AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

AIR FORCE RESEARCH DIVISION

AIR RESEARCH AND DEVELOPMENT COMMAND

UNITED STATES AIR FORCE

AIR FORCE OFFICE

OF

SCIENTIFIC RESEARCH

THE AIR FORCE'S MAJOR ACTIVITY FOR THE SUPPORT OF NEW IDEAS

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UNITED STATES AIR FORCE
WASHINGTON 25, D.C.

AUGUST 1960

FOREWORD

A little over a decade ago the Air Force, as chief consumer of advanced technology, realized that applied research is essentially the middleman drawing heavily on supplies from the basic research of gifted scientists. But it faced the situation where its raw material was fast diminishing.

What the Air Force felt it needed was an office concerned solely with selecting fresh and new ideas which could conceivably have a bearing on Air Force problems of the future. Out of this concept came the *Air Force Office of Scientific Research* (*AFOSR*), with the principal mission of planning, initiating, and managing a contractual basic research program in the natural sciences.

As originally set up, AFOSR was an integral part and later a separate activity of the Air Research and Development Command. It is now one of four specialized activities of the Air Force Research Division (AFRD); itself, one of four divisions of ARDC. At present AFRD's other three activities are the Aeronautical Research Laboratories (ARL) at Wright-Patterson Air Force Base, Ohio; the Cambridge Research Laboratories (CRL) at Hanscom Air Force Base, Mass.; and the European Office of ARDC, known as EOARDC, at Brussels, Belgium. Although ARL and CRL may contract for basic research, their primary mission is that of conducting an internal research program.

AFOSR however *is the sole U.S. Air Force activity* whose primary mission is the support of scientific research by either contract or grant. Through its contracting system, supported by EOARDC liaison with the European scientists, AFOSR aids the research activities of the entire free world. It has contracts with many of the more noteworthy laboratories in this global scientific community.

In the interest of improving communications with such a vast community, this brochure briefly describes what the Air Force Office of Scientific Research is, tells how it works, what its research interests are, and how scientific investigators may seek its support for new and novel ideas.

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AFOSR AND BASIC RESEARCH

The Air Force Office of Scientific Research is charged with building a stockpile of knowledge which someday will provide the *know-how* for developing Air Force weapon systems of the future. In one sense, AFOSR may be thought of as a very inexpensive insurance policy for future defense. Stockpiling basic knowledge today may, and no doubt will, preclude such expensive *"crash"* programs as those brought on by World War II.

As the *major* AFRD activity for sponsoring basic research, AFOSR supports approximately 1,200 contracts in the United States, Canada, Europe, and South America. These contracts fall under all areas of the natural sciences related to Air Force interests and planning objectives.

AFOSR operates on the premise that *scientific advances cannot be ordered or scheduled,* but that *selection and emphasis* from the infinite possible directions of basic research can foster those scientific areas most probably related to present and future Air Force needs. For this reason, AFOSR acts *only* on unsolicited, original research proposals offered by scientists in universities, nonprofit institutions, and industry. Selection is made essentially on the basis of originality, significance to science, scientific competence of the investigator, and relevance of the proposed research to Air Force needs.

A major objective of AFOSR's program in support of basic research is to become a *vital partner* in man's unending search for new scientific knowledge. The capability for carrying out this mission is tied directly to the many scientists working in laboratories throughout the free world. To obtain the maximum output of basic science, AFOSR makes every attempt to provide the appropriate environment and support for those inspired individuals who are capable of making first-class contributions. The kind of research sought is fundamentally a *quality* item.

YOUR RESEARCH PROPOSAL

We wish to reiterate that the Air Force Office of Scientific Research can accept unsolicited proposals only. We are not interested in telling researchers what they should do, for we feel the best ideas originate in the minds of those free from direction.

We would like to learn of your research interests, either by letter or in person, and have found that the scientists doing the work usually makes the more affective presentation. Elaborate presentations are not required; good science is. In this respect we do not reject the unconventional, either in subject or approach. If our philosophy were to be summed up in one sentence, it would be: "If you can completely predict the results, it is not basic research."

If you choose, your *first* contact with AFOSR may be in the form of a preliminary proposal. This should set forth *your field of investigation* and outline *your specific objectives, approach, previous work* (citing related contracts held where appropriate), and *an estimated total cost of proposed work*. Your proposal should also name the principal investigators and indicate what percentage of their time would be devoted to the project.

