Excerpts from the report of the director

July 1, 1968 - June 30, 1969

To the President of the University:

Scientific and Engineering Activities

During the year, the scientific and engineering work of the Laboratory was distributed as follows: research—13%; exploratory and advanced development—20%, engineering—26%; systems engineering and integration—17%; and technical evaluation of operational systems—24%. The major part of these efforts has been directed to continuing major and complementary problem-solving programs in the field of fleet air defense, evaluation of fleet ballistic missile systems, development and use of navigation and scientific satellites, related supporting research, and exploratory development. My report for last year treated this portion of the Laboratory's work in considerable detail which need not be repeated here.

R. E. Gibson

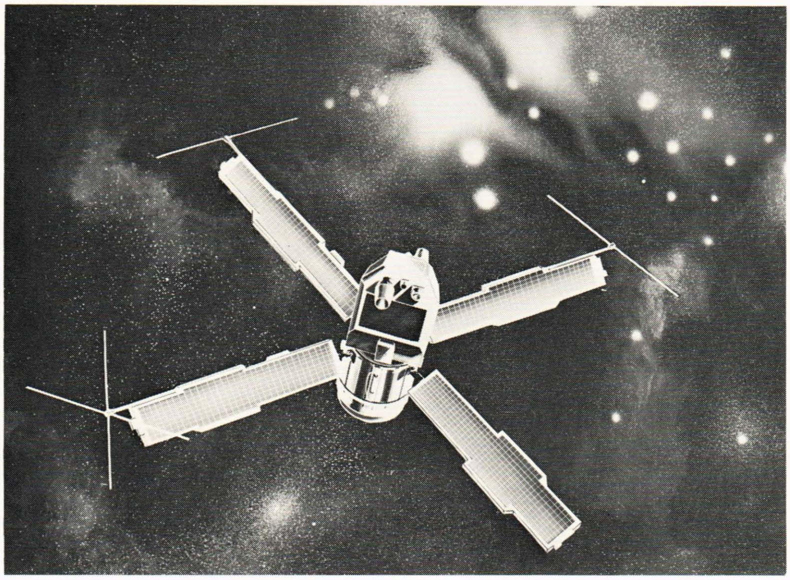
However, two trends may be noted. The first is a continuing and increasing effort to explore and apply techniques of design and fabrication that ensure that devices and assemblies developed by APL will function properly and reliably in the environments in which they are to be used. These environments may be a satellite orbit, a ship at sea, an advanced aircraft, or a clinic in a hospital. This has led to increasing use of new techniques such as microelectronics and the meticulous design, instrumentation, and test of mechanical devices. Experience has shown that problems in this field call for imagination, ingenuity, and disciplined effort that are as challenging and interesting to scientists and engineers as are those involved in exploratory work on novel devices. An interesting result of this effort is to be seen in the experience with the Navy Navigation Satellites, OSCARS 12, 13, and 14, which were built at the Laboratory and which now have an accumulated operating life of seven years and three months. The operational availability of these satellites is well over 99.95%, and together they have had one electronic part failure in nearly 119 million part hours of operation in orbit.

The second trend is towards the extensive use of computers and data-processing methods to investigate in detail the performance of operational systems, the effects of proposed technical and tactical improvements on this performance, and the design of new systems to satisfy realistic operational requirements. Proper combination of digital and analog computers with operational hardware such as radars, supplemented by realistic knowledge of environmental effects, such as those obtained by the recording equipment known as RAVIR (Radar Video Recording System), has proved to be such a powerful instrument in the investigation of systems used by the Navy that it has aroused serious interest and support in other agencies of the Department of Defense and, indeed, other departments of the Government. The results of both these trends are evident in the prototype of an advanced radar which went into operation this year, and which sets new standards of reliability and performance. Thanks to methods of design and design analysis, this sophisticated assembly of equipment required very little modification to put it in complete operation.

On March 4th, 1969, the Secretary of Defense, Mr. Laird, in an official communication to Secretaries of all other Departments in the Federal Government, placed at their disposal the services of Federal Contract Research Centers such as the Applied

Physics Laboratory for the solution of problems arising in areas of their cognizance. It was emphasized that this offer did not imply reduced support of these centers by the Department of Defense, but suggested that, if the other departments wished to avail themselves of the knowledge and experience gained by the centers at no expense to DOD, they were invited to do so. Even before this letter, representatives of the Departments of Health, Education and Welfare, Transportation, and Housing and Urban Development had approached the Laboratory with some of their problems, requesting any suggestions we might have concerning their solution. The Laboratory is very interested in working with these departments and is anxious to establish areas of mutual interest wherein the competence of the staff of APL is uniquely fitted to contribute. One or two such areas have been found. Indeed, you will recall from my report of last year that an interesting and mutually fruitful relationship had been established with the Department of Transportation in the field of urban transportation development. This relationship continues to grow.

