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AIR FORCE RESEARCH OBJECTIVES

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AIR FORCE RESEARCH OBJECTIVES

OFFICE OF AEROSPACE RESEARCH
UNITED STATES AIR FORCE, WASHINGTON, D. C.

DON R. OSTRANDER, MAJOR GENERAL, UNITED STATES AIR FORCE

FOREWORD

This description of Air Force research objectives is designed to provide you with as current and complete a list of our areas of interest as we are presently able to foresee them.

We offer this information because we want to stimulate your interest in Air Force research problems, encourage you to participate in our program, and solicit your cooperation in an exchange of information in areas of mutual concern.

The Office of Aerospace Research conducts or sponsors scientific research for the United States Air Force. Our role in the development of superior aerospace systems is vital, for only through research can we gain knowledge of scientific principles upon which are based all technological improvements and inventions. Therefore, your participation in our research activities will be a definite contribution to the general furtherance of science in the Western World.

Perhaps the most important question we can pose has not been included in this listing of our problems: "What do we need to know tomorrow?"

As you consider the following objectives, you may want to look beyond our stated areas of interest and propose an answer to this question. We will welcome suggestions for including research objectives we have not recognized or for redefining problems we have not fully identified.

When changes in our objectives occur, we will incorporate them in future editions of this publication.

Don R. Ostrander

DON R. OSTRANDER
Major General, USAF
Commander

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INTRODUCTION

The responsibility of the Office of Aerospace Research is to conduct, within its own laboratories, and to sponsor, through its grants and contracts program, scientific research and some exploratory development for the United States Air Force.

In carrying out this responsibility, the Office of Aerospace Research (OAR) operates well-equipped and expertly-manned laboratories and field sites, under the direction of Air Force scientists who are engaged in those areas of research most likely to contribute to the continued technological growth of the Air Force. It also draws upon the scientific talent of the free world, through its sponsorship of studies (in areas of Air Force interests) by leading scientists in colleges, universities, nonprofit and industrial organizations, and through contracts in support of existing Air Force research.

As used in this brochure, the term "research program" includes all research activities designed to contribute to our total reservoir of knowledge in the physical sciences, mathematical sciences, environmental sciences, biological and medical sciences, and the psychological and social sciences which have broad, general application to Air Force technology. This is essentially a program of basic research in these five major areas. As a means of differentiation, the term "exploratory development program" is used to describe efforts to solve specific military problems short of major development projects. In this sense, OAR has responsibility over two areas of exploratory development: environment and aerospace environment. Both are integral parts of our program.

To maintain close association with the scientists and research laboratories in the free world, not only to encourage the best talents and facilities to participate in the Air Force research program but to assure the maximum impact of science on Air Force technology, we have prepared this brochure. It is designed to acquaint the members of the scientific community with those areas of science which are of paramount interest to the Air Force. We hope, too, that Air Force scientists, engineers, and managers, as well as those in other military and federal research agencies, will find *Air Force Research Objectives* a clear statement of our goals and the scope of our program.

RESEARCH PROPOSALS

Direct grants and contracts supported by the Office of Aerospace Research are selected on the basis of the originality and caliber of the research to be accomplished, the competence of the investigator, the adequacy of the proposer's facilities, and the relevance of the proposed research to Air Force interests. At times, we will invite research proposals in certain areas in which we feel there is a need for more studies.

We suggest, before you submit a formal proposal, that you investigate the interests of several Air Force agencies and that you discuss with them your ideas—and theirs. The best way to inform the appropriate Office of Aerospace Research element of your interests is by letter or by informal conference. An elaborate presentation is not necessary. The proposal can best be presented by the scientist who will do the work. The purpose of this preliminary contact is to spare the time and expense of a detailed, formal proposal until such time as your interests and ours have been thoroughly explored. You will then be in a better position to determine the specific proposal to present and to whom it should be submitted.

An informal proposal should contain a description of the research to be undertaken, its objective, its relation to existing knowledge and comparable research already in progress, and previous work performed in the field by the proposer and the organization for which he works. It should outline the approach to be taken, the equipment to be used, and should include an estimate of the time and total cost of the investigation. Of great interest to the Office of Aerospace Research is information about the investigator himself, his previous experience, and the percentage of his time he will devote to the investigation.

To enable you to relate the various areas of research described in the body of this pamphlet with the appropriate elements of the Office of Aerospace Research, we provide the following description of each element and the areas of science in which they sponsor or conduct research.

OAR ORGANIZATION

The Office of Aerospace Research was established as a major command on 1 April 1961, as part of a general reorganization of Air Force research and development activities that saw the creation of the Air Force Systems Command (AFSC).

It is composed of ten subordinate units, four of which are major research organizations, four are research supporting units and two are field liaison offices. The four major research organizations are the Air Force Office of Scientific Research (AFOSR), the Air Force Cambridge Research Laboratories (AFCRL), the Aerospace Research Laboratories (ARL), and The Frank J. Seiler Research Laboratory (FJSRL). The research supporting organizations are the European Office of Aerospace Research (EOAR), the Latin American Office of Aerospace Research (LAOAR), the Churchill Research Range (CRR), and the Office of Research Analyses (ORA). The two field liaison offices are the Patrick Field Office at the Air Force Missile Test Center and the Los Angeles Office of Aerospace Research.

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

The Air Force Office of Scientific Research, located in Washington, D. C., is charged with the sole mission of procuring and administering contracts and grants with outstanding scientists and research institutions of the national and international scientific communities. It is responsible for contributing to the stockpile of knowledge which will form the basis for developing aerospace systems of the future. In performing its unique function, the AFOSR supports a broad spectrum of research in almost all the scientific fields within the physical sciences, the psychological and social sciences, the mathematical sciences, the environmental sciences and the biological sciences.

AEROSPACE RESEARCH LABORATORIES

The Aerospace Research Laboratories, at Wright-Patterson Air Force Base, Ohio, form a major Air Force in-house research facility in the physical and mathematical sciences, including general physics; nuclear, atomic and molecular physics; gaseous and plasma physics; solid state; general chemistry; physical chemistry; fluid dynamics; flight mechanics; mechanics of solids and energetics; and theoretical and applied mathematics. Although the primary function of the Aerospace Research Laboratories is to conduct research within its own laboratories, contractual research is employed in support of research being carried out by ARL scientists.

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES

The Air Force Cambridge Research Laboratories, located at L. G. Hanscom Field, Massachusetts, make up the leading Air Force center for research in the environmental and physical sciences. This large facility, employing about 1100 people, of which about 600 are scientific personnel, combines a large and varied in-house research program with a vigorous contractual program of research in the broad areas of electronics and geophysics. The Air Force Cambridge Research Laboratories conduct and sponsor a diversity of research and exploratory development programs throughout the free world. In addition, it maintains many field sites for work in communications, propagation, weather observation, and radar and radio astronomy. Among these are the Sacramento Peak Observatory at Sunspot, New Mexico, and the Balloon Instrumentation Branch at Holloman Air Force Base, New Mexico.

The Air Force Cambridge Research Laboratories conduct and sponsor research in the physical sciences, primarily radio physics, gaseous and plasma physics, solid state electronics, and quantum electronics; all of the environmental sciences; and the mathematical sciences, primarily applied mathematics and information studies. It also performs exploratory development programs in environment and the aerospace environment. Both programs, research and exploratory development, are vital contributors to the over-all OAR program.

THE FRANK J. SEILER RESEARCH LABORATORY

The Frank J. Seiler Research Laboratory, at the United States Air Force Academy, Colorado Springs, Colorado, is an in-house research facility in the physical sciences, primarily general chemistry, physical chemistry, fluid dynamics and flight mechanics. Because of its unique location, the Seiler Research Laboratory is able to draw upon the research talents of Air Force Academy faculty members and outstanding cadets to supplement work conducted by OAR scientists.

THE EUROPEAN OFFICE OF AEROSPACE RESEARCH

The European Office of Aerospace Research in Brussels, Belgium, extends research support by grant and contract to scientific communities of Free Europe, the Middle East and Africa. The office provides a contact for European research scientists and a United States Air Force capability to identify unique research abilities abroad. The European Office is manned by Air Force scientists experienced in Air Force Exploratory Development and Research Programs. Unique projects are referred to Air Force and Department of Defense Research Agencies when supported projects are administered by the European Office.

CHURCHILL RESEARCH RANGE

The Churchill Research Range at Fort Churchill, Canada, is managed by the Office of Aerospace Research to provide a high latitude research rocket launch capability. Range facilities are used by Canadian research agencies, the Department of Defense and the National Aeronautics and Space Agency. Churchill Research Range, this country's only high latitude research rocket firing facility, is vital to studies requiring data on auroral effect and polar magnetic fields.

LATIN AMERICAN OFFICE OF AEROSPACE RESEARCH

The Latin American Office of Aerospace Research extends Air Force grant and contract support of unique research capability to Central and South American countries. Located in Rio De Janeiro, Brazil, it is a part of the Defense Research Office for Latin America. Representation assures recognition of research effort applicable to Air Force research objectives.

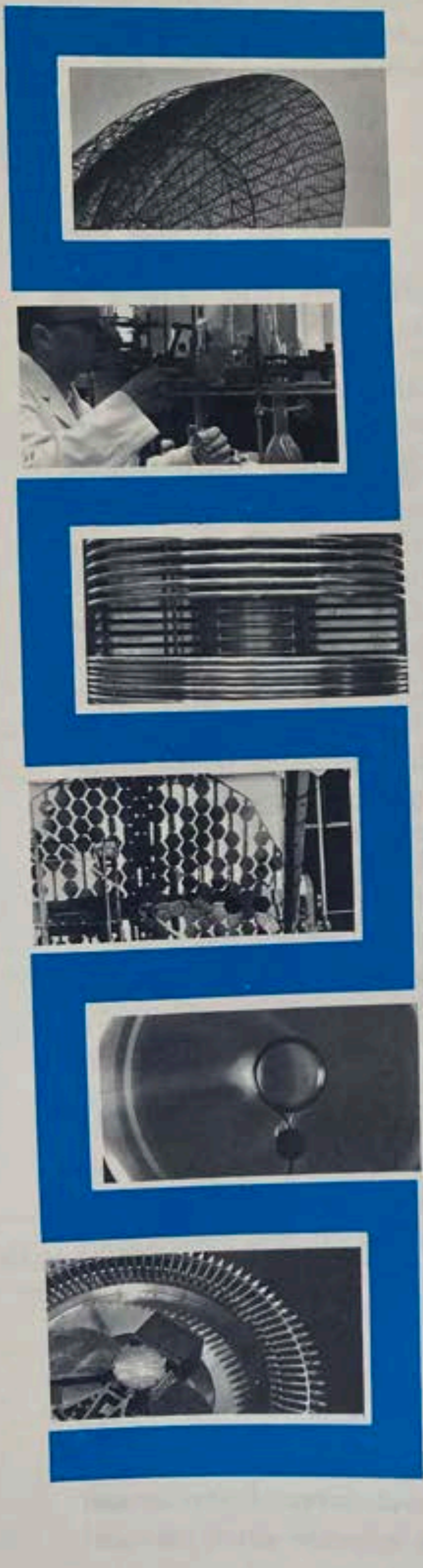
OFFICE OF RESEARCH ANALYSES

The Office of Research Analyses is located at Holloman Air Force Base, New Mexico. It evaluates future Air Force systems and provides consultant services to Air Force research and planning organizations. Studies involve future defense systems, their vulnerability, initial cost and cost of operation. The Office of Research Analyses is instrumental in the initial decision to develop a missile weapon system to operational capability.

AIR FORCE SYSTEMS COMMAND LABORATORIES

Several elements of the Air Force Systems Command conduct and monitor a portion of the Research Program for the Office of Aerospace Research. Studies are in fields related to these Air Force laboratories' primary exploratory development mission. The laboratories involved include elements of the Air Proving Ground Center, Eglin Air Force Base, Florida, and the Arnold Air Development Center, Tullahoma, Tennessee. Also participating are the Air Force Materials Laboratory and the Electronic Technology Laboratory (Wright-Patterson AFB, Ohio), the Rome Air Development Center (Griffiss AFB, New York) and the Air Force Weapons Laboratory (Kirtland AFB, New Mexico), all elements of the Research and Technology Division of AFSC, as well as the 6570th Aerospace Medical Research Laboratory (Wright-Patterson AFB, Ohio) of the Aerospace Medical Division of the Air Force Systems Command.

RESEARCH OBJECTIVES



PHYSICAL SCIENCES

Physical Sciences research includes theoretical and experimental studies in areas of physics, chemistry, mechanics, dynamics, and energetics. The purpose of this research is to accelerate effective use of new concepts in structures, propulsion, command and control communications, guidance and surveillance.

GENERAL PHYSICS

The objective of this portion of the USAF research effort is to increase the understanding of physical phenomena, processes and theories by means of experimental and theoretical investigations.

THEORETICAL PHYSICS

Extensive investigations are needed to establish a generalized theory describing transport phenomena in liquids. Such effort will involve study of boundary problems to obtain solutions which include effects of viscosity variation with pressure and the transmission of sound, heat and electromagnetic energies into and through fluids. Extension to nonequilibrium situations and processes, including irreversible thermodynamics and turbulence is the goal. These studies are closely related to experimental investigations being conducted in low temperature physics. The approach to a theory for irreversible thermodynamics and turbulence is being made from two directions. Theoretical efforts involve studies of the behavior of liquid helium at low temperatures and near the lambda phase transition point (about two degrees above absolute zero). Such efforts approach the problem from essentially a quantum mechanical viewpoint. Studies of the characteristics of normal fluids use classical thermodynamics and statistical mechanical descriptions to approach the same conditions. Several of the present efforts are devoted to developing a quantum statistical or a differential space quantum theory. The aim is to combine these two approaches for a direct attack on the problem. Current theoretical approaches include efforts to understand reversible processes more fully and to describe more adequately conditions leading to phase transitions in all materials. It is expected that considerable research will be performed in this area over the next few years.

Investigations of the theory of fields need to be expanded into gravitational and electromagnetic fields. Here the major area is gravitational field theory, including both classical and quantum. Questions related to transformation groups, conservation laws, invariants, and properties of gravitational radiation will be examined. Problems related to the introduction of a quantum theory of gravitation on the theory of fundamental particles are treated. Supplementary to the over-all theoretical research, evaluation of experiments may lead to verification of the theoretical structure; for example, time differential comparisons between satellite and earth-based clocks. Because of the general fundamental nature of field theory in describing all physical processes, advances in understanding have a wide ultimate application to all areas of physics and chemistry. Results of the work may uncover phenomena that influence astrodynamical and astrophysical efforts, particularly for long-range, later-time-era mission conducted at high velocities.

In addition, investigations of Lorentz invariant quantum field theories are needed, with particular emphasis placed on a study of the nonlinear Yang-Mills theory. The idea of using it as a simplified model for studying the problems related to this quantization of the gravitation field has merit. Also, the approach can be extended to include the quantum theory of measurement.

ACOUSTICS

A modest effort is under way to develop and refine theories relating the physical and thermodynamic properties of substances to the velocity and dispersion of ultrasound. This effort consists of studies in rarefied diatomic gases, liquids, and solids. An expansion of this effort will be necessary to develop general theories of non-equilibrium and irreversible thermodynamics, and solutions to the many-body problems. It is hoped that theoretical advances will justify an expansion of experimental efforts.

OPTICS

Research efforts in optics are directed toward investigations in optical communications, modulation and demodulation of light beams, optical wave guides and diffraction, coherence, polarization, and geometrical optics. It is expected that the recent rapid growth in this field will level off but there will be continued interest in optics research, primarily in support of new investigations.

LOW TEMPERATURE PHYSICS

Helium, in the liquid phase and within a few degrees of absolute zero, ceases to behave like ordinary fluids. In fact, the viscosity decreases so much that it is often called a superfluid. Certain mathematical models have been developed. From this it has been necessary to postulate the existence of elementary packets or quanta of energy called the phonon or roton. Now the validity of the theoretical model has to be established by experiment and other questions raised by earlier experiment must be resolved. A related problem concerns development of a single mathematical description that accounts for both superconductive and superfluid phenomena.

