Exploratory Research

The following account of the new "Institute for Exploratory Research" which has been established within the organizational framework of the US Army Signal Corps' Research and Development Laboratory at Ft. Monmouth, N. J., is coauthored by the Laboratory's director of research (Dr. Zahl) and the director of the newly created Institute (Dr. Reilley).

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MANY military laboratories are today being subjected to increasingly severe requirements as this country seeks to emphasize its scientific effort. The immediate problems of defense, the missile program, and the now intense interest in the race for outer space, all call for trying to buy ten years time in two. The relatively calm environment of many military research laboratories is gradually being replaced by crash requirements, deadlines, and "budget hassles". In such a situation research having generalized long-term objectives always seems to yield to the exigencies of the immediate.

With the growing national awareness that defense is a multidimensional problem, with time as a variable extending between zero and infinity, the pendulum seems to be slowly swinging toward the recognition that basic and exploratory research, while admittedly not as urgent in real time, must be given equal importance with the problems of the present. To this latter point many fine words have been spoken or written, but translation of good intentions into action inevitably comes slower.

The spending of a large fraction of the dollars appropriated for defense R&D is directly or indirectly controlled or influenced by some military laboratory or equivalent staff organization before passing into our civilian economy for bolstering the over-all national effort. Therefore, military laboratories carrying an assignment based on optimizing internal and contractual effort must carefully shape their organizations to assure that military R&D monies buy the most and the best possible. During periods when national policy dictates an expansion of external research and development programs, effective management requires diversion of scientific and engineering personnel into contractual administrative positions. The natural consequence of such diversion of talented personnel is deterioration of the internal research and development capabilities of their laboratories. Over a long period of time such laboratories would evolve into mere appendages of contracting offices, having no attraction for future generations of professional personnel. The end result of this decay process can be seen to be the lack of scientific imagination necessary to administer wisely government research and development funds.

To insure the perpetuation of the required scientific competence within government requires a steady flow of talented young people into government. Expert consultants may help temporarily, but can offer no long-term solution. Salaries which are competitive with industry also help, but will not do the job alone. Only if actual opportunities exist for research interesting to the more gifted people can government hold and increase its competence in the administration of a multibillion-dollar R&D program. Once started in research, as time passes and career concepts change, as we know some will, a fraction of this new scientific talent becomes responsible for policy making, planning, and administration. With them, they bring fresh scientific imagination coupled with real appreciation of government problems —both very important ingredients for persons charged with keeping military-supported programs reflecting the country's highest capability.

Within the Department of the Army, Dr. William H. Martin, the Director of Research and Development, Major General J. D. O'Connell, the Chief Signal Officer, and Brigadier General Earle F. Cook,[1] Commanding General of the US Army Signal Research and Development Laboratory, have studied the problem of how to enhance internally conducted exploratory research in collaboration with the authors. From these studies it has been decided that a reasonable percentage of the scientific staff of the US Army Signal Research and Development Laboratory at Fort Monmouth, N. J., should be relieved of those responsibilities inherent in directed applied research programs, crash developments of military equipment, and the problems of research contract planning and administration.

FROM this decision a concept leading to an Institute for Exploratory Research was born, and within each of the three major departments of the Laboratory, specifically Communications, Surveillance, and Electronic Components Research, there was established an Exploratory Research Division broadly dedicated to the long-range mission of its department. Program responsibility for the new Institute comes to focus in an Exploratory Research Council composed of seven senior scientists, one from each of the three Exploratory Research Divisions, and three others representing the ap-

[1] Now Chief, Research and Development Division, Office of the Chief Signal Officer.

plied research programs of the departments, with the director of the Institute serving as council chairman.

It was agreed that the senior scientists selected for Institute research must have previously demonstrated competence in opening up, or substantially expanding, new areas of science and with this background they would be permitted freedom from the mandates of military requirements, which frequently also carry harassing time deadlines. However, our intent in organizing the Institute was not to consolidate all scientific personnel capable of doing research. The need for top scientific talent continues to remain in all divisions of our laboratory.