Your preliminary proposal will be evaluated by the appropriate technical division. If favorably considered, you will receive instructions on how to prepare a formal proposal. Here we might add: A preliminary proposal saves you time and expense; formal proposals are detailed, official documents. This is why we suggest you *informally explore* our interests first.

You may direct your proposal *either* to the Executive Director or to the Director of one of our research directorates, Air Force Office of Scientific Research, Washington 25, D.C.

OUR RESEARCH INTERESTS

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AERONAUTICAL SCIENCES

The basic research needs of the Air Force demand the fullest use of many diverse scientific disciplines, some of which previously have never been considered a part of aeronautical sciences proper. How rapidly they are solved will be determined mainly by the ingenuity and rate of effort put forth by scientists of the free world.

Because of the rapidity with which satellites, ballistic missiles, and other hypervelocity vehicles are expected to be introduced into Air Force operations, AFOSR has intensified its support of basic research in problems of hypervelocity flight. Even so, emphasis will continue to be placed on a select aerodynamics programs in the low speed flight regime.

It is recognized that all hypervelocity vehicles will still face severe, yet-unsolved aerodynamic problems during operation in all speeds regimes within the atmosphere. Indeed, high-speed flight generally intensifies lower flight speed problems, rather than eliminates them. As a result, the research interests of the Aeronautical Sciences Division range over the entire spectrum of basic investigations in the broad scientific areas of—

- *Aerothermodynamics,* including heat transfer, plasma dynamics, magneto-gasdynamics, boundary layer theory, and aerodynamic noise;
- *Aerostructures,* including aerothermoelasticity, areoelasticity, elasticity, viscoelasticity, and plastic structural behavior;
- *Isentropic gas dynamics,* including supersonic, transonic, and incompressible flow, as well as jet mixing and rarefied gas flows;
- *Nonisentropic gas dynamics,* including aerophysics, nonequilibrium flows, reacting flows, and other chemical kinetic effects in flows; and
- *Nonlinear and orbital mechanics,* including orbital dynamics, servomechanics theory, and nonlinear mathematics.

Other research interests of the aeronautical sciences include research into laboratory simulation, instrumentation, and flight dynamics under extreme flight conditions.

PROPULSION SCIENCES

The Air Force mission requires manned and unmanned vehicles of ever-increasing performance in range, speed, and altitude, extending far beyond the earth's effective atmosphere. One of the keys to this performance is a *significant increase* in propulsion capability.

The possibilities for improving propulsion are many. The art of propulsion can be improved by empirical or scientific methods, but both have their time and place. In the early states of a new art or technology, empirical methods are often necessary to provide the initial data on which to base a coordinated analysis and basic understanding. In a field that has advanced as far as propulsion technology, however, empirical investigation *can* and *must be* replaced almost entirely by a truly scientific method of investigation.

Therefore the primary objective of the basic research program in propulsion sciences at AFOSR is to provide the knowledge and understanding needed to rationally approach applied research and development and to fertilize the ground for *new* and *revolutionary* concepts.

Primarily the science of propulsion is the *fundamental* study of energy in all its forms, and thus the program is designed to develop theoretical descriptions, substantiated by experimental facts, for the structure and properties of energy sources, the working fluids and the processes by which energy is transformed.

There are a number of forms of energy requiring further intensive study to establish adequate theoretical models. Among those under investigation are antimatter, solar, gravitational and electromagnetic fields, nuclei, atoms, and molecules. The working fluids range from hydrogen and combustion products to ions and plasmas.

The hypotheses connected with these energy sources and working fluids are, at present, largely tentative and exploratory. By contrast, a considerable proportion of the program consists of work aimed at elucidating the many still-unsolved scientific problems connected with propulsion by chemical means. Studies in new chemistry of light elements, basic thermodynamic and physical properties, mechanisms and activation energies of fast reactions, and interior ballistics of solid and liquid rocket combustion are examples of those problems requiring further attention.

CHEMICAL SCIENCES

The Air Force has a tremendous stake in advancing the frontiers of chemistry. Research in this field is supported for the blocking out of basic principles, not for immediate practical ends. These are certain to come later.

Many investigators have research ideas; some have new ideas; a few have *significant* new ideas for basic research. It is easy, for example, to choose chemical compounds for study because they are available or experimentally convenient. It is harder, *but more vital,* to take the trouble to undertake those experiments which will fit significantly into a larger pattern of scientific inquiry. Also when a new theory or method makes it possible to enter a new domain of knowledge, that fact is not always obvious. Yet it is from the discovery of these new concepts that science, industry, and the Armed Forces take their signals to move ahead. The *insight* and *imagination* it takes to recognize such opportunities is an important quality sought by the Directorate of Chemical Sciences in its potential investigators.