NUCLEAR, ATOMIC AND MOLECULAR PHYSICS

This type of research has an underlying significance to many areas of Air Force application, ranging from nuclear propulsion to atmospheric physics. With better theoretical and experimental knowledge of atomic functions, better prediction can be made in such areas as communications, lasers, weapons phenomena, and re-entry vehicle surface reaction. In the area of nuclear physics, the ultimate interest of the Air Force remains in the use (for many purposes) of the tremendous energy stored in the nucleus. The research objective is to generate new knowledge and thus accelerate the progress of Air Force exploratory development and advanced development programs.

ELEMENTARY PARTICLE PHYSICS

Bubble chamber research in elementary particle physics (dealing with the energy of the nucleus) deals with relatively new resonances and with mesons and their interactions. Since experiments in general analysis have been accomplished for the most part, future emphasis will be placed on more detailed analysis, a search for all possible interaction or reaction modes. Modes occurring at very low frequencies will require longer accelerator exposure times (weeks rather than days) and additional orders of magnitude of pictures will be required (millions rather than thousands). To use this wealth of information in such a large number of pictures, automation of the processing and analysis appears to be mandatory.

To provide a point of departure for determining the direction of further work in quantum electrodynamics, a colliding beam experiment is being made on one Bev linear accelerator. A one Bev energy is supplied in the center of mass of the colliding electrons which becomes a crucial test of quantum electrodynamics. To further these investigations, a two-mile linear accelerator is being built at Stanford University.

Finally, there is a growing interest in neutrino experiments now that a neutrino beam of usable intensity appears feasible. It is expected that increased support will be available to exploit this avenue of investigation, heretofore unavailable.

FIELD THEORY

Field theory in nuclear physics research is concerned with the complexities of elementary particle physics and related gravitational effects. Precise calculations are required in order to explain observed phenomena. This, in turn, requires more computer time. Projected increases in this area are based primarily on computer costs and a modest increase in the number of investigations. However, the majority of the investigations will be theoretical, rather than experimental.

NUCLEAR STRUCTURE PHYSICS

The area of nuclear structure physics consists of studies of energy levels, the properties of these levels (such as spin and parity), decay schemes, scattering, angular correlation, and the formulation of models of the nucleus. These studies are both theoretical and experimental, and are designed to increase our knowledge of the structure of matter. As Air Force operations expand into interplanetary space, the natural shields provided by the earth's atmsophere and magnetic field will be lost and must be replaced by other man-made shields. The more that is known about the fundamental constitution of matter, i.e., nuclear structure, the sooner the shielding problem will be overcome.

There will be continued support of both theoretical and experimental studies in nuclear structure, with about 50% of the funds going into each effort. This will, in effect, increase the ratio of the number of theoretical investigations to experiments. In the theoretical portion of the program, additional support will be placed on such topics as the foundation of scattering theory, the application of perturbation theory to the shell model of the nucleus, the optical model of the nucleus, and the many-body problem. In the experimental area, we plan to support mainly "user" groups, i.e., groups that make use of accelerators with or without paying for the exposure time, but which are not involved in the administration and operation of the facility.

ATOMIC AND MOLECULAR PHYSICS

With the improvement in, and the increased availability of, high speed computers, more detailed theoretical calculations are possible in atomic and molecular physics. An example is the detailed study of magnetism—a phenomenon which has proved extremely deceptive to theoretical researchers. Also, cross sections for the collisions of electrons, ions, atoms, and molecules are presently being studied in great detail. More work along these lines is planned to understand collision effects in the upper atmosphere, solar phenomena, and gaseous discharge. Present difficulties in attempts to inject ion beams into various plasma devices are largely the result of lack of data on low-energy charge-exchange cross sections. Efforts are now underway to improve calculations on atomic structure, and to calculate elastic and inelastic cross sections for the scattering of electrons by hydrogen.

Experimental efforts are being initiated to measure the properties of free atoms, such as nuclear spin, electronic angular momentum, nuclear and electronic magnetic moments, nuclear quadrupole moments, and hyperfine structure constants. These data are needed to test atomic and nuclear theories and to aid nuclear spectroscopy studies.

RADIO PHYSICS

Radio physics covers electromagnetic processes and interactions involved in the radio frequency range. It includes communications theory, electromagnetic interaction, electronic properties of materials, and the interaction and use of plasmas in radio communications. The Air Force objective is to acquire efficient use of the radio spectrum and to expand our knowledge of the principles which govern more sophisticated application of this knowledge.

MICROWAVE PHYSICS

Microwave physics investigations include work on such techniques as geometric and spatial network analysis. Geometric-analytic methods will be applied to plasma waves and signal transformations in noise and space networks. Spatial network analysis will determine fields of sources in nonlinear plasmas and phonon interactions. Magnon-phonon and two-magnon interactions will be studied, and means sought to avoid Suhl instabilities.

Data on microwave scattering by regular bodies needs to be compiled in handbook form. In addition, a new technique for the asymptotic treatment of truncated regular and diversely irregular bodies must be developed.

Emphasis on the electronic properties of materials will include ferroelectric research, paramagnetic resonance measurements for determining lattice dynamics, studies of materials with combined ferroelectric and ferrimagnetic properties, and investigation by neutron diffraction of the atomic arrangement of magnetic moments.

New methods will be investigated for extracting maximum information from microwave and light beams by means of amplitude and intensity interferometers. The connections between coherence theory and quantum electrodynamics will also be explored.

COMMUNICATION THEORY

New coding theories and concepts are needed to achieve more efficient processing, transmission, and reception of information. We will make intensive efforts to find new ways of limiting error rates in a communication channel without appreciably reducing rates of information transmission or requiring prohibitively complex equipment. Detailed study of known codes, invention of new codes, and new decoding techniques will be emphasized. Optimum mean square predictors for Gaussian processes of partially constrained spectrum, performance bounds on nonlinear controllers, and design for other criteria such as minimum probability of decision error will be sought. This theoretical work will provide backup for experimental communications research. The mechanisms of human speech production and perception are inadequately understood. Future speech research investigations will include voicing description, development of measurement capabilities, description and explanation of the pitch perception process, speech perception, the relation between these phenomena, and the phonetic and linguistic structure of speech signals.

ELECTROMAGNETICS AND ELECTRON PHYSICS

With the discovery of the laser, which permits generation of coherent radiation in the visible and infrared portions of the electromagnetic spectrum, use of the entire electromagnetic spectrum for practical and military purposes has come close to reality. The ability to produce coherent radiation in useful quantities for research in the submillimeter wavelength region will close the only remaining known gap in the electromagnetic spectrum.

Current research in electron physics employs combined electric and magnetic static fields for such purposes as energy level selection, magnetic sublevel selection, and spin orientation. Current isotopic and quantum level investigations will continue.

GASEOUS AND PLASMA PHYSICS

Gaseous physics research is aimed at uncovering information concerning the physical and electronic properties of matter in the gaseous state under varying degrees of purity, pressure, temperature, density, and excitation. Current studies in plasma acceleration and thermalization will be carried to higher energy levels. The great potential of plasma physics in areas of hypersonic fluid dynamics, propulsion, electromagnetic propagation, and many phases of space travel, has resulted in an urgent need for accelerated study of plasmas. This is particularly true of partially ionized gases. OAR will sponsor research on plasma dynamics to achieve an understanding of the physical processes associated with various plasma states. The knowledge obtained may be applied to planetary radiation belts, interplanetary regions, and electronic components.

ELECTRIC ARCS

High power propulsion of the magnetohydrodynamic type is based on the understanding of high density plasmas. Ignition tubes in radar systems are based on plasma arc technology. Rotational symmetric boundary conditions can be provided by a swirl of sufficiently high angular velocity. However, certain peculiar instabilities have been observed which invite further investigation. The aim of the investigation is a complete theory of vortex stabilization as opposed to wall stabilization and electrode stabilization of electrical discharges. The experimental facts are to be obtained by aerodynamic, electric, and spectroscopic measurements, the latter yielding information on the temperature profiles of the discharge.

The vortex localized arc, due to the absence of metallic walls, lends itself to further heating by high current pulsing. A plasma of very high energy density results, which permits a study of the phenomena associated with the extreme temperatures. Transient operation, dictated by the lack of a suitable method of containment, creates problems for the experimental instrumentation as well as for the correct interpretation of experimental results. The necessity for expansion into the vacuum ultraviolet can be foreseen in the future.

HIGH ENERGY ELECTRIC DISCHARGES

Most phenomena in high energy electric discharges are of very short duration; therefore, a very fast shutter is necessary to record the transient processes. Photoelectronic image converter diodes operating with pulsed voltages are being used as high speed shutters, but a complete analysis of the diode's operating characteristics does not exist at present. In particular, it has not yet been proved that the image appearing on the fluorescent screen of the tube is a true reproduction of the picture projected onto the cathode at the instant of the very short applied operating-voltage pulse. The recording of the complete time history of a very fast light trace, as seen by the diode as it actually takes place, will point out the limitations of the image diode as a recording device. These studies are related to areas such as lightning and fusion research and have wide application.

LOW DENSITY PLASMA

To better understand the attenuation of RF waves in plasmas, investigations of long range interaction forces and related phenomena in low density plasmas need to be made. Some present work in this area is aimed at determining the oscillatory state of a stationary cloud of electron plasma with thermal velocity distribution, through which a low energy monoenergetic particle stream with known initial velocity will be passed. The effects of the stationary cloud on velocity distribution of the stream are to be studied. Other work is aimed at exciting and measuring propagation characteristics of longitudinal electrostatic waves in an ionized medium. Accurate measurement of their frequency versus wave number relationships can, in principle, give knowledge of plasma density, electron temperatures, and the moments of the distribution function of the electrons.

PROBE MEASUREMENTS

Langmuir probe measurements are important in giving spatial resolutions of plasma properties. OAR plans to use experimental methods based on the Druyvestyn analysis of energy distributions to extend the use of double probes. The goal is to obtain the first derivative of the current-voltage curve rapidly and without distortion by noise. The second derivative will be obtained using a special computer circuit, which does not accentuate high-frequency response. The simplicity and rapidity of the measurements offer considerable advantages as a diagnostic technique.

THEORETICAL STUDIES

Because of inherent complexities, theoretical studies of collision processes are limited mainly to hydrogen-like atoms. Even in these instances, accurate calculations are only possible for the simplest of collisions. Therefore, the most immediate and reliable data can be expected from experimental studies that may form a fruitful basis for theoretical calculations. Specifically, OAR plans to investigate electron and ion differential and total scattering cross sections. Emphasis will be on the thermal energy range, electron attachment rates and cross sections at low pressures, and thermalization rates of electrons, including those produced by x-rays. The possibilities of further work include radiation attachment, photodissociation, and photodetachment cross sections.

PLASMA INTERACTION

The interaction of an ion or an electron beam with a plasma and the resulting effects on the beam velocity are not well understood at present. A complete study of plasma waves, their modes of instability and methods of producing stable plasmas at various temperatures, is needed.

Companion studies in ionospheric and interplanetary plasma phenomena at radio and microwave frequencies are under way and will be enhanced by an ionospheric observatory now under construction. This facility will be assigned a large portion of the support in this area because of the potential for exact surveys of plasma constituents, energy distribution, and related phenomena of interest.

Complementary theoretical programs are underway on motion description of charged particles in a slowly varying magnetic field, and related problems of charged particle quantum electrodynamics.

SOLID STATE

Our objectives in solid state studies include the determination of properties and characteristics of materials, and the discovery of techniques for controlling material properties. Determining material structures and understanding the effects of many widely varying natural and induced environments are inherent in the two general objectives noted. Advances in electronic materials technology, such as transistors and masers, can be expected to continue with further research. Other classes of materials, such as CdS thin film solar cells, offer prospects of great significance.

GENERAL SOLID STATE EFFORTS

Solid state research is involved in the synthesis and preparation of ultrapure materials, their growth and their characterization in single crystal form. A fundamental goal is to devise new concepts based on physical phenomena exhibited in both bulk and surface form. An important aspect is the effect of diverse environments such as pressure, temperature, and particulate radiation exhibited by these materials.

There will be intensive investigations of physical and structural perfection of large boules and many types of electronically or optically active crystals grown in the new OAR crystal physics facility. Use of the new linear accelerator and radiation physics facilities, combined with the existing radiation source (3 Mev Van de Graff, 1.2 Mev Dynamatron, 7.2 kilocurie cobalt-60 source) will provide capabilities for concentrated and comprehensive programs on the alteration of basic properties of materials by energetic radiation.

Studies in connection with deliberate or natural irradiation of materials are essential if we are to understand: (1) the exchange of energy between the incident radiation and the atoms of the solid, (2) the dissipation of absorbed energy within a crystalline matrix, and (3) the formation of complex defects. Clarification of the radiation effects process is dependent upon definitive experimental data, such as threshold energy of displacement, the displacement cascade process, and the interaction of defects. Investigation of radiation damage is to be emphasized.

We will conduct studies on reactions and reaction kinetics of matter with highly excited species produced by the interaction of high energy ionizing radiation, both particulate and electromagnetic. This area includes the effects of state on reactions, energy transfer mechanisms and reaction kinetics. The extension of radiation chemistry to structural chemistry is also possible and will be considered for future efforts. Another facet of OAR solid state research is aimed at determining the fundamental nature of semiconductors and, in particular, of compounds prepared from Group II-

Group VI elements of the periodic table. Investigations devoted to cadmium sulfide have led to the development of some very practical applications of this material to problems of considerable interest to the Air Force; e.g., the solar battery. A more intensive study of several of the other II-VI compounds is contemplated over the next five years, to include the use of electron bombardment to make tailored changes in grown crystalline structures. In addition, studies will be made to identify property changes with specific defects bombardment by a one MEV Van de Graff and 250 KEV Cockroft-Walton accelerator.

Further investigations are to be conducted toward improving purity and the lattice perfection of materials by chemical techniques, some refining, distillation, and other applicable techniques. The mass spectrograph (sensitive to almost all types of impurities) will be used to supplement other analytical techniques.

Energy transport research on CdS and ZnS at different temperatures will include theoretical and experimental investigations to assign photo current diffusion coefficients, cyclotron resonance, and polarization. Research on the growth of compound semiconductor crystals in several different forms such as whisker, platelet and bulk will be continued.

Optical and electrical property research on semiconductor materials under high hydrostatic pressures will elucidate details of the energy-band structure of crystals. Studies will be conducted on crystal fields and exchange interactions (by means of electron paramagnetic resonance) to detect paramagnetic impurities in undoped crystals. In addition, studies of internal fields in purposely doped crystals will provide information about the fundamental nature of materials.

Cryogenics and magneto-optics research will be initiated to investigate material properties to temperatures as low as 0.01°K, and to investigate optical properties of materials at low temperature as well as in high magnetic fields.

Additional theoretical solid state research on a particle density formula for one dimensional fermion system will be extended to the three-dimensional case and applied to the derivation of fundamental properties of atoms and single crystals. When the theoretical work on HE III is completed, investigations will be extended to other unit solids with particular emphasis on the study of effects of many-body forces.

GROWTH OF SOLIDS

Increased emphasis will be placed on the growth of solids. Support of new studies designed to increase our knowledge of the detailed mechanisms of nucleation and growth processes; the techniques of purification; the mechanics of impurity segregation; impurity density and distribution; techniques for forming precise compounds; and the origin and generation of structural imperfections will be initiated. Along with these studies, new techniques of crystal growth will be investigated. Highly successful growth techniques for elemental materials are inadequate for even the simplest compounds. High pressure and temperature environments, previously unavailable, will be used in attempts to prepare highly perfect known materials and to synthesize new materials. Studies of more radical approaches to crystal growth, chemical decomposition, ultrahigh pressure growth, arc imaging, and flash evaporation are planned.

Increased emphasis will be given to sophisticated measurements during the crystal growth process. In addition, more quantitative evaluations will be made of imperfections in crystal aftergrowth by x-ray spectroscopy, optical absorption, electron microscopy, electron diffraction and electron paramagnetic resonance techniques. It is anticipated that experimental investigations will be initiated on improved infrared and Raman spectral measurements at various temperature ranges for selected materials in connection with analytical studies in lattice vibration dynamics. Studies are planned on the properties of matter in the 3000-4000°K range, using thermal imaging techniques and thermal sources.