For many years now the Laboratory has received substantial support from the National Aeronautics and Space Administration in the development of satellites for scientific explorations, and in the solution of some communication problems associated with the Apollo flights. We recall the Beacon Explorers, BE-B and BE-C, and the Direct Measurement Explorer, DME-A, which are still providing scientists throughout the world with data concerning the ionosphere and the high atmosphere, as well as the geodetic satellites, GEOS I and GEOS II, which, together with the TRANSIT or OSCAR Navy satellites, have revolutionized our knowledge of the Earth's gravitational field. At present, the Laboratory is working with NASA in the development of what are called Small Astronomy Satellites, that is to say small, relatively inexpensive satellites that carry into orbit a single significant observational instrument. The first of these, SAS-A, is designed to carry an X-ray telescope developed by the American Science & Engineering Corporation. The control system of this satellite contains very novel features. Its construction is proceeding on schedule and it will be launched from a platform close to the equator on the east coast of Africa in June 1970.



Artist's concept of Small Astronomy Satellite.

With support from the National Institutes of Health, and in cooperation with The Johns Hopkins Medical Institutions, the scope of the Laboratory's Biomedical Engineering investigation is increasing steadily. A very interesting joint project with the Wilmer Opthalmological Institute has come to fruition in the form of an Argon Ion Laser which can supply an intense continuous beam of light in the blue green region where absorption by blood is high and which can be focused to diameters as small as a few microns. With this instrument, small blood vessels whose growth in the retina or adjacent areas of the eye are impairing the sight can be coagulated and inhibited. After extensive tests on animals, it has been used on human patients with exceedingly beneficial results.

An important event in the scientific life of APL occurred on August 9th, 1968, when, after an almost incredible series of negotiations which could contribute interesting reflections on the current government scene in Washington, the IBM-360/91 computer went into operation. This computer, one of the highest capacity and speed in the world, provides "time sharing" on a large scale for many governmental agencies. It also provides a mechanism for the simulation and development of complicated systems in order to estimate their performance before commitment to costly hardware. A "graphics" attachment to this computer allows an engineer to design electron circuits providing him with quantitative values of performance to be expected from the components he has assembled on the drawing.

There follows a short description of some other interesting results which have come from the Laboratory's work during the year. The list is by no means exhaustive but illustrates the type and variety of studies in the research and development area.

Space Physics

After more than two years, the many instruments carried on the DODGE satellite continue to send back excellent data from a nearly synchronous orbit. The gravity gradient stabilization system has amply demonstrated its capability to maintain the attitude of the satellite within close limits at an elevation of 20,000 miles. For a period of six months during the year, the mean fluctuations in attitude were 5° in pitch, 10° in yaw, and 5° in roll.

Analysis of the data obtained from a triaxial set of flux gate magnetometers carried aboard DODGE has made it possible to detect hydromagnetic waves in the vicinity of the satellite that are the source of continuous geomagnetic pulsations observed on the ground. For the first time, hydromagnetic waves, long suspected of being the source of PC-1 micropulsations with periods varying from 0.2 to 5 seconds, have been observed at 20,000 miles above the earth and will be invaluable in understanding the physics of the magnetosphere.

The GEOS I satellite moves in a very eccentric orbit and carries highly stable, temperature controlled, crystal oscillators to provide high quality data for geodetic measurements. The combination of these two properties of GEOS has presented an opportunity for observing the relativistic effect on its oscillator (or clock). In travelling along such an eccentric orbit, the satellite senses significant changes in the Earth's gravitational field and its velocity changes greatly as it moves from perigee to apogee. According to relativity theory, these variations should cause a periodic change in the observed frequency of the radio signals from the satellite, which has a period precisely equal to the anomalistic period of the satellite. A relativistic formulation of the doppler shift in a satellite's signals was developed and coded for the Orbit Improvement Program, which was then used in conjunction with a four-day span of data from GEOS I, obtained by the Tranet tracking system. This experiment established the presence in the doppler data of an oscillation with the predicted frequency and amplitude, and constitutes an independent verification of the special theory of relativity and the "principle of equivalence." The relativistic formulation of the doppler shift improves the theoretical model relating the doppler shift in the radio signals received from the satellite to the satellite motion, and its inclusion in the doppler tracking program improves both the accuracy of orbit calculation and the timekeeping capability of APL-built satellites.

