ}\text{C}$  on aircraft moving with a velocity of 400 knots. Future work will attempt to extend this accuracy into the transonic range of velocities. Current studies to determine an interpretation and the value of meteorological data obtained by constant level balloons will be continued.

#### P06-UPPER ATMOSPHERE

Studies of phenomena of the upper atmosphere are carried out through the use of rockets, balloons, and other similar vehicles which aid in the development and use of necessary instrumentation.

The program investigates: (1) pressures, densities, temperatures, and winds; (2) measurements of ozone and oxygen dissociation; (3) solar radiations; (4) electron and ion densities, and collision frequency in the ionosphere; (5) heights and intensities of various wavelengths in the night airglow; (6) cosmic-ray composition; (7) the earth's magnetic field with techniques employing ionospheric current sheets; (8) photography at high altitudes as afforded by flights of rockets, and with results that are applicable to atmospheric, weather, and military research.

#### P07-PHOTON AND PARTICLE COUNTERS

Research and development work is conducted on Geiger, crystal, proportional, and ion chamber counters with interest in the counting characteristics of gaseous mixtures, low-voltage counters, high-efficiency and directional gamma-ray counters, proportional alpha-particle counters, scintillation counters and photon counters. Past research under this program led to the development of all of the standard Geiger tubes now used in navy radiac devices. Prototype models of radiac devices using pulsed, instead of steady dc voltages to the tube are in production. Emphasis is currently given to photon counters sensitive to narrow-wavelength bands of the short ultraviolet spectrum. The counters were originally developed under this program.

## P08-ELECTRON MICROSCOPY, X-RAY AND ELECTRON DIFFRACTION

The electron microscope provides a means for the study of pigments, catalysts, colloids, smokes, corrosion films, and other surface structures. Currently, an extensive electron microscope investigation of the surface structure of steel is in progress in conjunction with the ASTM with the purpose of standardizing techniques and procedures. Miscellaneous investigations of a wide variety of materials are made from time to time in support of other programs.

X-ray diffraction is applied to fundamental investigations of the crystalline state and chemical composition of materials, the effects of temperature and stress on phases in alloys, and, in X-ray fluorescence analysis, to the determination of chemical composition of materials. The first X-ray diffraction studies of materials under tensile stress at high temperatures were made under this program, and the use of the reflection-type bent crystal spectrometer in X-ray spectrochemical analysis was brought to practicability and has spread widely into industrial applications. Continued improvements and applications of the method are the aims of the current program.

Electron diffraction is a tool for examining the detailed geometric arrangements and motions of atoms as they occur in crystals and vaporous molecules. Currently, it is being applied to the study of the structure and internal motions of molecules such as formic acid and hexachlorethane to learn more of hydrogen bridging, and of diatomic molecules to learn the nature of the forces between atoms and the electron distributions in bonded atoms as related to chemical valence theory. A new algebraic and statistical treatment of the crystal structure problem was successfully tested on the naphthalene structure and offers hope for the future solution of highly complex structures such as proteins and antibiotics.

## P09-CRYSTALS

Investigations are conducted for exploiting the properties of nonmetallic crystals for naval use. This includes the study of the growth mechanisms and properties of such crystals, the development of improved materials for existing applications and the exploration of various solid-state phenomena for possible new applications with emphasis on dielectrics and semiconductors.

Studies in physics now include dielectric, piezoelectric, and electro-optic phenomena in ferroelectrics and radiation effects and emissive phenomena in dielectrics and semiconductors. An integrated study of the optical and electrical properties of semiconductors is aimed at the development of both photoconductive infrared detectors and electronic components. Paralleling the physics program is research on crystal growth mechanisms and imperfections.

The applied research program will be directed toward whichever crystal devices represent the greatest need including such things as display tubes, energy-detecting devices, and special electric components.

## P10-APPLIED MATHEMATICS

This program is devoted to the development of mathematical methods for extending the applicability of existing physical theories and the creation of new ones. Most effort is devoted to the fields of continuum mechanics, dynamics of complex structures, electrodynamics, and some statistical problems.

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Past work accomplishments have contributed to the theories of continuum mechanics, dislocations, dynamics of finite systems, fluid dynamics, and structural vibrations. Present work is devoted to visco-elastic materials, plasticity, ultrasonic absorption, armoring, and the mechanics of finite systems. A high-speed digital computer is nearing completion and a rapid all-electronic analog multiplier is under development. It is expected that these studies will be emphasized for some time to come.

#### **P11-LUMINESCENT MATERIALS**

The conduct of fundamental research on luminescence and tenebrescence contributes to the program which also seeks to develop new luminescent and tenebrescent material; apply such materials to new uses.

Experimental and theoretical researches have clarified important problems regarding the absorption, transport, transfer, and emission of energy in phosphors; the energy levels and configuration coordinates of phosphor systems; and electron trapping centers in luminescent and tenebrescent materials. A new system of gamma-ray dosimetry has been developed using radiophotoluminescent materials. This system has been adopted for field use by the Navy and the Air Force. New tenebrescent materials have been developed for dosimetry by color changes.

Studies of phosphors at low temperatures and of photochemical changes induced in solids by high-energy radiations are expected to result in further advances along the above lines.