Ultrapurification and analysis form an important aspect of current research on the influence of minute amounts of impurities on the properties and performances of materials. Investigations of techniques for preparing and analyzing ultrapure materials and characterizing defects in solids will be continued. Analytical techniques will be improved to the extent of detecting and identifying impurities of a few parts per billion. Mass spectroscopy, emission spectroscopy, and new methods of activation analysis will be among the techniques emphasized.

ELECTRONIC PROPERTIES OF SOLIDS

Electronic properties of insulators, semiconductors and metals are to be studied. Increased support will be given to investigations of electron behavior in metals including electron velocities, densities, and studies leading to the determination of the Fermi surface. Such investigations should be extended to the study of impurity and phonon scattering of the conduction electrons and the influence of deformation on the conduction mechanisms involved.

Emphasis in the study of insulators will be given to details of color center formation by methods of irradiation, x-ray, and thermal treatment. Additional studies will be conducted on impurity centers, excitons, photoconductivity, and luminescent behavior. Defect generation will be investigated by study of movement dislocation and its influence on electrolytic conductivity.

Semiconductor research will investigate the details of band structures in various types of compounds, impurity conduction processes and thermoelectric behavior. Newer semiconductor materials (such as metal oxides) will receive increased attention and support.

In solid state electronics, emphasis is shifting toward investigations of new forms of active devices that appear to offer increased possibilities for radically extending frequency response and overcoming environmental limitations of present bipolar transistors. Research will continue on the phenomena, theory, and experimental techniques involved in fabricating and quantitatively evaluating new types of power gain and conversion devices. This research includes devices using materials in the polycrystalline, amorphous, glassy state, and in the single crystal state. It also includes films and fibers as well as boules of material.

Laser research will aim at correlating measurable material and optical parameters. Future studies will be directed toward defining the fine structure of laser output and investigating the properties of solid and gaseous materials having the potential for increasing laser outputs.

SURFACE AND INTERNAL REACTIONS IN SOLIDS

Differing reactions of materials to similar environments may be directly related to adjacent layers of bulk material, or imperfections terminating in the surfaces. Efforts will be increased to investigate properties during interactions with selected environments, the nature of the altered surface, the passage of contaminants through surface layers, and changes in bulk properties as a result of surface changes.

Similarly, internal reactions which affect the characteristic behavior of materials will also receive increased emphasis and support. The formation of separate and distinct phases within an existing material as a result of external or internal influences will be studied to learn details of the processes involved. The transport of material within the solid and the interaction of energy which is able to penetrate, react to and alter material characteristics will also be of increasing concern to OAR investigators.

THEORY OF SOLIDS

Research support in the theory of solids includes pioneering studies in the theory of ionic crystals and simple solids, free-electron theory of metals and semiconductors, collective modes and the many-body approach, cohesive energy in metals, ionic and molecular crystals, work function and surface barrier, and excited electronic states.

MATERIAL MECHANICS

Research will be expanded on the synthesis of a wide variety of highly purified substances, and substances of carefully controlled and known composition. High temperature thermochemistry, free energies, and specific heats will be studied to improve understanding of limitations or the usage of refractory materials. Mechanistic studies of the nature of flow and fracture, including investigations of ductile fracture, ductile-brittle transitions, conchoidal fractures, kinetics and energetics of crack propagation, and creep impurity must be expanded. Additional studies in electrochemistry and casting techniques are contemplated. Studies of strengthening processes, with emphasis on clustering, vacancy effects, and defect structure related to composition, are required.

CHARACTERIZATION OF MATERIALS

Methods of characterizing materials or changes in materials produced by extreme environments are needed. Efforts to determine electrical and magnetic material properties and the microstructure of liquids and noncrystalline solids are to be included. More stable sources for emission and absorption spectroscopy, as well as a better understanding of ionization and excitation processes in arcs and gaseous discharges, and electron bombardment phenomena are necessary to achieve gains in the sensitivity and precision of mass spectroscopy. Radio frequency spectroscopy, nuclear quadrupole resonance and molecular stark effects are inherently capable of giving information on molecular structure not obtainable through other means. Optical spectroscopy measurements of absolute intensities are needed.

We will investigate the electrical and magnetic properties of solid solution alloys and intermetallic compounds of rare earths and transition metals, including spontaneous magnetization, magnetocrystalline anisotropy constants, and hysteresis properties. The properties of vapor deposited ferromagnetic thin films will also be studied. The magnetic behavior and the domain structure of ferro- and ferri-magnetic fine particles in the multidomain, single domain, and superparamagnetic regions will be investigated both experimentally and theoretically.

In superconductivity, extensive studies are needed on the transitions of normal conductors to the superconducting state in search for materials with higher transition temperatures, critical magnetic fields and current densities. Additional investigation of fundamental thermodynamic properties of solids, liquids, and gases at very low and very high temperatures will be pursued.

METALLURGY AND CERAMICS

It has become increasingly obvious in recent years that the presence of defects within a crystal lattice may be the determining factor in the transport properties of materials, particularly ceramics. Basic studies of the mechanisms by which each of the transport properties is affected by intentional changes in the defect structure, of the stability and compatibilities of crystal structures, and of the effects of microstructure on both physical and mechanical properties, should lead to the control and improvement of the engineering properties of ceramic materials.

In metallurgy, the two current areas of interest are deformation and fracture, and high temperature thermochemistry. Thermochemical investigations will continue to use electrochemical techniques to study the thermodynamic properties of selected alloy systems. This basic knowledge is important to studies of re-entry and high speed vehicles which react with atmospheres and are weight limited. In addition, it is desirable to expand thermochemical investigations to include a study of the chemistry of the purification of metals and the reactions in liquid metallic systems. The study of carbon and oxygen content of matter will be continued.

Studies on deformation and fracture will be concernd with detailed microscopic and macroscopic analyses of dislocation mobilities and interactions in iron at low temperatures, with the anomalous elastic behavior of chromium, with the deformation associated with the advancement of a moving fatigue crack, and with the processes responsible for the stopping of fatigue crack propagation at the fatigue limit.

The dependence of defect structure on transport properties is an area of considerable interest. The possible gradients of defect concentration and effective charge below the surface of an insulator, producing anomalous conductivity and diffusion effects, and the vibration frequencies and energies for movement of point defects are being studied by precise measurement of dielectric properties as a function of temperature, frequency, and composition. Other studies include charge and atom movements, and conduction and diffusion in ionic crystals.

In the search for materials with a promising potential for high temperature applications, studies of the effects associated with crystal structure and characteristics of polycrystalline bodies must be extended. In addition to extending these studies, preliminary investigations of the fabrication and properties of bicrystals have suggested the feasibility of studying the effects of grain boundaries on some of the physical and mechanical properties of polycrystalline ceramics. These studies on electrical properties are of considerable importance in high temperature behavior of ceramics (where insulator leakage increases) and ultimately in areas such as batteries and cells for vehicle use.

STRUCTURE OF MATTER

High magnetic fields form a valuable probe for investigating the innermost details of the structure in matter. The provision of external fields comparable with the atomic fields offers a uniquely powerful way of studying internal fields themselves, as well as extending the range of magnetically related phenomena. The National Magnet Laboratory at MIT is a large magnetic facility (up to 250 kilogauss) for fundamental investigations in solid state, low temperature, and related areas. This includes extension of cyclotron resonance measurements to the millimeter and infrared ranges, magneto-optic experiments (including Faraday effects), magneto-absorption, Zeeman effects, magnetic resonance experiments in ferro-, antiferro-, and ferri-magnetic materials, and many others. The facility is available to any research group for fundamental investigations.

GENERAL CHEMISTRY

Included in investigations under general chemistry are efforts in analytical, inorganic and organic chemistry. Research objectives under the heading of general chemistry are to gain understanding of the formation of molecules of organic and inorganic compounds, and to clarify the mechanics, kinetics, and energies of reactions. Also sought are processes for making particular compounds and materials having prescribed properties.

ANALYTICAL CHEMISTRY

New analytical techniques, methods, instruments, and tools are needed for the conception, formulation, production, and possible use in space-age materials and propellants. Nuclear magnetic resonance spectroscopy, optical rotary dispersion, chromatography, scanning spectrometry, and mass spectrometry are techniques that will have continued importance in future investigations. Efforts will be made to use masers and lasers as analytical tools for photochemical and high-temperature sources. New x-ray tools, coupled with computers, are techniques requiring further development for studying heavy element and isomorphous substitutions, and for analyzing structures of protein cells and nucleic acids. High-pressure chemistry and the Mossbauer effect will be included in future efforts of analytical chemistry. These new techniques will be used to provide new knowledge on fast reactions, chemical bonds and structure, and new materials.

In addition, investigations in analytical and inorganic chemistry will concentrate on volatile metal coordination compounds, and will encompass (1) synthesis, (2) gas chromatography, (3) physical properties, (4) analytical chemistry, (5) reaction mechanisms, (6) stereochemistry, (7) bonding, and (8) chemical properties. Volatile compounds open up a new field dealing with such applications as ultrapurification of metals, vapor phase metal coatings at low temperatures, and preparation of very pure compounds for use in semiconductors. Techniques are needed for separation of optical isomers and element isotopes.

Other classes of metal coordination compounds should be investigated to determine if gas chromatography techniques can replace, or at least supplement, existing techniques in micro- and trace analysis.

The preparation of unique, new analogs of the ligands coordinated to a metal atom is an area needing further investigation. The active groups of these ligands are stably bonded to the metal atom and protected from undesired reactions. The ligand can thus be induced to react at the less reactive unprotected sites. The removal of the new ligand from the metal affords a new approach to the synthesis of new compounds which cannot be obtained by existing techniques.

By studying metal coordination compounds in the gaseous phase, we are seeking a new means of determining reaction mechanisms and steric factors influencing them. This type of investigation cannot be satisfactorily accomplished in solution or in the solid state. The separation of geometrical and optical isomers of metal coordination compounds by gas chromatographic techniques has met with partial success. A more intensive study of this technique should afford a greater insight into the bonding and stereochemistry of these molecules. A study of the electronic density about the rings of the metal coordination compounds will afford a measure of their aromaticity and render possible a prediction of the kinds of chemical reactions they will undergo.

INORGANIC CHEMISTRY

Refractory metals and alloys, intermetallic compounds, oxides, nitrides, halides, borides, silicides, carbides, semiconducting and superconducting compounds, magnetics, dielectrics, and many others (in both stoichiometric and nonstoichiometric compositions) are items of interest to OAR. Future research will include chemical factors which influence the nature of matter.

Solid state studies of the properties and nature of solid materials will include studies of matter in other states that are designed to elucidate the chemical principles which determine the behavior of solids. Stereochemical requirements of the various oxidation states of the metals involved, and the detailed electronic nature of bonds formed by these metals should be determined.

The conversion of stored chemical energy to useful forms requires basic knowledge in areas where little exists. The mechanisms of reactions of inorganic substances, the detailed nature of significant electrochemical processes, and the principles of behavior of high temperature solvent systems will be emphasized. The nature and behavior of inorganic species in nonaqueous media is an area of research that will be encouraged.

Spectroscopy, used in understanding the ultraviolet spectra of inorganic substances, is providing valuable information for inorganic chemistry. Efforts in surface chemistry, catalysis, interfacial films, corrosion of metals, ablation phenomena, and surface recombination of gaseous atoms, will be gradually increased.

ORGANIC CHEMISTRY

Investigations in the chemistry of silicon and aromatic groups in organic molecules and of certain long-neglected simple nitrogen compounds are progressing. The thermally stable compounds are of considerable interest for high temperature applications in fluids and lubricants. Organic chemical reactions related to life processes are of interest for the mechanisms of information transfer in molecules. These mechanisms would offer a potentially high efficiency system through a reduction in size and energy consumption as compared to present computers. The initial work in this area involving either energy or information transfer between enzymatic systems or isolated cell systems will probably be done by organic (or physical) chemists with predilections towards biochemistry.

Organic chemistry is also concerned with organometallics, syntheses, and new ideas concerning bonding. Various compounds with a surplus of electrons will be studied such as benzyne chemistry, nonbenzenoid aromatic systems, and cyclobutadiene to increase the understanding of chemical bonds.

Investigations in structural chemistry, particularly conformational chemistry to learn how molecules are put together are to be continued. Stereochemistry of organotin compounds, structural studies of polymers, ionic organic species, carbonium, and carbon ions as well as interactions between phosphorous and silicon, and reactive free radicals are areas of interest for future studies. Photochemical and radiochemical studies in the mechanisms, kinetics, and total energetics of reactions are required.

Another important area deals with organic chemical reactions at very high pressures. These reactions are expected to be extremely rapid and may even require the formulation of a new set of chemical laws to apply under these conditions.

Increased emphasis will be given to investigations on rheological properties of macromolecules, new ideas on the role of intermediates in electron-seeking types of substitutions, better understanding of the factors effecting the properties of small ring compounds (such as cyclopropane), effect of high temperatures on the stability, and decomposition of organic materials.

In addition, we will emphasize research on new synthetic approaches to macromolecules of particular structural arrangement, such as regularly repeating space-oriented units, and/or repeating units of particularly novel composition.

Our specific areas of interest are (1) transition metal complex monomers and polymers of the ferrocene type, (2) organometallic polymers containing silicon, germanium, tin and lead, (3) inorganic monomers and polymers possessing novel chemical bonding, such as sulfur-nitrogen and aluminum-phosphorus, and (4) compounds to provide desirable chemical intermediates for unique monomer and polymer synthesis. High precision techniques for the analysis and characterization of pure materials on basic structure-property relationships will be directed toward insoluble and infusible three-dimensional, network-type macromolecules.

Other specific areas for future study include (1) properties of polymers at high temperatures, (2) quantitative mechanical, and (3) chemical property-molecule structure relationships in viscoelastic compounds under extreme environments.

PHYSICAL CHEMISTRY

The research objectives in physical chemistry are (1) an explanation of the effects of molecular structure of various forms of energy fluxes, ionizing radiations being of particular interest, and (2) an understanding of energy transfer mechanisms. Other items desired include theories of material properties and descriptions of transport phenomena in diffusion processes.

INTERACTION CHEMISTRY

A fundamental problem in physical chemistry is an understanding of the interactions between various forms of energy and the molecules in various forms of matter. Chemical reactions caused by shock waves are beginning to be studied intensively. The production of unexpected chemical changes originated by intense sound fields that cause deterioration of materials or interference with biochemical processes will be studied. Cryogenic capabilities, precise control, and instrumentation over extremes are needed. With such capabilities our studies in high temperature thermodynamics, thermal transfer mechanisms, and other phenomena would be enhanced.

Theoretical approaches to properties of materials, based on quantum chemistry, irreversible thermodynamics, and other mathematical and computer techniques will require investigations to determine the nature of chemical bonds, whether metallic, covalent, or electrovalent. Molecule orbital theory is fundamental to the understanding of energy transfers and needs expanding. A study of quantum mechanical descriptions of processes involving interactions of polyatomic molecules has resulted in the reduction of a number of equations to forms suitable for machine computation. This is expected to permit more accurate determinations of bonding energies of linear three- and four-atom molecules.

PROPULSION CHEMISTRY

Investigations in propulsion chemistry directed toward the attainment of a fundamental understanding of chemical and physical processes in high temperature gases are to be continued. Theoretical and experimental studies should be undertaken to elucidate basic mechanisms of combustion reactions, flame propagation, detonation, the nature of the coupling between chemical reactions and gas dynamic effects in flowing gases, and energy transfers in reacting gas systems. These mechanistic investigations should be complemented by research on the chemistry of high energy compounds, and the high temperature kinetics of selected gas reactions. Theoretical and experimental investigations of the mechanisms and kinetics of flame propagation and detonation, microstructure of flames, high pressure combustion phenomena, ionization in flames, kinetics of solid state chemical reactions, collision and transport processes in high temperature gases, and applications of the theory of irreversible processes are to be continued. These investigations should provide the fundamental knowledge leading to new approaches to Air Force problems in high energy propellants, heat transfer from high temperature gases and chemical influences on hypersonic flow phenomena.