Within AFOSR, the chemistry program is viewed as a vital search by scientists for understanding in areas of usefulness to the Air Force. With any one chemistry project, benefits could be derived for use in aircraft, weaponry, detection, or communication, and improved materials for increasing Air Force capabilities are certain to result from advances in basic science. In every case the results will flow into the reservoir from which technology is constantly drawn: *scientific knowledge.*

To insure that this flow continues, the Chemical Sciences research program is kept *flexible* to permit change and growth, which means its interests do not remain static. Typical areas of interest include studies in the chemical properties of matter, surface chemistry, research in chemical synthesis, and new chemical and theoretical techniques. This interest is general and will remain so since key ideas for filling gaps in chemical knowledge may, and often do, come from people in any field of science.

BEHAVIORAL SCIENCES

Investigations that touch upon Air Force interests in the field of behavioral sciences form a *broad spectrum* stretching from complexities inherent in the social interactions of men to those inherent in the psychological makeup of the individual man. This affords a diversity of disciplines, subject matters, and methods which equal, *if it does not exceed,* that found in the physical sciences.

Some of these broad-front areas are moving ahead satisfactorily. For example, in the field of psychology, subareas of human engineering and personnel techniques for planning, classification, and assignment (based on aptitude testing and prediction of performance) are on the way toward becoming well developed. There are, however, areas in which scientific understanding is *less* advanced.

Such areas as job and work analysis, human relations, design of organizations, methods for training men to perform more effectively in complex man-machine operations, and theories for creating complex systems are in need of additional, intensive research effort. One of the more challenging areas requiring attention, for example, is that described as *man-computer symbiosis.* Basic research in this field could shed knowledge in two ways: (1) By learning how man can *use* and *communicate* with such systems; and (2) by learning about the complex control and decision-making functions of biological organisms, such as man, which can serve as a *source of ideas* and *models for the improvement* of machine systems, as well as contribute to the more effective use of men in automated weapons.

Research interests for the future can be summed up, in general, as support for more work on the *frontiers of knowledge* in those areas where continuing effort is essential. These include motivation, intellectual processes, sensory and associational deprivation, perceptual mechanics, criteria for measurement of performance, personality and aptitude structures, learning efficiency, communication and decision making, organizational effectiveness, strategic planning and intelligence activities, and communication processes within and between military organizations.

BIOLOGICAL SCIENCES

With increasing sophistication of Air Force weapons, mental demands upon operating persons overshadow physical requirements. Therefore, biologists at AFOSR have selected the exploration of the broad area of *brain mechanisms* as a major task. A concerted, integrated program has been constructed to uncover, if possible, basic principles of the central nervous system operation.

AFOSR is continuing its program in *environmental research,* with emphasis on *hazards* rather than *tolerance.* Although AFOSR studies may lead to new techniques for combating deleterious stresses, this area has been studied so extensively that applied physiologists and engineers now have many of the important basic principles available to them. AFOSR believes it more profitable, instead, to concentrate on those studies of environmental hazards, where present knowledge is still primitive or contradictory. One such study is the biological effect of air ions.

Another area of interest is that of *communications biophysics.* An increased understanding of the central nervous system and of the highly developed sensing mechanisms of animals lead to basic principles for computer and communications development.

Two other tasks which AFOSR is expanding significantly are *photosynthesis and molecular biology.* Photosynthetic techniques promise the only known methods of providing gaseous exchange and, possibly, food for prolonged space flights. Of even greater significance is an understanding of the plant's ability to convert solar to chemical energy. Studies in molecular biology—that is, the relation of molecular structure to biological function—are the most unpredictable yet potentially the most rewarding for future Air Force application. AFOSR considers such investigations to be in the very *forefront of knowledge.*

In such a fundamental biological program, discoveries of immediate import to the Air Force are unlikely. *Progress, rather, is measured by the slow, meticulous fitting of experimental findings into a broad mosiac in which significant principles gradually become apparent.*

MATHEMATICAL SCIENCES

The mathematical sciences are of central importance in the AFOSR research program. This interest reflects the wide range of requirements arising from the complexity of modern weapons systems.

The program of the Mathematical Sciences Directorate has as its over-all objective the systematic advancement and invention of mathematical techniques, in close association with the AFOSR program objectives in the other sciences.