With this recognition, great care was necessary in selecting the Institute's staff so as not to impair the effectiveness of the much larger applied research and development program going forward in areas of combat surveillance, radar, countermeasures, meteorology, avionics, communications, data processing, power sources, frequency control, electron devices, photography, use of satellites, etc. The technical aspects of this very large program are jointly supervised by the director of engineering and the director of research. To assure proper coordination of the exploratory research program with the applied research effort, the director of the Institute dually serves as an assistant director of research for the over-all laboratory effort.

THE scientific program of the Institute must be directed and managed with due regard to its stated mission. For the large part the program must supplement other parts of the Signal Corps research programs which directly support established component and equipment development objectives. It must not duplicate work planned under these programs; instead it should supply ideas on which future applied research and advanced developments can be logically planned. In addition, the scientific program of the Institute must be closely linked with the fields of basic research supported by the Signal Corps at many university and industrial laboratories.

One of the natural aims of the Institute is to produce, within the Signal Corps family, men with competence in scientific fields having great significance to future Army technology. In many cases, the new fields of science are growing outside of established areas of investigation in which we have gained competence. Only by direct contact between laboratory scientists and leaders in these new fields can these new ideas and techniques become familiar and thereby useful to us.

Certain applied research programs in industry have become so vast, and so well manned and supported, that any token studies by the Institute in the same fields would likely lead to insignificant results. In this category we find research on synthetic rubber, a host of plastics, and most of metallurgy, as typical examples. Newer fields of science, especially those in which major discoveries have occurred since the end of World War II, are of especial interest to the Institute. Much of the Institute's program will be concentrated on investigations in these fields, as will be seen in the following planned work.

Radio astronomy is a field in which many future Army operations demand information. As surveillance equipment becomes more and more sensitive, radio sources of noise from the cosmos will determine the background against which targets must be detected. Studies of signals from extraterrestrial sources have already yielded interesting information on peculiar ionospheric propagation effects which are extremely important for future communication system designs and for long-range radars. In the future, extension into the microwave region is seen to be of great interest since present results show very undesirable phenomena in received vhf signals. Additional work in this field may also be accomplished in several collaborative experiments in which one part of the experiment (either transmission or reception) will be accomplished with Institute facilities, and the other end carried out by a university laboratory, as is the case in the present USASRDL-University of Illinois propagation study. Another such important experiment has very recently been initiated in collaboration with Lincoln Laboratory, MIT, on the measurement of extragalactic hydrogen distribution.

Plasma physics is a field in which startling and rapid developments are taking place in the United States, due primarily to the highly competent scientific talent supported under Project Sherwood by the Atomic Energy Commission program on controlled thermonuclear power. Plasma physics is not a new field of Signal Corps interest; in fact much of this work was supported in the past by our hydrogen thyratron program. Studies by the Institute in this field may greatly assist solution of Army problems aside from the thyratron. For example, potent sources of gamma rays and neutrons may be created by plasma processes. These sources may be of invaluable assistance in studies of transient effects of radiation pulses on materials utilized in electronic components and devices, now an important target area for future Signal Corps attention. In addition, controlled plasmas may now permit us to simulate the peculiar ionospheric effects mentioned in the radio-astronomy program within a small laboratory where detailed studies can be carried out.

Molecular engineering, a term coined by Von Hippel, refers to the design of molecular structures to secure desired properties in materials. Crystal physics and solid-state physics are important branches of physics from which some day such an ambitious technology may be derived. These fields are considered to be rich for future exploration.

Since World War II we have seen ferrites developed having enormous impact on electronics, we have seen transistors and solid-state rectifiers revolutionize the combat radio, computer, and telephone fields, and we are now achieving nearly noiseless microwave amplification with the solid-state maser, and almost unending satellite power with the solar cell. The program of the Institute must, to remain healthy, concern itself with

materials of the future having equally important application to electronics. Part of the present program is concerned with the growth and properties of extremely pure crystals, since many of the useful properties are completely masked by the presence of undesired impurities. Part of the program is in the field of growth and study of more complex structures—in particular the garnet group. Future work is planned in superconductivity research and on determination of electrical and magnetic properties at extremely low temperatures. It might be mentioned here that a new concept is gaining momentum—that of operation of a complete electronic system in a low-temperature environment, in which would be included solid-state amplifiers, detectors, and computer-switching elements such as the cryotron. Since many present-day components and devices will not function well, or in some cases at all, under these conditions, much research and future development will be needed in order to prove or disprove the value of the concept.