Research in molecular energy exchanges will be conducted on luminescence and photochemistry of complex aromatic systems. Experiments in energy transfer include: (1) the quenching of fluorescence in a large number of aromatics (comparing lifetimes of excited singlet states obtained in this manner with lifetimes measured directly by the phase-shift method), (2) the measurement of energy transfer for the second singlet state of aromatics, (3) the measurement of low temperature absorption spectra in rigid media, and (4) the gas-phase photolysis of molecules which can be selectively excited to triplet levels. Potential uses of the ever present sunlight for space vehicle systems depends on improved understanding of energy conversion mechanisms in photosensitive molecules.

Research in flame chemistry is being diminished in favor of increased emphasis on the kinetics of strong detonation waves. Of primary interest is the development of techniques for measuring translational temperatures behind detonation waves and the measurement of vibrational temperatures behind detonation fronts. Studies are to be made of the combustion of binary fuel systems in both the constant pressure bomb and the flame temperature burner in an endeavor to explain burning velocities in such mixtures in terms of reaction kinetics. The studies will include intermolecular forces, energy exchange mechanisms and transport properties in reacting gases. Research on the decomposition of hydrazine in shock waves will be extended to explore the influence of oxygen or decomposition reactions.

DIFFUSION CHEMISTRY

Research in diffusion chemistry is of practical interest due to the potential development of methods for ultrapurification of mtaerials for use in nuclear reactors and in semiconductors. Further development of the theory of liquids is the key for making useful engineering predictions of the macroscopic properties of fluids as a function of temperatures and pressure. Experimental measurement of various transport coefficients (particularly Soret coefficients and isothermal diffusion coefficients) of a variety of pure liquids and binary solutions are to be continued. However, attention should be paid to the application of methods of irreversible thermodynamics as a supplement to the kinetic interpretation of experimental data.

RADIATION CHEMISTRY

Radiation chemistry investigations will define (in terms of kinetic rate) constants for several elementary chemical reactions of the highly excited species present in the radiology of simple systems. This information may be pertinent not only to the present research area but also to such problems as chemistry of the upper atmosphere, photochemistry in the vacuum ultraviolet, energy conversion, and aerodynamic phenomena. Required experiments in this area include the sensitized radiolysis of deuterium-labeled hydrocarbons and alcohol, radiolysis of propane gas at extremely low conversion, studies in flash photolysis, and studies of charge exchange and ion-molecule reactions.

ELECTRONICS

The electronics program includes research in solid state electronics, electromagnetic propagation, plasma processes, and ion bombardment. Research objectives include the determination and manipulation of electronic properties of solids, thin films, and extended filaments, the extension of network theory, and the determination of the characteristics of sputtering processes.

CLASSICAL ELECTRONICS

Classical electronics encompasses the areas of solid state electronics and electromagnetic wave sciences. Attention will be focused on the microwave, plasma, and ionized gas dynamic phenomena. Expanded capabilities will be sought to allow for increases in the limits of temperature, humidity, pressure, and radiation. An expansion of the useable frequency spectrum will be sought for many Air Force uses.

Research will be concentrated on network and circuit theory, and on electromagnetic interactions. Accurate determination of the physical and electronic properties of films will be required for studying tunnel emission phenomena and anomalies associated with epitaxial growth. Studies of the theoretical mechanism of thin film growth on substrates with vastly different atomic spacing, together with studies of single crystal film growth on amorphous substrates are necessary. In the solid state area, other than thin films, measurements of the specific heats and magnetic properties of various materials, both superconducting and non-superconducting, are needed.

PHYSICAL ELECTRONICS

Research will be conducted on low temperature plasmas with efforts to correlate measurements with theory. Diagnosis of the microscopic properties of plasmas by probe will be included. Apparatus that will produce controllable monoenergetic ion beams properly collimated for high density ion bombardment must be developed for conducting this research. In addition, velocity distributions of sputtered atoms must be studied to correlate existing sputtering theories with space probe data on nose cone ablation.

QUANTUM ELECTRONICS

The quantum electronics research program is intrinsically involved with stimulated emissions, inverted population distributions, absorption and emission processes, and light amplification through stimulated emission of radiation. Therefore, quantum electronics is concerned with the study of an unstable ensemble of atomic or molecular particles which may be stimulated by electromagnetic waves to radiate excess energy at the same frequency and phase as the stimulating waves.

STIMULATED EMISSION

Methods for obtaining stimulated emission are to be investigated to acquire an understanding of basic principles involved. Fundamental studies of discrete energy levels have been undertaken where the upper level populations exceed those of lower level populations. Future investigations will attempt to determine luminescent phenomena in crystals where transitions between impurity states are important and where the conduction or valence bands are factors. Also, transition between energy levels split by electric fields requires additional investigation.

INVERTED POPULATION DISTRIBUTION

The study of inverted population distributions is necessary to provide knowledge and understanding of the means of pumping and exciting for stimulated emission. This requires study of problems associated with optical pumping sources, and in particular with those which are complex. New efforts should be devoted to chemical pumping and its associated concepts and principles. Electron beams for quantum electronic research will require increased emphasis.

ABSORPTION AND EMISSION PROCESSES

Absorption and emission processes involved in solids, especially crystalline solids, require further study. A detailed examination of the principles involved in anisotropic emission and absorption of optical radiation in crystalline solids is needed. Related to these efforts are the problems and effects produced by pressure and anisotropic strain on the energy of optical transitions in crystalline solids. Internal electric fields influence the energy levels of impurities in solids, and resulting effects must be determined to complement absorption and emission efforts.

LASERS

The study of lasers, or optical masers, and masers will center primarily on the problems associated with control, modulation, and spectroscopy. Control feedback in lasers is an area of study requiring additional emphasis. Fundamental to laser research is the acquisition of coupled coherent light sources and modulation at optical frequencies.

Additional research interest in lasers has centered about their use in the study of materials. The use of the laser as a tool for mass spectroscopy has merit. Research on focused beams of light capable of evaporating small regions of a solid specimen is of interest.

FLUID DYNAMICS

The objectives of research in fluid dynamics are to establish fluid flow principles and properties through concepts of conservation laws, flow analysis, flow simulation, and physical states.

CLASSICAL CONTINUUM FLUID DYNAMICS

Research in subsonic, supersonic, and hypersonic aerodynamics as well as shock wave and shock-shock interaction studies are to be continued. However, increased emphasis is needed on problems of the transonic phenomena associated with hypersonic flow and chemical reactions expected in extraterrestrial atmospheres. The obvious applications to all classes of flight vehicles are many and varied.

RAREFIED GAS DYNAMICS

Theoretical investigations to simulate (in low density tunnels) attainable conditions of rarefied gas dynamics are being continued. Research in arc jets and on controlling ionized boundary layers is under investigation. Efforts to learn more about the stability of high enthalpy arc discharges which have promise as future wind tunnel heaters are needed. In addition, the study of interactions between partially ionized boundary regions and externally generated magnetic fields could lead to means for controlling lift-drag ratios of hypersonic vehicles.

Investigations of the interaction of ionized gas flows with electric and magnetic fields (electrokinetic heating through MHD acceleration) will seek to determine (1) the motion of arc in magnetic fields at varying pressure and current levels; (2) effects of varying strength, geometry, and magnetic fields; (3) effects of changing arc lengths; and (4) influences of gas flow fields and wall effects.

Interactions will be investigated under acceleration of high pressure (1-10 atm) ionized gases with combined actions of electric and magnetic fields by varying (1) the geometry of electrodes and magnetic field, (2) electrode temperatures and materials, (3) ionization levels (seeding), and (4) gas pressure levels. Finally, the conditions for maximum energy addition to a gas stream by combined electrothermal and electrokinetic heating needs to be determined.

BOUNDARY LAYER EFFECTS

BLE studies include (1) the transition from laminar to turbulent flow, (2) flow separation and reattachment, (3) heat transfer to the wall, (4) skin friction, (5) shock wave-boundary layer interaction and, (6) real gas effects which influence these phenomena. An important problem for future study is the determination of the thermodynamic state of flow (whether it be in frozen, nonequilibrium, or equilibrium state), depending on the presence of chemical reactions. Reaction rates, relaxation times involved, and flow velocity are factors influencing future areas of interest. A growing problem is the determination of accomodation coefficients for both momentum and energy transfer to a wall under low density flow conditions.

TWO-PHASE FLOW

Two-phase flow phenomena efforts are keys to solutions of aeromechanics problems associated with gas and dust core reactors. These reactors hold promise for future applications in propulsion and power for aerospace vehicles. Droplet separator and aerodynamic containment problems require investigations into particle cross flow speeds in curved channels. The principal efforts should be guided along lines to determine similarity laws. Effects of free-steam turbulence, perturbations boundary layer, and secondary flows are factors to be investigated separately and in combination. Shock and expansion wave effects on the cross flow speed of the particles, related heat transfer problems, and separation and collection of particles merit continued investigation.

SEPARATED FLOWS

Some of the problems encountered at hypersonic speeds are concerned with drag, aerodynamic control, and heat reduction. There is evidence which suggests that a solution to these problems may lie in use of an aerodynamic spike to cause a separated region ahead of the body. Measurement of the effectiveness of spikes for control of bodies at hypersonic speeds is required.

Studies of (1) the patterns about bodies at hypersonic speeds, (2) interactions between shock waves and boundary layers, and (3) heat transfer measurement are to be continued. Experimental determination of the mechanisms of separation and separated flows is needed to analytically formulate and predict their effects on heat transfer and vehicle aerodynamics. Investigations of laminar boundary layer separation in the low Reynolds number range corresponding to atmospheric re-entry flight are required along with studies of flow and pressure fields about typical re-entry configurations.

SLENDER CONE FLOW

Work on slightly blunted, pitched, slender cones in hypersonic flow is to be continued, and measurements correlated with the theory of the surface pressures and heating rates. These are of great interest in connection with re-entry bodies. Depending upon the manner in which the data compare with theory and the experimental trends shown at lower Mach numbers, this work may be expanded. If possible, a comparison will be made between surface pressure data obtained on slender cones in uniform and nonuniform flow nozzles to verify semiempirical corrections now applied to the data obtained in the nonuniform nozzle. With these case studies, investigations of the flow near a corner in hypersonic flow, involving pressure surveys and surface heating rate measurements, are required.

The importance of advanced fluid flow machinery having high pressure ratio and high volume flow handling capabilities is recognized as essential for vertical take-off and landing vehicles, supersonic aircraft, cryogenic pumps, and many other applications. Research therefore is aimed at obtaining knowledge from curved and swirl flow pattern investigations. Cascade efforts will investigate boundary layers, shock wave-boundary interactions, and pseudo-shock phenomena in both rotating and stationary curved closely spaced passages. Likewise, studies of the effects of passage curvature, divergence, and convergence should be made along with wake studies behind blunt trailing edges. Similar studies of three-dimensional effects will be included. Swirl flows passing through radially outward and radially inward flow ducts should be studied to determine the total pressure recovery, flow field, and effects of axial lengths between ducts. Energy transfer within the fluid body under conditions of high supersonic swirl, as well as thrust developing nozzles will be included in the investigations. Several factors affecting or influencing the meridian flow field in swirl flows (geometry of chambers, contour, center bodies, exit ducts, and flow admission) need to be investigated.

SKIN FRICTION AND HEAT TRANSFER

At hypersonic speeds a major contributor to the drag of slender body vehicles is skin friction. If a way can be found to reduce skin friction, the lift to drag ratio of a vehicle can be substantially increased. Experimentally, it has been shown that at supersonic speeds transpiration cooling can reduce both skin friction and heat transfer. Other methods for reducing skin friction and heat transfer should be investigated and theoretical analysis made in order to predict the effects on other body configurations.

Power requirements and temperature levels of advanced propulsion systems, particularly those related to space vehicles and other high temperature designs, have brought on the need for a great deal of new knowledge in the field of heat transfer. Flow fluctuations, noise, turbulence, flow separation, acoustic disturbances, and high temperature can cause serious errors in design calculation and the need for costly corrections and time consuming trial and error experimentation. Therefore, the associated phenomena must be better understood.

INSTRUMENTATION AND SIMULATION

Present work on flow visualization at hypersonic Mach numbers by ionization will be continued to perfect this method as a usable tool for the Mach 12-18 range. Using this visualization technique, a study of wake flows can be made. It has been tentatively shown that at low-density high-Mach-number conditions, the wake is initially laminar and goes through a transition to turbulent flow. This item needs to be studied.

Investigation of the problems of achieving stabilized electric arcs under high pressures is to be continued. However the problems associated with electrothermal heaters for gases require additional parametric studies if compatible arrangements between electric arc and electrode surfaces are to be attained. Various electrode materials are to be tested while varying operating temperatures and the geometry of electrodes. Related efforts on cooling methods, magnetic arc-spot motion, effects of gas flow, and operating pressure level effects are needed. Mass and energy exchanges between arc discharge columns and the surrounding gas will require detailed investigation and analysis. Diagnostic tools and methods for the measurement of local and average heat transfer and the thermodynamic parameters should be determined as a part of these studies.

The study of test techniques to obtain hypervelocity flow conditions by the addition of thermal energy alone is limited by attainable flow rates. Consequently, other techniques are to be investigated to obtain required flow rates. Investigations of various

MHD accelerator techniques (and problems relating to them) will be given considerable emphasis.

Investigations of accelerators, using electrostatic acceleration with charge exchange neutralization, to obtain hypervelocity flow show promise. For high temperature flow, techniques to predict and to reduce the degree of nonequilibrium effects should be studied, including such things as the use of catalysts to enhance recombination. Theoretical and experimental studies to determine effects of testing in nonequilibrium free streams, and the effects of contaminants, such as catalysts and seeding materials from a MHD accelerator are needed.

FLIGHT MECHANICS

Research in flight mechanics is primarily aimed at acquiring an understanding of the principles and concepts required to study the motion of solid bodies through physical space. This includes the control of such motion. As such, our research is concentrated mainly in the areas of dynamic stability and control effectiveness. Obviously, an understanding of these subjects at all speeds, all altitudes, and under various operating conditions dictates that the mechanics be thoroughly studied and supported.

DYNAMIC STABILITY

Considerable experience in statically stabilized finless and spinless vehicle configurations at transonic and supersonic speeds has been obtained for various types of high drag shapes. Dynamic stability, however, is more difficult to obtain. It has been conjectured that dynamic stability at hypersonic velocities will be a critical problem area even for low drag (slender) shapes. In fact, the importance of dynamic stability on low drag re-entry vehicles has only recently been realized. Dynamic stability investigations to reduce severe weight penalties now encountered in the design of re-entry vehicles must be pursued.

Dynamic stability research towards future vehicle designs requires advanced facilities for accomplishment. For dynamic stability in the hypersonic range, there are indications that the damping derivatives vary with frequency not only in magnitude but in sign. Therefore care must be taken to simulate those frequencies which actually occur in flight and which may be lower than the reduced frequencies generally used in wind tunnels today.

CONTROL EFFECTIVENESS

With the advent of manned orbital flight, there exists a need for research in the field of control effectiveness at hypersonic speeds. Research to investigate re-entry vehicles having lifting surfaces equipped with various types of aerodynamic controls must be accomplished. The aerodynamic phenomenon which is believed to cause a loss in control effectiveness at hypersonic speeds requires further study. This phenomenon is believed to be the result of operating trailing edge control surfaces in a separated flow region coupled with the fact that re-entry takes place at altitudes where the density and the resulting control hinge moments are very low. In view of the fact that separated flow regions are a function of the local longitudinal pressure gradients, and of the vehicle and control configuration, both are to be investigated.

Both the fluid dynamic and aerothermodynamic phenomena will be investigated. Fluid dynamic problems will be studied by obtaining pressure and force measurements. The aerothermodynamic part of the problems will be investigated by using so-called "thin skin" heat transfer methods.