Its research program is potentially directed to the problems of air technology and military application, with special consideration of potential future physical, chemical and engineering uses. Proposals for *quality* research of an *original* nature are invited in appropriate theoretical and applied areas.

Theoretical areas of interest include:

- Analysis;
- Geometry;
- Probability theory;
- Modern algebra;
- Topology; and
- Logic;
- Much contemporary importance attaches to modern techniques for the solution of ordinary and partial (linear and nonlinear) differential equations, and the investigation of analytical techniques as related to modern geometric, topological, and algebraic structures.

Broad areas of applied mathematics include, for example:

- Statistics, decision and prediction theory;
- Numerical analysis;
- Approximation techniques;
- Logic for computer design;
- Information theory; and
- The range of mathematical techniques for elasticity, fluid dynamics, potential theory, celestial mechanics, adaptive control systems, and operations synthesis and analysis.

INFORMATION COMPLEXES

The information complexes research program is concerned *ultimately* with the structure of knowledge, as reflected in language, using the broadest possible definition of language as any ordered area of symbols. The most probable application of this research effort will be in the areas of automatic language-processing systems—systems which use the resources of modern technology, including both general and special-purpose computers, digital, and analog storage devices for automatically abstracting, indexing, cataloging, and retrieving the evergrowing volume of scientific information.

The research program is *interdisciplinary* in nature, bounded by such standard disciplines as biophysics, psychology, physics, solid state sciences, mathematics and mathematical logic, philosophy, and even library science. Within this area the research program ranges from extension of the best in modern library practices (including certain specialized bibliographic and abstracting services), through the use of present generations of large digital computers in language processing (in such new areas as special recognition and pattern recognition), to modest efforts in certain aspects of artificial intelligence relevant to information processing and fundamental investigations on the structure of information.

The information-handling problems of AFOSR are used as a pilot plant for experimentation. Two operating mechanized technical information systems have been built: One using an external index to a computer store of information on all AFOSR research contracts; the other using tape-controlled typewriters and a simple magnetic tape-searching device to exploit fully the latent resources of existing research documentation.

The future research interests of this program lie in the relevant areas of *mathematical logic* as applied to computers, in the form of algorithms, and, in some cases, even debugged programs for language processing. Any new and interesting area of interactions between computers and living systems is approached in this program usually from the aspect of logical analysis and mathematical models, rather than through direct experimentation with living systems.

GENERAL PHYSICS

In its quest for the most modern of weapons and for the most effective of support systems, the Air Force has developed a *voracious appetite* for advanced discoveries in the physical sciences and technology. The main advances sought by AFOSR physicists are the more general theories combining presently unrelated data or phenomena and, additionally, more accurate theoretical models to describe the finer structure of multiple events occurring together.

Current interests of this division are: (1) *Electronic physics* (extreme-frequency generation, E–M propagation, quantum level devices, plasma excitation and diagnostics, radio astronomy); (2) *atomic and molecular physics* (beam and particle dynamics, radionuclei and isotopic property trends, magnetic resonance phenomena, rare-earth spectroscopy); (3) *astrophysics* (stellar computational models, element abundances, hydromagnetic phenomena, cosmical gas dynamics); (4) *theoretical physics* (thermodynamics and statistical mechanics of irreversible processes, probability theory and quantum processes, theoretical optics, turbulence theory, information theory, line broadening theory); and (5) *miscellaneous* (low-temperature properties of matter, extreme-scale acoustic effects, chemicophysical phenomena, stellar image criteria, soft X-rays).

For each of these problem areas, this Division takes into account the support offered by other research sponsors of defense or national agencies—*particularly* that of special relevance to another agency's major mission or its past history of support. In radioastronomy, for instance, the long-term support of ONR and the large-dollar support of National Science Foundation's Greenbank facility have led AFOSR physicists to emphasize interferrometric techniques and crossed-arm antennas. Similarly the large AEC-Sherwood effort in 1-to-20 million degree plasmas has focused interest on the free ends of this temperature bracket of:

- Low temperature or partially ionized plasmas important to electronic devices or deenergization processes; and
- Fully ionized plasma processes on astrophysical scales including cosmic gas clouds.

Declining interest is exemplified by nuclear magnetic resonance.