Information theory is a new field of very broad application to future Signal Corps developments, since it is becoming the formal science treating detection and identification of signals of all types. Exploratory research is greatly needed in this field in order to turn theoretical predictions into useful techniques. Hopes are high that from this field will spring new practical methods for compressing bandwidth, for reducing transmission errors, for improving message security, for obtaining far greater intelligence from target omission, and for improving transmission or detection range by multiple correlation. Future plans of the Institute in this field include the complete digital simulation of the above processes, which is thought to be an important step in permitting rapid exploration of the many interesting possibilities. Such a simulator may remove from the research worker the need for redesigning experimental equipment in order to explore each new technique, a costly and time-consuming process. Adaptable to study by such simulation are present studies on ambiguous modulation schemes, error-correlation codes, speech-compression systems, as well as many other new communication techniques.

A most ambitious goal lies ahead for the Signal Corps in this field of digital simulation of communications. It should be possible at some point in the future to include basic propagation statistics, along with coding and detection schemes, in the simulation problem, so that an entire, hypothetical communication system could be tested under simulated field conditions without building a single black box. With the rising costs of equipment development and increase in complexity of communication systems, such a goal is considered well worthy of attempt.

THE Institute laboratories are equipped with the usual laboratory facilities as well as specialized equipments for research in several major fields.

Solid-state research facilities include: (a) a complete electron-microscope laboratory (with electron diffraction equipment), (b) an infrared spectrometer laboratory, (c) a crystal-growing laboratory, (d) a precision nuclear-resonance laboratory, and (e) an x-ray diffraction laboratory. The latest model liquid helium producing plant has been installed within the laboratory, improving our capability for low-temperature research. Planning for the future improvement of the solid-state research facility includes a superpressure plant permitting experiments on growth of crystals not now possible, as well as measurement of the properties of matter at superhigh pressures.

Radiation research facilities include a 2-Mev Van de Graaff machine and a 250 000-volt x-ray machine, as well as handling equipment for utilizing high-intensity radioisotope sources. Planning is underway to establish an additional radiation facility, perhaps of the pulsed-gamma and/or pulsed-neutron type. Needed also is a special high-voltage capacitor bank for the study of the radiation from pulsed plasmas. Detailed planning of the requirements of this laboratory facility will be accomplished in the very near future.

The equipment for studies in radio astronomy consists of two large radio telescopes. The 50-foot diameter moon-radar antenna is already fitted with high-powered transmitters for propagation experiments. The second, with a 60-foot aperture, is being equipped with a 1400 megacycle/sec solid-state maser receiver. Considerable additional receiving equipment will be added to this latter installation in the future, including several receivers of the multichannel radiometer type.

Also a part of the Institute's plant is a computational facility which includes two IBM model 650 computers. A planned addition to this laboratory is a high-speed analogue-digital converter which will be of great value in processing experimental data from various experiments as well as in utilizing the digital computers in simulation applications.

A CONCEPT has been laid out with the objective of placing greater stress on relatively unrestricted research of an exploratory nature bearing on long-term aspects of the US Army's Signal Corps technological objectives. The present extent of implementation of these plans has been limited only by the desire to maintain a strong laboratory potential in applied research and development fields having immediate importance to the Signal Corps, and by the total available scientific manpower. It is anticipated that the establishment of the Institute for Exploratory Research at USASRDL will serve to insure the adequate and reasonably coordinated long-range research effort so urgently needed to allow most effective use of the scientific potential available to our laboratory. We intend to create an environment in which suitable allowance is made for those vital exploratory research efforts which might otherwise not be initiated or adequately supported.

In closing, the authors wish to acknowledge the very valuable and constructively critical staff assistance provided by Mr. Norman J. Field during the formative period of the new Institute for Exploratory Research.