FREE FLIGHT CORRELATION

Free flight data should be correlated with tunnel data on new configurations, and new dynamic stability coefficients in the stable, no-lift attitudes must be obtained. Corrections to viscous interaction parameters and hypersonic relations of the wind tunnel data are necessary to permit comparison of the tunnel data with real in-flight conditions. Variations of static stability coefficients, lift, and drag of the bodies of interest over a wide range of Mach numbers, densities, real-gas variations, and angles of attack are to be correlated with tunnel data. Emphasis is being given to achieving velocities similar to portions of re-entry trajectories in the hypersonic range where viscous interaction effects become significant.

MECHANICS OF SOLIDS

Research in mechanics of solids has as its main objective the determination of an explanation for underlying physical mechanisms which control the behavior and response of solid media, including structures.

MECHANICS OF DEFORMABLE BODIES

Research in this area provides an insight into material response to mechanical and thermal stresses in both atmospheric and high vacuum environments. Areas under study include: elasticity, plasticity, elastic stability, wave propagation in solids, and plate and shell theory. In each area the effects of thermal stresses and high vacuum environments are considered. Studies can be oriented toward flight in exotic atmosphere and flight at ultra high speeds. Increased emphasis will be given to exploratory research necessary to provide techniques for advanced concepts in gasdynamics, aerophysics, and aerostructures.

Future research should concentrate more heavily on nonlinear approaches although modest efforts will continue in elasticity and viscoelasticity. Problems to be investigated will be primarily concerned with (1) all types of stresses, (2) various types of material and structural behavior, (3) wide ranges of propagation problems,

(4) most aspects of material properties, (5) responses of elements to dynamic phenomena, (6) methods of analysis, and (7) protection problems. Research is needed on fatigue, structural arrangements, thermal protection, radiation mechanisms, and damage assessment (particularly, solid mechanics problems which possess high potential to future aerospace structures). Studies of strength, stiffness, plasticity, elasticity, viscoelasticity, fatigue, and equations of state will be continued and will include the use of nonlinear relationships.

STRUCTURAL MECHANICS

Fundamental studies in structural research are contemplated to provide a better understanding of the mechanical behavior of structures and structural components suitable for flight vehicles. Modest analytical and experimental programs on limited areas of structures research, such as mechanics of crack propagation, mechanics of fatigue, stresses in heated structures, behavior of viscoelastic materials, multiaxial creep, theories of shell structures, hypervelocity impact, and effect of strain rate on strength are included in this research.

STRUCTURAL DYNAMICS

The response of structures, systems, and materials to impact, flutter and other dynamic loads will be studied. In addition, research on methods of analysis of elastic, thermoelastic, aeroelastic, and other structural systems is required. Investigations are aimed at determining fundamental principles of structural dynamics, vibration, stress and response with time varying force loads. These investigations should cover the protection of structures, materials and biological specimens under the influence of heating, radiation, impact, erosion and other flight hazards.

ENVIRONMENTAL EFFECTS

Studies in structural and material mechanics will be continued with particular concentration on the effects of elevated temperature, fatigue, fracture, redundant structures, and most important, hypervelocity impact. Hypervelocity impact investigations should look at (1) the long-term strength of metals, (2) hyperstrong particles, (3) electron diffusion impact effects, (4) empirical data for impact parameters, and (5) impacts on oblique, stressed, and special panels.

Theoretical concepts of the behavior of projectiles and targets involved in collisions at ultrahigh and cosmic velocity will ultimately consider all types of advanced aerospace structures, including stressed structures and a wide variety of projectiles both of natural and man-made origin.

ENERGETICS

The objectives in energetics research are to determine and explain the mechanisms for conversion, transfer and storage of many forms of energy, and the development of concepts for exploiting such knowledge. Increased emphasis on this area of research is expected.

FLUID DYNAMIC ENERGY CONVERSION

Fluid dynamic energy conversion research includes studies in free condensation phenomena of vapors in carrier gases, two-phase flow phenomena, supersonic cascade and swirl flows, and energy exchange phenomena. Research is to be expanded in (1) condensation delay and freezing, (2) supersaturation, (3) droplet growth, rise, and re-evaporization, and (4) viscous, seeding, and physical property effects. Methods for diagnosis and control of flows must be developed. Such investigations are expected to open new avenues to high performance, direct electrofluid dynamic power generators, thrust devices, and gas-core reactors.

SOLAR ENERGY CONVERSION

In solar energy conversion, the development of a better understanding of photochemical processes may lead to their use in storing solar energy as chemical binding energy, for direct conversion to useful work, and for photochemical synthesis of useful products. Efforts in photochemistry involve the studies of mechanisms of energy transfer and loss, reaction kinetics, photochemical sensitivity and efficiency, and reaction mechanisms.

Photocatalysis investigations may result in making a greater portion of the solar spectrum available for use. Research will include development and characterization of photocatalytic materials, studies of photosensitization mechanisms, mechanisms of energy transfer in both homogeneous and heterogeneous systems, the effects of structure on catalytic activity, and dye sensitization phenomena.

Photobiology research includes the investigations of detailed action mechanisms of photobiological catalysts, semiconductor behavior of biological and bio-organic materials, separation, purification, and crystallization of photobiological catalysts and their synthetic analogs, and the mechanisms of energy transfer in complex organic and biological systems. These studies may be expanded to include the chemistry of visual processes.

Photoelectricity investigations include studies of photovoltaic and photogalvanic cells, electron-transfer spectroscopy of ions and complexes in solution, determination of the chemical, physical, and electrical properties of photoexcited systems, energy-transfer mechanisms in semiconductor solids, and preparation and purification of photo-active materials. Particular emphasis will be placed on various classes of organic compounds.

HEAT ENERGY CONVERSION

The two most promising thermal processes for converting heat to electricity are thermionics and thermoelectrics. Studies in this field include the precise determination of material functions and their dependence on the nature of the emitting surface, thermo-emissive properties of materials as a function of structure, temperature, and state of aggregation, techniques of low temperature plasma generation, and single crystal emitters.

CHEMICAL ENERGY CONVERSION

Research to be stressed is the conversion of chemical binding energy directly to electricity. Activity in electrochemistry will include both primary and secondary batteries, and fuel cells. This should involve studies of the properties of electrochemical couples, high temperature electrochemistry, solvent-solute interactions, properties of electrode-electrolyte interfaces, ion and electron transport phenomena, and overvoltage phenomena.

ENERGY EXCHANGE

Direct electrofluid dynamic energy conversion is a promising area for many potential applications. These include gas compression, high temperature generation, liquid pumping processes, and various other energy conversion processes that work without employing rotating fluid machinery.

Information needed to understand the fundamental of electrofluid dynamic energy conversion should result from a systematic and concurrent investigation of energy transfer processes between liquid and gaseous fluids. Electrofluid dynamic energy transfer necessarily requires knowledge of steady and nonsteady processes in addition to condensation phenomena and mixing losses. Investigations to analyze, formulate, and test concepts which will meet requirements for an efficient thermodynamic cycle and an efficient electrofluid dynamic energy conversion cycle are required.

ENERGY RELEASE

In this area, fuel reaction rates, variable tunnel geometry, ignition delay, energy transformation pressure losses, and fuel distribution in energy release processes are to be investigated. Also, analytical and experimental studies should be conducted to study changes in gas momentum, as well as kinetic and thermal energies in energy transformation processes. Methods of fuel injection for shock generation will be investigated to determine feasibility for shock induced energy release. To evaluate changes in gas momentum, kinetic and thermal energies, theoretical and experimental studies of the kinetics of energy release in an expanding supersonic flow by chemical processes are required. Constant pressure, constant Mach number, and constant static temperature energy release and transformation processes should be studied. The influence of friction losses, mass addition, and heating gradients are to be evaluated. Energy addition will be accomplished by burning hydrogen. Experimental studies at higher temperatures will be conducted by using plasma generators. Studies will also be conducted on the effects of higher inlet Mach numbers, pressures and temperatures.

Fundamental investigations in the high polymer field, including the introduction of high-energy groups directly into the combustion of the polymer, and the addition or substitution of atoms such as fluorine to polymer combinations are required. Detonation wave processes, including the measurement of momentum and other parameters related to the energy released are being studied at this time.

COMBUSTION DYNAMICS

To promote developments involving the use of chemical energy, new knowledge must be gained in basic mechanisms of energy release in gases, liquids, and solids as well as in kinetics and energetics of detonative and deflagrative combustion reactions. An understanding of the coupling of chemical reactions to gasdynamic effects in energy release processes and homogeneous and heterogeneous catalyzed reactions are of real interest for advanced chemical propulsion or power systems.

Future research in the field of combustion is envisaged to cover more comprehensive studies of supersonic combustion to obtain information directly pertinent to hypersonic air breathing combustion processes. Efforts to determine effects of ions and electrons on chemical reactions in very strong detonations are required.

Problems included for study in the propulsion area are those connected with rocket or jet engine combustion reactions, kinetics of recombination of radical species, relaxation rates, kinetics of radiation, high temperature interaction of gases with solids, and mechanisms of reactions.

Research on certain aspects of H_2 -O_2 reactions will be continued. In addition, there are at least two other subareas which require immediate expansion. One of these is the mechanism of plasma interaction with solids. The contribution of this research to "materials" technology as related to rocket propulsion has not received sufficient attention in the past. Other work which needs to be expanded concerns chemical kinetics of new inorganic species involving O-F, N-F, Be- and Li- linkages. This area will require research to cover a wide range of temperatures and pressures.

THERMOPHYSICAL PROPERTIES

Studies on thermochemical and thermodynamic properties of chemical compounds concern the precise determination of thermochemical and thermodynamic values at ordinary or moderate temperatures (2000°K) to improve the background for sound theory; and a considerable expansion of effort to obtain data in higher temperature regions up to 5000°K and beyond. Another segment, concerned with thermal conductivity, viscosity, and diffusion coefficients of propulsion gases at higher temperatures and pressures, should be studied both theoretically and experimentally.

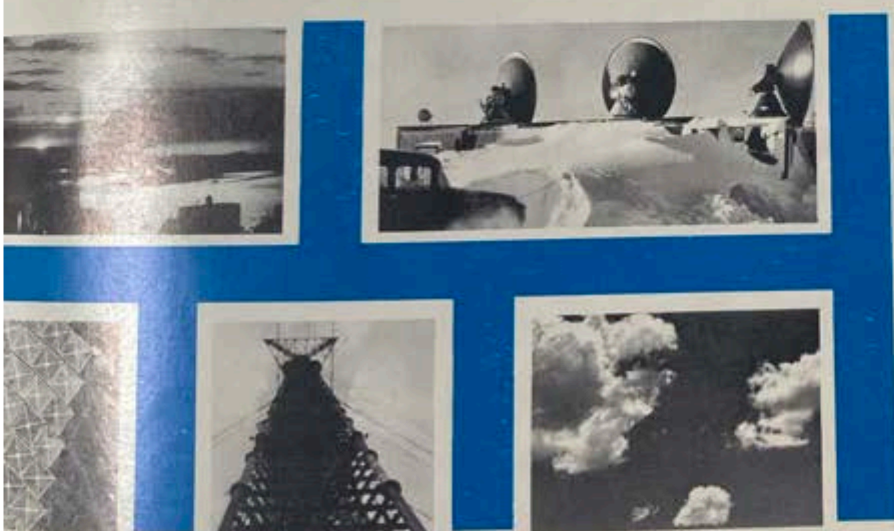
FIELD AND FLUID INTERACTION

Field and fluid flow interaction processes are significant to the area of electrical thrust and power generation since such processes affix a means to accomplish the desired thrust and power without the use of mechanical parts. This means that fundamental investigations should be established in electrically charging of media, impact phenomena, and promising energy conversion processes. Electrical charging of colloids, ionization methods, corona discharge, electrode configurations, potential physical properties, characteristics, seeding, and droplet phenomena are subjects of desired investigations.

MAGNETO PLASMADYNAMICS

Many types of investigations are underway on such items as "rail," "pulsed," "toroid," "pinched," and other plasma dynamic configurations. Some research is continuing on problems of ion beams and charged heavy particles (very large compared to molecular ions). In all of these areas (except ion beam) an expansion of effort is foreseen. These research investigations will continue to be concerned with plasmas in the low energy range where temperatures are less than 4000°K. Ranges of interest in the technology of working fluids for nuclear propulsion with temperatures from 15,000°K up, will be coming more and more to the fore. A number of problems have not been tackled even theoretically in this area, and experimental difficulties have prevented much quantitative information from becoming available.

ENVIRONMENTAL SCIENCES



Research in this area includes investigation in geodesy, earth physics, aeronomy, meteorology, energetic particles and fields, astronomy, and astrophysics.

The purpose of research in environmental sciences is to provide new and improved knowledge of the environment in which the Air Force is or will be operating. The aim is to promote a more rapid advancement of the Air Force technological capabilities.

The secondary purpose is to provide Air Force designers with knowledge of the environmental problems which will affect future systems. Intense exploration of this complete area is very costly. Therefore, coordination between the Air Force research community and Air Force designers is of great importance, both financially and time-wise.

EARTH PHYSICS

With geology as the science, geophysics as the main tool, and physics, chemistry, and mathematics as the base, the earth, and to a lesser degree other plants, are being analyzed to determine their composition, form, and dynamics. Basic seismological studies will provide further aid in analyzing and describing the earth's structure.

TERRAIN ANALYSIS

Terrain analysis includes studies of the crustal materials, surface morphology, and dynamic processes of remote and little exploited areas of the earth. Research on the dynamics of permafrost, heat exchange, and the effects of meteorological parameters on surface conditions and bearing strength will be directed toward the formulation of general laws of thermal phenomena in earth materials. Research into the use of ice and snow aggregates as engineering materials, including determination of physical constants of fresh and salt water ice, will be continued. Photogeologic studies of middle and low latitude deserts will investigate desert surface morphology. Such efforts will be expanded and analogs will be determined between regions being investigated by photogeologic methods and other remote and inhospitable areas for which data are unavailable. Studies in soil science will be extended to the tropics.

GRAVITY

Gravity research will continue along the lines of absolute earth-gravity measuring experiments including the reversible pendulum technique for determining earth gravity to about ± 1 milligal. Research on new techniques such as the gravity gradient method for accurately determining the gravitational constant will also continue. Investigations of other earth constants of the gravity field, and of the gravity tide effect, are needed.

GEODESY AND SELENODESY

Geodesy and selenodesy studies indicate that the classical heliometric technique for relative height measures is accurate to about 700 feet on the lunar surface, and lunar shadow measurements are accurate to 100 feet. However, determination of absolute elevations or selenodetic locations of lunar features is much less accurate. Research is to be initiated on the use of optical radar or laser transmissions to scan the moon's visible face to measure directly lunar topography and earth-moon distances. Lunar transponders will also be developed to study lunar optical librations. Terrestrial and balloon-borne telescopes will be essential for high resolution photography of the moon and planets. Control networks need to be established to improve lunar and planetary mapping products. A list of astrodynamic constants needs to be derived for purposes of standardization.

SEISMOLOGY

There is a continuing need for knowledge of elastic wave genesis, propagation, attenuation, and dispersion for use in structural analysis and interpretation of the earth. Techniques and principles for new seismological probing are needed. In addition, the Air Force research efforts need to be broadened in areas applicable to detection problems. Such areas are (1) research on the generation of seismic waves (sources mechanisms), (2) research on the propagation of seismic waves in the crust and mantle (wave propagation), (3) research on the identification of signals in the presence of noise, and (4) research on seismic data to determine the nature of the source.

METEOROLOGY

Regions of interest in this area extend from the earth-air interface to beyond the stratosphere, where the physical processes occur which eventually influence surface weather. The latter may provide the key to both successful long-range forecasting and weather control. Objectives include the determination of the dynamics of atmospheric motions and the determination of properties and understanding of clouds, fogs, and precipitation.

BOUNDARY LAYER AND MESOSCALE STUDIES

Boundary layer and mesoscale studies currently emphasize energy exchange, momentum, and water vapor in small-scale processes. Future research in boundary-layer processes should stress the analysis of experimental data and the construction of numerical models to account for micro- and mesophenomena in the boundary layer. Collection by U-2 aircraft and analysis of mesoscale data on such parameters as cloud types, patterns, electrification, radiation variations, and ozone distributions are to be continued.