NUCLEAR PHYSICS

The program of the Nuclear Physics Division is identified broadly with the areas of: (1) *Nuclear structure;* (2) *experimental high energy physics;* (3) *theoretical nuclear and elementary particle physics and field theory;* and (4) *the cosmic radiation.*

The immediate objective of the *nuclear structure research* is to measure and systematize the properties and structural details of nuclei and to develop improved techniques for analysis and correlation of these data. The long-range objective is to develop a theory capable of quantitatively describing and predicting these nuclear properties. Research interests in this area include precision nuclear energy level measurements, studies of scattering cross sections, nuclear reactions and energetics, nuclear mass measurements, and polarization effects.

The acquisition of data to help fill the tremendous gaps in information existing in the measurements of the properties of nucleons and elementary particles is the objective of the research in *experimental high energy physics.* Research interests include cross sections and angular distributions of pions, antiprotons and K-mesons scattered by protons and neutrons, electron-photon scattering at high momentum transfers, branching ratios in the decay of unstable particles, and the properties of hypernuclei. Studies of the validity of quantum electrodynamics at distances smaller than nuclear dimensions are also of interest.

Strong emphasis is being placed on *theoretical research* because of the growing need for: (1) unification of ideas regarding the elementary particles, (2) reassessment of the theoretical foundations of modern physics and a rapprochement of quantum field theory and general relativity, and (3) a quantitative theory of nuclear reactions.

Since the energies of some of the primary cosmic particles far exceed those available with accelerators, studies of these phenomena are being supported to elucidate various aspects of very-high-energy interaction physics. Other interests include studies of the *nature and origin of the cosmic radiation,* and the manner in which it relates to astrophysical and geophysical phenomena.

RESEARCH ANALYSIS

The Air Force mission requires manned and unmanned systems of ever-increasing performance and complexity. Analyses must be made of all proposed and purely conjectural systems so that areas of applied and basic research may be identified which seem to have the best chances of solving the related problems. These analyses include investigation of performance parameters to establish envelopes of performance possibilities and must, upon occasion, delve into detailed phases of systems design such as structural innovations, exotic propulsion systems, futuristic guidance methods and, in general, anything that may be proposed to improve future systems.

APOSR must originate and conduct research in support of possible weapon and space systems for the defense of the United States from 5 to 10 years in the future. This does not preclude the support of basic research in areas where there is no presently known application to any weapon system. The Directorate conducts systems synthesis and analysis of all aspects of these hypothetical or future weapon systems based on the known and projected potential enemy threat. Analyses are conducted on the technical validity, operational effectiveness, and program feasibility in terms of development schedule of the proposed weapons system. These recommendations aid AFRD and ARDC in making research and development decisions on future weapons systems.

To enhance the effectiveness of these analyses the Directorate conducts in-house research and monitors contract research in areas of specific scientific competence related to present or anticipated needs. The Directorate maintains a small physical sciences laboratory in which the scientists and engineers may conduct experimeental work in support of their theoretical findings.

SOLID STATE SCIENCES

The solid state sciences embrace many of the traditional areas of science—physics, chemistry, metallurgy, ceramics, electronics, high polymers, as well as the glassy state of matter. It recognizes the importance of and, indeed, encourages the *interdisciplinary* approach to the theoretical and experimental study of solids.

Much of the success of science results from the crossing of barriers that traditionally are associated with the classical disciplines of science. In science it is the *understanding* which stems from a broad base of knowledge that provides the essential ingredient to progressive, technological advancements. An important part of the mission of AFOSR is to deepen and broaden this source. This is done by exploring new areas of fundamental research in concert with many scientists working in laboratories throughout the free world.

The solid state sciences program of contract support has the twofold aim of (1) clarifying existing knowledge on which many applications now rest, and (2) exploring unusual phenomena which may result in significantly new ideas. Particular emphasis is given to unsolicited original proposals reflecting—

- *Novel ideas* for fundamental research in the unexplored areas of the solid state sciences, combining theoretical and experimental approaches offering greater insight into an understanding of solids; and
- *Broad concepts* governing atomic and molecular phenomena underlying the behavior and function, or growth and degradation, of matter in the solid state.

Typical areas of current interest in the solid state sciences are:

- Structure-sensitive properties of crystalline and non-crystalline solids under both normal and extreme environmental conditions;
- Special properties and behavior of surfaces and interfaces;
- New synthetic methods for the genesis and perfection of crystals of controlled purity; and
- Widely applicable theoretical and experimental techniques which provide useful and analytical tools for fundamental research.

U.S. GOVERNMENT PRINTING OFFICE : 1960 O—557903

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