#### **P99-EXPLORATORY RESEARCH**

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CYBERNETICS

Y01-SYSTEMS ANALYSIS AND SYNTHESIS

Analytical techniques are developed to investigate quantitatively the operation of naval information handling and control systems and to establish effective methods for predicting the performance of such systems in tactical situations. It is the aim of the program to apply these methods and techniques toward the design and improvement of specific naval systems.

Activity is proceeding along three general lines: (1) development of generalized symbolic models of selected information handling and control systems; (2) investigation of machine coding procedures for mathematical models and machine aids to organize and process information pertinent for developing useful descriptions of complex systems; and (3) isolation, analysis, and experimental investigation of selected subsystems.

Y02-ORGANIZATION OF PERSONNEL IN INFORMATION PROCESSING SYSTEMS

The mission is to investigate methods and establish principles for organizing information processing systems to obtain effective communication arrangements and associated procedures, readily adaptable to changing situations, and to measure the effect of communication structure modifications on systems output.

Work is proceeding along two main lines. The first is the use of functional simulation in the development of principles for efficient information handling in filtering operations, and for studying the characteristics of the information required in tactical evaluation and decision making. The second involves experimental analysis of the sociometric structure and procedures used in problem solving situations.

Y03-SYSTEMS FUNCTIONAL DESIGN AND ENGINEERING

It is the purpose of the program to translate the results of systems analysis and organization studies into functional design and layout of command and control spaces for specific applications. Guidance is furnished on tactical and operational matters to other groups working in the systems field. NRL personnel act as consultants to the Bureaus and Offices of the Navy Department on systems matters.

Specific effort has been devoted to the preparation of reports on: (1) the instrumentation and manning of control spaces in command ships (ACC and CBC), (2) the improvement of interior communications in CVA conversions, and (3) the development of an instrumentation manual of command and control systems in the CLC-1.

Y04-HUMAN TRANSMISSION PROPERTIES

The aim of studies in human response is to quantize man's behavior in terms of bandwidth, transmission characteristics, transfer functions, time constants, and other such concepts of the engineering and physical sciences.

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Bandpass limits for human transformation of step function information into action have been established, and effects of self-pacing versus external pacing determined. Gain versus frequency is being measured. Translation of information into decisions is being studied.

### Y05-MACHINE DISPLAYS AND CONTROLS

The purpose of the program is to conduct research on and participate in the development of: (1) improved modes of displaying information to the human operator, and (2) control arrangements which permit optimum "impedance matching" between the man and the machine he operates.

Display-control compatibility is being further investigated. Application of results of this study are being made to the gunfire control system Mark 63, and to manual diving control for submarines, with very promising results. Similar applications to surface ships and aircraft are under study.

### Y06-HUMAN ENGINEERING OF OPERATIONAL EQUIPMENTS

Operating tasks are analyzed as they are posed by specific surveillance, guidance, and control devices currently under development in the various bureaus of the Navy. The program assists engineers in designing the displays, controls, and operating stations of such equipments. As manpower becomes available, work is continuing on various weapons control systems and air traffic control systems.

### Y07-PSYCHOPHYSICS

Research is conducted on the capabilities and limitations of the human eye, ear, and other sense organs with particular attention to those aspects of sensation and perception related to the operation of man-machine systems. The influence of body posture upon speed and direction of motion in the "autokinetic phenomenon" is being investigated.

### Y99-EXPLORATORY RESEARCH

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## SPECIAL SERVICE FUNCTIONS

### K01-RDB SHOCK AND VIBRATION CENTRALIZING ACTIVITY

Many basic scientific investigations are being conducted in the field of shock and vibration as it relates to technological weapons and the military vehicles that carry them. In 1949 the Research and Development Board established a Centralizing Activity to serve technical personnel of the Army, Navy, Air Force, and their contractors, working in the field of shock and vibration.

For the past six years NRL has coordinated this interchange of information and has devised methods for channeling related current knowledge to all workers in the field. Planned conferences and symposia have been employed to disseminate the information. Policies are set by the Interservice Agenda Committee, composed of Army, Navy, and Air Force representatives. The subject for a particular symposium is selected by a nationwide survey to determine the most urgent shock and vibration problems which need study. Benefits of the series of symposia are extended and consolidated through the publication and distribution of a Bulletin.

The Activity renders advice, provides consultation, and responds to requests from Government Agencies for recommendations with respect to new test facilities, contemplated research projects, and measurement techniques. Because the Activity has become well-recognized as a center for information on all phases of shock and vibration, its recommendations help to eliminate duplication of effort and blind alley investigations.

### K02-HARBOR DEFENSE INFORMATION AGENCY

Established by a request of CNO early in 1951, the Harbor Defense Information Agency acts as technical and scientific consultant to the Office of Naval Research in matters relating to harbor defense. It seeks ways of coordinating and integrating information on the various technical aspects of the problem, and takes steps to disseminate current knowledge for the over-all program.

The Information Agency publishes the Harbor Defense and Countermeasures Bulletin, and distributes it to authorized activities and individuals needing the information. The articles in the Bulletin are written by invited specialists in the fields of magnetism, sonar, radar, mines, torpedoes, nets, etc. Six Bulletins, as well as a Digest of Harbor Defense Bulletins have been published. The 7th Bulletin is now in the process of assembly. A report on the progress of NATO harbor defenses was written in October 1952.

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