CIRCULATIONS

Current studies in stratospheric and mesospheric circulations are concentrating on hydrodynamical, statistical, and mathematical models of the larger atmospheric motions. Future studies are needed on the mechanisms controlling the broad-scale features, such as prominent monsoonal changes in wind regimes. Quantitative investigation of general circulation mechanics should also be performed through analysis of constraints imposed by the long-term balances of momentum, enthalpy, and ozone. Special attention will be given to theoretical analysis of dramatic changes in stratospheric circulation that occur over relatively short periods of time in the winter stratosphere. Investigation of dynamical linkages between the stratosphere, troposphere, and mesosphere should be included.

CLOUD PHYSICS

Cloud physics research on techniques for dispersing warm fog, and studies of cumulo-nimbus structures will be continued. Future efforts on the development of research instrumentation, field experimentation, and data analysis are required. Research instrumentation needs include an improved temperature-measuring system employing infrared techniques, a Doppler wind system, an improved turbulence and vertical velocity measuring system, and a system for observing magnetic effects of lightning discharges. Experiments at specially instrumented field sites, preferably in regions of existing mesometeorological networks are to be conducted. Analysis activities include completion of the coordinated studies of growing cumulus in the Flagstaff area, and of dryline cumulus growth and electrical properties of large thunderstorms in the Oklahoma area. Future analyses should be facilitated by rapid data-processing systems being developed.

WEATHER RADAR

Weather radar studies on hailgrowth mechanisms, snowfall-rate measurements, radar attenuation, statistics, and reflectivity-profile analysis should provide for determinations of back-scatter and attenuation cross-sections of nonspherical hailstones and ice crystals. Extensive empirical data will be acquired on storm reflectivities at several wavelengths to determine whether the frequency response does, in fact, characterize hail and ice crystal sizes.

OPTICAL PHYSICS

It is necessary to extend the usable portion of the spectrum and to obtain additional basic knowledge of the interaction of optical radiations with transmitting media. Areas to be clarified range from the mechanisms of infrared radiation to the mechanisms of ultraviolet radiation.

INFRARED

Infrared research investigations of the basic mechanisms involved in transmitting infrared radiation through gases will continue. These studies include research on high-resolution spectroscopy and interferometry, absorption band and line intensities, emission and transmission of hot gases, and inter- and intra-molecular interactions of coherent radiation of very narrow spectral bandwidths, such as is found in and emitted by lasers. Various techniques for analyzing infrared radiation from various sources, backgrounds, or targets need to be developed. Attention will be given to interferometric techniques for improving spectroscopic analysis. More emphasis will be placed on optical coherence studies. Laboratory experiments involving the bombardment of atmospheric gases with electrons, and eventually with heavy ions, will be conducted to complement the theoretical studies on the emission of infrared luminescent radiation.

ATMOSPHERIC OPTICS

Atmospheric optics is a new research area in visible optics in the atmosphere. The problem of multiple scattering in a turbid atmosphere should be investigated, and calibration techniques for polarimetric equipment needs to be improved. A mathematical model of atmospheric radiative transfer will be constructed and will be used for comparison with actual observed data.

Ultraviolet techniques research on ultraviolet sources, spectroscopy, and interactions in the atmosphere is to be expanded. Theoretical and experimental study of naturally-simulated, ultraviolet radiation should be accomplished. Observational efforts of UV background measurements from balloons, rockets, and from X-15 research aircraft will be undertaken to establish the spectral radiance levels of the sky in the 2000 to 4000 Å region.

AERONOMY

Aeronomy efforts seek to determine the composition and characteristics of the upper atmosphere and the prevalent reaction mechanisms. Also the characteristics of solar, ultraviolet, and X-ray radiation in aerospace, and the interactions of extraterrestrial particles with the atmosphere must be determined. Direct probing methods, primarily involving rocket-borne and satellite instrumentation, are of particular importance.

COMPOSITION

Composition research including theoretical investigations of such physical and chemical processes as excitation, dissociation, recombination, diffusion, and heat transfer will be continued. Increased emphasis will be placed on more closely correlating mass spectrometer measurements with actual ambient conditions and on studying the relation between atmospheric composition and solar phenomena.

SPECTROSCOPY

Spectroscopic studies by rocket and satellite experiments will be undertaken to obtain a better understanding of the upper atmosphere and interplanetary space. Two 21-foot grating spectrographs will be constructed and placed in operation for use in determining the structure of molecules found in planetary atmospheres. The constituents of the upper atmosphere will be measured by rocket absorption spectroscopy. Upper atmosphere collision cross sections can be calculated theoretically. Reliable techniques and instrumentation must be developed for measuring night airglow at various locations, together with ground-based instrumentation for measuring day airglow.

UPPER ATMOSPHERE CHEMICAL PHYSICS

Theoretical and experimental studies to determine cross sections for scattering, for UV absorption leading to dissociation or ionization, for radiative and collisional de-excitation, and for molecular, atomic, ionic, or charge-exchange reactions from radiation absorption are required.

SOLAR EUV AND X-RAY FLUX

Theoretical and experimental studies of solar flux are to be conducted on photoelectron emission phenomena associated with materials exposed to EUV and X-rays. Ultraviolet absorption coefficients of various gases should also be investigated.

METEOR PHYSICS

New studies on the integrated effects of meteoric materials on the ionization level of the upper atmosphere are required. Perturbing influences of meteoroids on the ionosphere in relation to sporadic-E and magnetic storms are to be studied.

DENSITY

Theoretical studies on drag coefficients in the transition region between continuum and free-molecule flow are needed. The influence of solar radiations, gas diffusion, and heat transport on density should also be investigated.

ELECTRICAL PHENOMENA

Research plans include the use of rockets and satellites to obtain measurements and determinations of variability of charge densities and their energy distribution, currents, electric force fields, and conductivities. Rocket and satellite experiments will continue to obtain information about the physical processes influencing the electrical state of the high atmosphere, such as ionization, dissociation, recombination and diffusion processes, the interactions between incoming fast charged particles and the earth's upper atmosphere, and the origin of electric fields and currents. Experimental and theoretical studies must be carried out to obtain precise knowledge of recombination and diffusion processes at low pressures.

IONOSPHERIC PHYSICS

Both theoretical and experimental research are needed to produce an integrated model of the ionosphere to indicate diurnal and seasonal variations in the ionosphere as well as the small and large scale irregularities and the influence and control by solar activity. Objectives are to obtain information on ionospheric characteristics and the composition, physical state, and excitation mechanisms of the earth's upper atmosphere. An understanding of the applicability of magnetoionic theory to the ionosphere and exosphere, to scatter theory and to meteor trail reflections is an additional objective.

IONOSPHERIC CHARACTERISTICS

The use of probes provides direct information on electron concentration, positive and negative ion concentration, electron energy distribution, ion temperatures, and collision frequencies. In addition, indirect information is obtained on the solar flux through photoelectric effects on vehicle surfaces. These probe measurements are particularly valuable in disturbed ionospheric conditions where propagation techniques fail.

One of the greatest difficulties encountered in studies on the transmission of waves in a bounded anisotropic plasma is that explicit expressions for the propagation constant do not exist. Concentrated efforts to determine this constant are needed. To overcome several difficulties that have arisen in the experimental work on nonlinear effects in plasmas, it is believed that a transmission device rather than a resonant structure would be more desirable.

In D-region studies, the lack of agreement between models developed and the experiments on the 75kc/s group height indicates a need for further study. In particular, the contributions of minor constituents, such as sodium, to the ionization of the D-layer will be investigated.

Theoretical studies on low frequency radiations from longitudinal oscillations of electron plasma in shock waves emanating from the sun will continue. Present estimates seem to indicate a very large radiation around 100 kc and 1 mc during period of solar activity.

AURORAL PHYSICS

Studies of the auroral conjugate will be made using data from various stations over the globe. Satellite observations of auroral emissions are to be made using both photometers and scanning spectrometers.

Laboratory auroral afterglow studies, using optical and mass spectrometric means are needed for the observations of the first negative bands of ionized molecular nitrogen at various states of the afterglow decay. A detailed review is needed of the photochemistry of the OH emission layer and of seasonal variations in the OH and temperatures.

PROPAGATION CHARACTERISTICS

Studies of inhomogeneous and time varying media are to be continued to determine proper ray tracing techniques, and the effect on propagation modes. Refraction by the atmosphere for ground to satellite propagation and satellite to satellite propagation will be investigated. Efforts to determine background below 1 mc in the upper atmosphere will be made.

Emphasis will continue on the studies of hydromagnetic waves in magnetoionic media. This will include investigations of generation, travel time, attenuation and moding, and dispersion relationships in various media. Further efforts on studies of the interaction of MHD waves at a plasma interface and on investigations of Carenkov radiation in magnetoionic gases are needed.

SPACE PHYSICS

Research in space physics encompasses studies of: (1) magnetic fields and energetic particles; (2) solar physics; (3) the lunar and planetary environments and surface features; (4) radio, radar, and optical astronomy; and (5) observational, laboratory, and theoretical astrophysics. As such, it is concerned with expanding our knowledge of the force fields, matter, and energy density and sources in the space environment.

MAGNETIC FIELDS, COSMIC RAYS & ENERGETIC PARTICLES

Although studies of geomagnetic phenomena and their relation to solar events and cosmic radiation provide the basis for a qualitative understanding of the behavior of particles trapped in the geomagnetic field, more detailed and continuous observations are needed to develop quantitative relationships and exact theories. Current emphasis is on obtaining data by means of high-sensitivity devices. Recent developments have changed the emphasis of cosmic ray research and have resulted in an intensification of studies on trapped radiation. Cosmic ray investigations are designed to obtain knowledge of the intensity of cosmic radiation in the vicinity of the earth. Particular studies include geographical dependence, time variation, mass and energy spectrum, sources, probabilistic and statistical variation, and solar and astrophysical dependence.

SOLAR PHYSICS

Research in solar physics is aimed at gaining fundamental knowledge of the physical processes of the solar atmosphmere and the activities and disturbances which occur in it. Optical observation of solar activity in greatest possible detail including spectra, velocity fields, magnetic fields, and structural peculiarities will be made. This research is to include theoretical interpretations of temperature, pressure, excitation, magnetic energy, and kinetic energy of mass motion, plus an integrated picture of the physical processes in the sun.

LUNAR AND PLANETARY PHYSICS

It is expected that a large amount of high quality data will be obtained from balloon-astronomy programs. Valid interpretation of such data will require laboratory studies of simulated lunar and planetary environments. As this work progresses, terrestrial and near-terrestrial experiments should give way to vertical probing rocket experiments and deep-space experiments. Instrumentation and techniques for obtaining data on such vehicles need to be developed.

RADIO AND RADAR ASTRONOMY

Radio and radar astronomy research will concentrate on investigations of radiations from the solar system, and from galactic and extra-galactic sources. Planetary radiation of several types (black-body, synchrotron, and burst) will be studied to determine emission properties of planetary atmospheres. Solar studies will continue to investigate modulation processes of solar bursts which are major sources of solar noise interference.

OPTICAL ASTRONOMY

Optical astronomy investigations will be needed to overcome limitations of present knowledge on the space environment caused by atmospheric absorption and by the lack of instrument sensitivity and high quality astronomical facilities in the southern hemisphere. Spectrographic, interferometric, and other astronomical instruments are being developed. Studies will be made on galactic kinematics by obtaining definitive data for both hemispheres on Cepheid variable stars, on star colors and radial velocities, and on radial velocities and color-magnitude diagrams of star clusters. Intensity interferometry to determine angular diameters and temperatures of over 200 bright, hot southern stars has started.

Objectives in this area include research in stellar models, nucleon-genesis, cosmology, and galactic phenomena. The principal investigations cover computational stellar model research over the stability range in mass from about 1/50 to 200 times the mass of the sun. Emphasis will be placed on energy-temperature conditions for normal stars at the helium flash point where a star changes from normal hydrogen burning to higher equilibrium temperatures and helium burning starts furnishing the raw materials for the onset of the carbon-nitrogen cycle.

OBSERVATIONAL ASTROPHYSICS

Some of the more significant but least understood problems in astrophysics are found in the development of shocks, instabilities, and turbulent interactions in strongly and weakly ionized gases. A single illustration of this is the recent observation of anomalous variations in the density of solar plasma flowing past the earth. A detailed theoretical analysis of this plasma in terms of shocks and of turbulent flow is now being conducted in the hope of explaining the observations. Polarization studies of galactic magnetic fields and on the state of ionized gases within interstellar clouds that form galactic nebulae are needed. Stars, emission nebulae, and much of the interstellar gas of the galaxy are in the plasma state and are governed by the laws of magneto-gas dynamics. Since stellar polarization measurements are the only direct method known for delineating galactic magnetic fields, the importance of this field of research to astrophysics is very great.

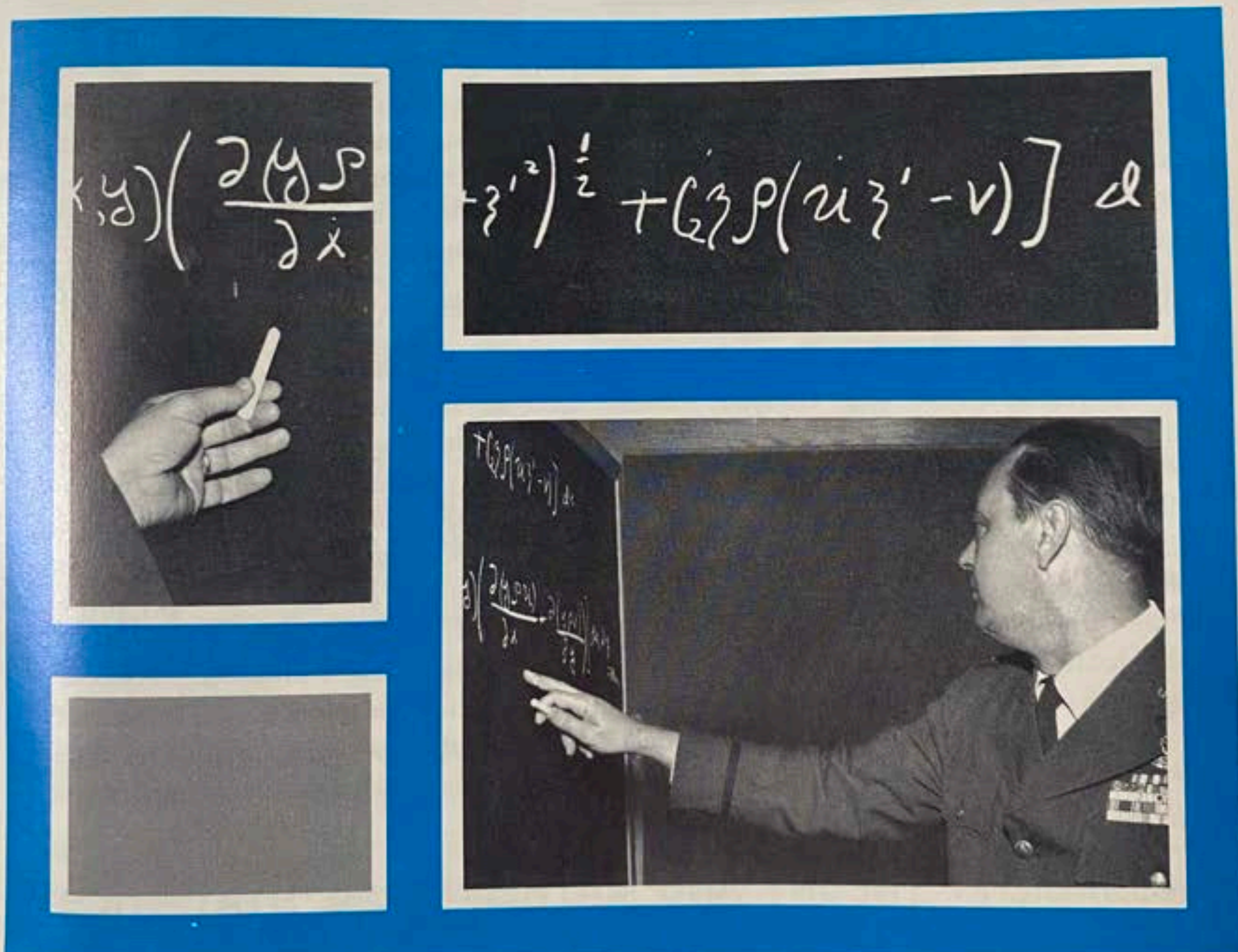
LABORATORY ASTROPHYSICS

Laboratory astrophysics, accenting modern hydromagnetics, extends to high-energy-density levels. This promises to be an important tool and technique in the development of both new and unconventional energy sources. An analysis and duplication of magnetohydrodynamic phenomena observed in space as a key to the understanding and application of magnetohydrodynamics is needed. Efforts should include the development of super-intense magnetic fields through the application of magnetohydrodynamic design and the study of plasma flow and shocks in magnetic fields, magnetostatic equilibrium and plasma containment, and high temperature conductivity of degenerate matter through exploding wire studies. Theoretical studies should be made to predict detailed shock wave structures in plasmas with and without magnetic fields. Absolute pressures, densities, and temperatures of shock-heated gases can be determined by electromechanical, optical, ultrasonic, and time-resolved spectroscopic techniques. Theoretical studies of the extended solar corona will continue. However, they should be augmented by laboratory models with the aim of simulating local solar electric and magnetic field effects as well as the effects of the general magnetic field of the sun. The aim is a unified theory which will predict the interaction of material ejected from the sun and the solar magnetic field.

Theoretical studies will continue with emphasis on solar coronal dynamo effects to determine interplanetary current systems and eventually, interplanetary climatic conditions. New investigations should be made of phenomena associated with the propagation of intense and other energy transfer mechanisms in conducting atmospheres.

Additionally, research is desired on optical decay models for tenuous gases traversed by light and heavy particles, on band spectra of light gases and free radicals, and on the chemical physics of hydrogen and hydride active species in radiation fields.

MATHEMATICAL SCIENCES



Three areas of mathematics are included in this element, namely: theoretical mathematics; applied mathematics; and information studies.

Research in mathematics is conducted for the purpose of developing new and improved techniques and to advance their scientific and technological application. These applications exist in all defined areas of Air Force interest in research. In general, the results of research efforts in mathematics will apply to all future aerospace systems. Reliability studies, operations analysis, and communication theory will make use of mathematical statistics and probability. Numerical analysis is used in the computer solution of many problems in vehicle design and flight path determination. Applied analysis makes contributions to areas such as aerodynamics, plasma physics, celestial mechanics, information systems, and many other research categories.

THEORETICAL MATHEMATICS

Efforts in theoretical mathematics form the core of analytical techniques which begin with the calculus and now include the extensions, generalizations, refinements, and related structures that have since developed. Future efforts will accent definitions of problems, qualitative theories of differential equations, operation and operators, topological dynamics, algebraic structures and distribution theory.

ANALYSIS AND FUNCTIONAL ANALYSIS

Research in mathematics is dominated by concepts and methods of mathematical analysis and functional analysis. Fundamental investigations will be continued in: functions of real variables, functions of complex variables, special functions, trigonometric series and integrals, integral transforms, ordinary differential equations, partial differential equations, calculus of variations, integral equations, differential geometry, topological dynamics, topological algebraic structures, functions spaces and linear differentials, and integral operators. The principal direction should be along the lines of the "well-posed problem" and qualitative theories of ordinary and partial differential equations with special concern for nonlinear differential equations. Secondary emphasis will be given to ordinary and partial differential operators in the framework of abstract functional analysis, topological dynamics, algebraic-topological structures for analysis and functional analysis, theory of distribution, calculus of variations, and differential geometry.

PROBABILITY THEORY AND MATHEMATICAL STATISTICS

Both probability theory and mathematical statistics continue to be definitely distinct but related approaches to the interpretation of our physical environment. Current research in probability theory and mathematical statistics is concerned with sophistication, power, and abstraction of the mainstream of contemporary mathematics, and the development of new probabilistic and statistical methods for specific physical uses. More effort is needed in: distribution functions, limit theorems, stochastic processes, markov processes, estimation theory, testing of hypotheses, nonparametric methods, design and analysis of experiments, decision theory, multistage decision procedures, sequential analysis, information theory, communication theory, and operations analysis. Emphasis should be directed along the lines of the interaction of probability theory and mathematical analysis, including topics in the sums of independent random variables, general random elements, functionals of random functions, tests, and estimations related to stochastic processes. This will include certain special processes, such as random walks, combinatorial analysis (including problems of enumeration), theorems of choice, the existence and construction of designs, and related investigations in the mathematics of information and communication theory.

APPLIED MATHEMATICS

Applied mathematics studies include many types of problems of current and forecast interest which are relevant to the Air Force mission. Mathematical problems of general interest are the solution of partial differential equations, variational problems, numerical analysis, and statistics and probabilities. Other applied mathematics investigations are a part of the research program in aerodynamics, plasma and modern physics and celestial mechanics.

MATHEMATICAL PHYSICS

Mathematical physics encompasses such topics as hydrodynamics, aerodynamics, elasticity and plasticity, fluid mechanics, quantum mechanics and celestial mechanics. Investigation in such areas as aerodynamic heating, gas dynamics, quantum field theory, solutions of applicable differential and integral equations, classical theory in celestial mechanics, optimization of trajectories for recovery, rendezvous and interplanetary soft landing, analytic orbit theory, and analysis of structures are of interest to the Air Force.

COMMUNICATIONS AND CONTROL SYSTEMS

Realistic formulation of control problems and transmission of information involves stochastic elements. Examples of such problems are: (1) final-time control to a random target, (2) optimization of Saturn-type rockets, where any one engine might fail in flight with a given probability and (3) transmission in the presence of noise. Research in the area of stochastic variational problems is needed. The general approach will involve the classification of types of systems and types of inputs followed by evolutionary methods of research on selected classes of these systems.

COMPUTATIONAL ANALYSIS

There are mathematical problems for which solutions are impractical to obtain, even with the most advanced computers. This situation requires new algorithms for future machines and for other than present sequential computers. Present research encompasses all areas of computational analysis. For the future, greater emphasis is required in the area of algorithms and numerical techniques for computer solutions, which can be achieved only by an expansion of the efforts in these areas.

INFORMATION STUDIES

Information studies include the body of scientific knowledge, methodology and techniques necessary for the acquisition, transmission transformation, evaluation, ordering, filtering, and interpretation of information. Research to develop a more general and flexible methodolgy will continue.

Research to develop deeper understanding of logic network behavior, especially in probabilistic nets, will concentrate on complex network structures with greater dimensionality, more elaborate connectivity schemes, and more complex probabilistic properties.

Study in the areas of artificial intelligence, learning, and adaptive and recognition processes will include work on the basic aspects of strategic, adaptive, and self-organizing machines, with emphasis on theorem-proving, problem-solving, and on decision problems involving learning and adaptation.

Additional research is needed on more exotic, nonlinear physical phenomena for use in future advanced data processing systems and of factors which may tend to impose limitations on such devices.

Knowledge of biophysical information systems, such as the mechanisms involved in sensory apparatus of mammals and humans, suggest further research on visual and auditory systems. Attempts to reach conclusions about the mechanisms of higher level concept formation are intended.

INFORMATION SYSTEMS

Information systems research is defined as research on the analysis and structuring of complex information systems. It is concerned with the interactions between machines, machines and their environments, and with systems comprised of machines, humans and environments. Research in systems theory endeavors to develop generalized schemes of classifying systems elements and parameters describing interactions between systems elements. This includes investigations of the variables affecting systems performance and methods of measuring and describing the effectiveness of generalized systems, and their dependence upon the parameters of the system environment.

Research in biophysical information systems is concerned with one aspect of the interaction between life sciences and mathematical sciences; i.e., that aspect which uses knowledge gained from research in the life sciences for improving man-made information systems. Emphasis will be broadened from its present concern with understanding the functions of the nervous system to the derivation of general properties of importance for new and better information systems. To obtain and influence such research, new sorts of transdisciplinary research efforts and institutes will be needed.

Research in machine programs, logic structures, procedures, and concepts will concentrate on simulating the complex information processing activities involved in human cognition and the neurophysiological mechanisms that underlie them.

Theoretical research in the information systems is concerned with abstract studies of the nature, organization and structure of knowledge. Studies should include automata, reliability theory, switching theory, self-reproducing machines, formal logic (as distinguished from mathematical logic), computability theory, and certain aspects of analytic and linguistic philosophy.

INFORMATION PROCESSING

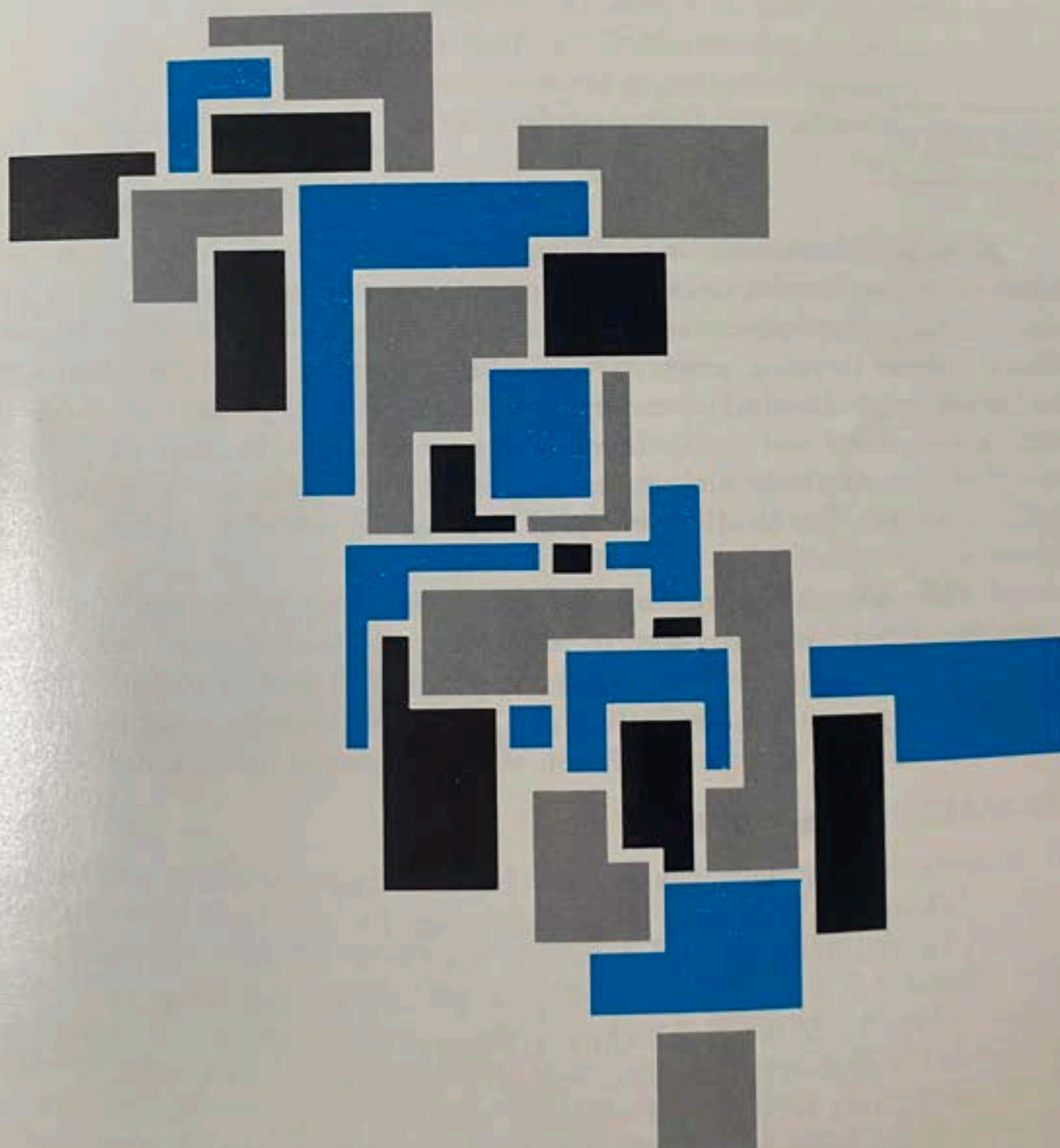
Research in this area is concerned with the logic, structure, and organization of information processing machines. Progress in microminiaturization and molecular electronics indicates that logic networks or iterative structures have the potential for parallel operation, flexibility and reliability through redundant operations.

Information theory is concerned with the transmission of information through noisy channels, without concomitant degradation of the accuracy or timeliness of the information. This research is concerned with study of signal degradation and of methods for alleviating it, with emphasis placed on signal reconstitution. Information as received usually contains not only the data of interest but also unwanted data or "noise" from the transmission channels and from the data processing or collection system itself. More efforts in this sub-area will be devoted to "pattern recognition" and/or automatic classification problems.

LANGUAGE AND LINGUISTICS

Language and linguistics research is aimed at achieving a better understanding of the properties of speech and writing as the principle media for communication. Research is necessary which includes studies of the fundamental aspects of the speech signal and the mechanisms by which it is produced and perceived, with a view toward learning more about how speech may be automatically processed.

PSYCHOLOGICAL AND SOCIAL SCIENCES



OAR research in the psychological and social sciences is pursued on the basis that people are the most important ingredient in both organizations and weapon systems. Accordingly, research is needed that will increase our knowledge of human capabilities and limitations as individuals or as groups and organizations. Since man is a very complex organism, an adequate approach to understanding his behavior requires frequent interdisciplinary collaboration between the psychological-social sciences and the biological-physical sciences. The latter can provide the more easily measurable neurophysiological and biochemical correlates of man's psychological and social behavior.

Major emphasis in psychological and social sciences research is oriented to efforts which seek to derive information, unifying principles, concepts, models, and techniques which will lead to more efficient use of man, better prediction of his performance, and techniques for defending and exploiting his vulnerabilities.

PSYCHOLOGY

Psychological research seeks to expand information, principles, and theories in human development, motivation, learning, memory, thinking, emotions, personality, communication, perception, motor skills, information processing, and decision-making. Processes such as learning, memory, motivation, perception, and information processing are emphasized to develop more efficient techniques of behavioral modification, prediction, assessment and manipulation. Extensive use is to be made of advances in other sciences, particularly biology, mathematics, and electronics to provide better research techniques for handling complex variables involved in studies of human performance.

Multidisciplinary approaches will be encouraged to discover fundamental processes associated with survivability and performance of man in customary and unusual environments, protection and/or exploitation of human vulnerabilities, efficient methods of persuasion, motivation and control of humans, communication and information processing, and the simulation of human neural network fuctions.

MAN-MACHINE SYSTEMS

Experimental psychologists and psychophysiologists, working with neurophysiologists and electronics specialists will be encouraged to develop a better understanding of man's capabilities and limitations as a component of electronic computers and complex automated systems. Efforts which show promise of elucidating novel concepts, principles or hypotheses in man-machine systems and programmed learning are desired. Answers are needed to questions such as: What functions can be performed most efficiently and reliably by man and which by machine? What are the limits of man's ability to use signs, symbols, and information codes in communicating with machines? What are the characteristics and function of short-term memory in operating machines under conditions of noise, adverse and changing environments, and critical situations? What are the characteristics of the sequence of material which most nearly produces optimum learning in the education and training process? What is the optimum programmed learning design for exploiting new concepts from the psychology of learning? What contributions can programmed learning or automated tutoring methods make to a comprehensive theory of learning?

INDIVIDUAL PERFORMANCE

Emphasis will be placed on studies to develop quantitative measures of human sensory and response systems, and define the processes of sleep, fatigue, monotony, and psychological stress as they affect performance in aerospace activities.

High priority will be accorded to studies which promise information of value in determining the most effective role of man in weapon and space systems. Attention will center on the hardware as an extension of man, with research efforts directed to ultimate designs which contribute to man's ability to develop, maintain, operate and exploit systems. Investigations of mathematical models and computer simulation of human psychological processes and their physiological corrrlates will be encouraged.

MANIPULATION AND CONTROL

Research efforts are needed to develop a better understanding of human attitude formation, motivation, persuasion, and their emotional and social concomitants. To provide information required for developing non-hardware defensive and offensive weapons of persuasion, studies of psychophysiologists, social psychologists, educational psychologists, and cultural anthropologists will be encouraged to explore the attitude formation and manipulation process.

Studies are needed of the uses and limitations of interpersonal influence and manipulation factors such as hypnosis, induced anxiety, limited sensory input, food and sleep deprivation, controlled administration of drug stimulants and depressants and their physiological response correlates. Emphasis will be placed in assessment techniques for interrogation and communication such as the polygraph and other psychophysical response recording and computerized analysis techniques.

SOCIOLOGY

Continuing international misunderstandings and tensions coupled with increasingly rapid transportation and communications systems dictate an urgent need for systematic study of the processes involved in man's interaction with other men. The need for investigation of group processes is further emphasized by the changing structural and mission characteristics of military organizations, both large and small. Modern social science studies have displaced literary discussions with mathematical treatments. Statistical techniques have generated new disciplines of econometrics, and have revolutionized research in economics, sociology, and political science.

Included within the scope of social sciences are cultural anthropology, economics, political science, social psychology and sociology.

ORGANIZATIONS

Research on organization structure and processes will stress not only the methodologies of sociology but also operations research, systems evaluations, economics, and social psychology. Investigations of large military organizations will focus on such problems as (1) evaluation of the effectiveness of large, unique and complex units, with particular emphasis on the development of criteria for assessing the efficiency of the organization and major subordinate units; (2) analyses of organizational structure for the purpose of designing organizational structures to meet demand of new weapon systems; (3) factors contributing to the success or failure of leaders and managers in military organizations; (4) providing information for coordination and control of organizations that are geographically dispersed and composed of semi-autonomous units characterized by personnel and subgroups highly differentiated in skill and outlook; and (5) personal commitment and loyalty in complex organizations.

Effectiveness substitutes must be found for the personal touch and strong bonds of loyalty which characterize relations in the small, tightly knit groups but which are lost in the modern large organization. These research efforts must be pushed actively since change is a common element of all Air Force plans and operations. Methods to overcome inertial forces must be discovered along with research on the requirement for new organizational methodologies to shorten the research and development cycle.

In addition to requirements for operational organization research, a strong need exists for studies of foreign and domestic social and political structures.

Investigations are needed in (1) studies of the attitude formation and social change in different foreign cultures, with particular reference to the cultural values, expectations, preferences, and opportunistic adjustment of the people to immediate political and social situations; (2) methods for identifying, measuring, reporting, and predicting attitudes of people in different cultures over successive time periods to such factors as aerospace weapon systems development, employment of military personnel for military aid, mercy missions, civic action activities, and other popular purposes, and scientific accomplishments of the West versus the East; and (3) studies which will identify all agencies, civilian and military, which actively sponsor aid to foreign cultures, and which will develop techniques for assessing the effectiveness of the aid in terms of attitude formation or modification.

ECONOMICS AND POLITICS

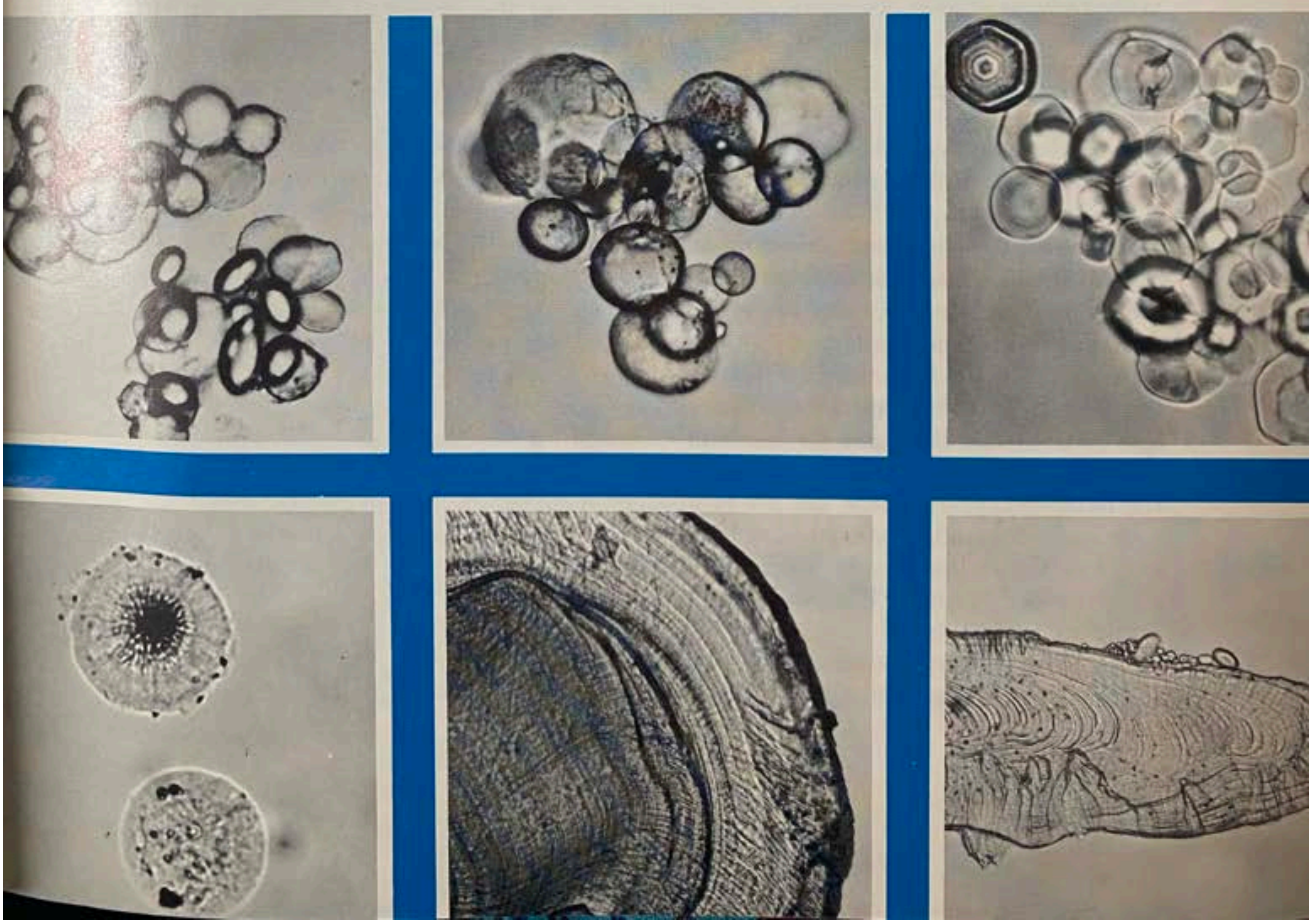
Analytical and predictive studies of foreign social systems are needed on new and neglected areas of the world. Strategic policy planning requires information based on studies of the interaction of aerospace power potential, arms control, international crisis and tension reduction, and national security. Political gaming and simulation studies should be conducted so that inputs of realistic variables can be altered to fit actual historical results of their alternatives. Hypotheses generated from such simulations should be augmented by actual field studies in selected countries to determine the nature of changing attitudes and convictions of people from grass-roots to leadership levels. The speed and reliability of predicting probable outcomes of alternate courses of action can be increased by simulation, using analytical models which lend themselves to testing and comparison on electronic computers.

COMMUNICATION AND INTERACTION

Communication and cross-cultural interaction are major areas in which to create persuasive influence. However, little information is available on the factors involved in these processes. Studies on processes of individual and group control, and attitude change, with particular emphasis upon cross-cultural effects under counter insurgency conditions are needed. Investigations conducted on the comparative effects of different media and channels of communication (mass media versus direct and informal personal influence of leaders and elites) in various countries at different levels of cultural and economic development are required. Of interest will be the interrelation of communications effectiveness with educational level, social values, economic development, and technological advancement.

Research analyzing the learning process and those studies which contribute toward a comprehensive theoretical learning structure are necessary. The development of useful principles applicable to learning, maintenance of skills, and retraining is encouraged. Learning research which promises better understanding of the higher mental processes is also encouraged. Studies to derive principles for exploiting the persuasive and attitudinal modification potential of education and training programs are needed. Explorations conducted to define the principles for optimum training of people to resist enemy exploitation and endure stressful environments and the usefulness of education as a nonlethal weapon are required. Special efforts devoted to those studies of education and the learning processes that promise information useful in developing techniques which radically reduce the time required to master complex subject matter while maintaining or increasing the quality of the training are needed.

BIOLOGICAL AND MEDICAL SCIENCES



The Biological and Medical Sciences employ physical, chemical, mathematical, and biological tools and techniques to advance the understanding of fundamental processes, principles and mechanisms found in living things. OAR efforts planned are predominantly in the biological sciences and will be presented under this heading. However, the topics selected for support may contribute to aerospace medicine as well as to military engineering technology.

Interest extends from the subatomic level through molecular and cellular structure and function to the organization and activity of tissues, organic systems and entire living beings.

BIOLOGY

Objectives in the biological sciences are to advance in selected aspects of anatomy, biochemistry, biophysics, bionics, physiology of sensory communications, reactions to stress, pharmacology, and biomathematics.

ANATOMY

As physiology advances, it is becoming clearer, as many biologists have long maintained, that structure is intimately related to function. This is particularly true in the nervous system. Anatomy, as such, has gone out of style and needs to be revived as an essential part of the study of biological organization.

BIOCHEMISTRY

The large, complex molecules of biological systems should be studied with the same thoroughness as inorganic and the smaller organic molecules have been studied in the past. Studies will be made of the biochemical processes underlying central nervous activity, with emphasis on the biologically active amines, their precursors and degradation products, on the biologically active peptides (oxytocin and vasopressin), and on other substances which are active in the nervous system. The chemical changes occurring within the brain must, in the final analysis, provide an explanation of the background of brain function. Efforts in this area will provide for a clearer understanding of the role of neuronal DNA and RNA in learning and memory; the structure of DNA and RNA and the mechanisms by which they carry out self replication, protein synthesis, and cell replication, the structure and chemical activity of enzymes and harmones, particularly, but not exclusively in the nervous system. New techniques have made it possible to snythesize large polypeptides and even small proteins. Considerable expansion of such work should allow the correlation of biological activity and chemical structure. The synthesis of artificial antigens, hormones, and enzymes is a distinct possibility.

Now that we have some indication of how the genetic code is made, we must look for the information system that programs the reading of this code and translates it into the myriads of forms we see in nature. This is one of the next challenges in molecular biology.

BIOPHYSICS

Biophysics includes the effects of physical forces in living things and the chemical and physical responses which allow them to adapt to such forces. Greatest expansion will be in the area of communications biophysics, which is concerned with the informational systems that permit animals to adjust their behavior to the outside world. Efforts explaining the origin, nature and function of nerve impulses, the nature and function of nerve synapses and specialized neurons, information processing in the visual, auditory, olfactory systems, and the function of special sensory systems, such as those in electric fishes are needed. Biological membranes have many properties which, if explained, will provide quantum advances in engineering and biological technology. Studies will continue on ion transport, membrane structure, and the role of membranes in the initiation of neural signals. Work will continue to determine the effects of such factors as acceleration, zero gravity, accoustical energy, heat, cold and vibration on humans. Of concern also are the compensatory mechanisms which enable man to adapt to environmental stresses.

BIONICS

Bionics is a word recently coined to highlight the possibility of applying principles of biological organization to man-made systems. Its emphasis has been in applications, but the biologist knows that his knowledge of biological principles falls far short of the theoretical foundations that are needed.

Attention to biological organization in the nervous system is already widening the scope of the engineer's imagination. This knowledge will increase immeasurably as more sophisticated studies of animals yield the kinds of theoretical knowledge that the engineer needs. Studies of the information processing system in a great variety of animals is still in a rudimentary stage.

Particular areas of work will include biological servo-mechanisms, biosensory mechanisms, bionic neurophysiology, neural networks, neuron function, and biosimulation.

PHARMACOLOGY

Pharmacology in this program is concerned with basic biology, i.e., drug receptor interactions, the effects of drugs on protoplasm, and the employment of drugs to study normal body function. These basic studies are necessary to support some of the applied pharmacological research which is so vital to Air Force needs.

PHYSIOLOGY

Physiological research is concerned with a study of the basic mechanisms by which animals carry out their life functions. The fastest growing field in physiology is that devoted to the function of the nervous system. There is a great deal of concern with those aspects of neurophysiology which will explain the mechanisms by which the human brain and nervous system operate. An understanding of these mechanisms can lead to the improvement of human performance and to improved electronic and computer technology. Some work is done on human subjects, but the major part must, of necessity, be done on lower animals. Electroneurophysiology, neurohumoral substances, their effects and reactions, metabolic pathways, the relationship of structure to physiological function, the neurophysiology of nerve cells, the neurophysiology of learning and memory, and the physiology of sensory mechanisms are areas of particular importance.

Studies on the vital organ functions of mammals will be continued, along with studies concerned with the response of organs and organ systems to various environmental conditions. Specifically, studies will include cardiovascular function, kidney function, electrolyte and water balance, liver function, and endocrine interrelationships. Since respiration has always been an Air Force problem, work will be continued on mammalian respiratory functions. Interest centers on the basic mechanisms of respiration and gas exchange to include the influences of pulmonary reflexes, alveolar gas composition, pulmonary blood flow, and changes brought about by abnormal gas composition and by environmental stress. Nutritional physiology and metabolism are becoming increasingly important due to anticipated long duration space flight. Primary interest will be in studies of the interrelationship between nutrition, health and functional capabilities, metabolic pathways, the mechanisms of digestion, absorption, and use of nutrient elements at the cellular level. Nutritional individuality is of particular interest. The physiology of diurnal rhythmic activity is a newly emerging field which needs expansion into a human physiology. Beginning efforts in this field must be expanded because of their implications for extended flights as well as the effects of rapid shifts in a person's "internal clock" with rapid flights across the earth.

PHYSIOLOGICAL-PSYCHOLOGY

Physiological-psychology, in which behavior is studied in relation to the underlying nervous and chemical mechanisms, is an area that will continue to attract attention. The links between physiology and behavior that may be uncovered offer a promising point of attack for applied research into ways to assess human performance and alter it in controlled ways.

BIOMATHEMATICS

One area of great promise must be encouraged and, to a large extent, developed; namely, biomathematics. Some of the biological decision-making devices far surpass nonliving systems in speed, flexibility and precision. The mathematics of these devices is largely unknown. Solution of some of the biological methods used offers great hope for major improvements in the quality of machine simulation.

The successful solution of some of the problems offers great advances in other scientific areas, such as control systems, computers, range finders and speed indicators.

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Department of Defense Program Element Codes

The following are the Department of Defense codes assigned to the five research program elements:

Physical Sciences	61405014	Psychological & Social Sciences	61420014
Environmental Sciences	61410014	Biological & Medical Sciences	61425014
Mathematical Sciences	61415014		

OAR-Managed Exploratory Development Program Elements

The Air Force Exploratory Development Program is the responsibility of the Research and Technology Division (RTD) of the Air Force Systems Command (AFSC). Two Exploratory Development program elements, however, are under the management control of the OAR. They are Environment, DOD code 62405394, and Aerospace Environment, DOD code 62405424 (these consist of the former applied research technical areas 760K, Electromagnetic Wave Techniques, and 770A, Aerospace Environment). Research in these program elements are sponsored and conducted by the Air Force Cambridge Research Laboratories.

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Other OAR Documents

Descriptions of OAR or its elements:

Office of Aerospace Research
AFOSR Programs in Basic Research
AFOSR Grants for Basic Research
AFOSR Contracts for Basic Research
Air Force Cambridge Research Laboratories
Aeronautical (Sic) Research Laboratories
European Office, OAR

Descriptions of research results or current efforts:

Basic Research Resumes, 1961-1962
OAR Research Review (biweekly)
OAR Research Program, FY 63-64
OAR Five-Year Plan

Documents in preparation:

Air Force Research Resumes, FY 63
Cummulative Index of OAR Rsch Results, 59-62
USAF Research and Other OAR Research Programs, FY 64-65

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