General Physics

Faraday Rotation of a Far-Infrared Laser Beam by a Plasma—In recent years research at the Laboratory has shown that lasers using gaseous hydrocyanic acid and water can be used to generate radiation in the far-infrared regions, wavelengths of 337,117, and 69 μm being prominent. These have now been used to investigate the internal field density and the internal magnetic field of magnetically confined plasmas by a combination of simultaneous measurements of Faraday rotations and changes in amplitude of the radiation transmitted through the plasma. Measurement of the signal transmitted is necessary to resolve the rotational effects from refractive effects. Small "theta-pinch" plasmas in the density range of 10^{13} to 10^{17} particles per cubic centimeter gave Faraday rotation angles up to 50° which were measured with an accuracy of something better than 10 percent.

Amorphous Semiconductors—An understanding of amorphous solids in which the atoms are not arranged in regular order remains one of the unsolved problems in solid-state physics. Many substances are amorphous only in the form of thin films whose properties are hard to investigate. Recently a group at the Laboratory has studied the effects of high electrical fields on thin amorphous films of boron, germanium, and silicon with a view to understanding the amorphous state and possibly finding electronic devices that operate under different conditions than do crystalline devices. They have found that in common with other more complex amorphous films, e.g. chalcogenides, the elemental semiconductors mentioned above, show transitions from a high to a low impedance state as the voltage across the film is raised. Two "switching" effects have been recognized—a threshold switching effect where a sustaining current is needed to keep the substance in the low impedance state and a memory switching effect where no sustaining effect is needed. The effects seem to be quite general.

Engineering Research

High-Speed Data Transmission—A real-time data-compression system for Apollo telemetry has been developed and demonstrated. This system transforms the information in a data stream of 51,200 bits per second so that it can be transmitted over two telephone lines, each with a capacity of 2,400 bits per second. This is believed to be the first real-time telemetry compression system developed to the point of actual operation. It is also noteworthy in being about twice as efficient as alternative schemes previously proposed. One element increasing the efficiency is a nearly optimum method of locating points in the telemetry format corresponding to changes of telemetered functions. A second element is the use of only two bits to indicate a minimum change of function value, which occurs more often than larger changes. In tests and demonstrations based on representative passes of Apollo vehicles over tracking sites, data were compressed and transmitted with less than 0.4% allowable error, using two telephone lines, or in some cases, only one telephone line.

S-Band Phased-Array Antenna—Phased-array antennas tend to be costly because of the large number of components that go together to make up the total array. Careful attention to design features, component selection, and quality control is necessary to assure high performance and reliability. An S-band module, or basic unit, has been developed. This basic unit consists of a power divider, phase shifters and drivers, monitoring equipment, and a radiating aperture. Emphasis has been placed on use of inexpensive components, producibility, and reliability while maintaining high performance.

For this program, a line array with steering in azimuth only was required. Sixteen basic units were built and arranged in a line. A rather complex beam-forming network was developed so that both sum and difference patterns could be obtained independently and with minimum loss. All of the array components were developed and built at the Applied Physics Laboratory. To prove production techniques, electronics assemblers were trained to assemble phase shifters, drivers, and power dividers. All of the microwave components were tested at high power levels in addition to the standard low level tests. With the component tests complete, the sixteen basic units and the beam-forming network were assembled into an array. Antenna pattern measurements showed good performance, with beams steered up to 60° from the array normal. Then a beam-steering computer was added, and once again good patterns were obtained. The array is presently being mated with an experimental radar.

Studies of the Lower Atmosphere

To make meaningful comparisons between the apparent structures seen in the clear atmosphere with ultrasensitive radars and the actual physical structure, an airplane is required that has fine-scale instruments capable of obtaining simultaneous measurements of the same volume of the atmosphere.

An airplane has been equipped with meteorological sensors and recording and telemetry equipment for use in the Clear Air Turbulence Program. A specialized need of that program is to measure the fine-scale structure of temperature, moisture, refractivity, and of wind structure down to sizes of the order of 1 centimeter. To obtain such small-scale measurements, the airborne system was designed with a frequency response usually attainable only in wind-tunnel systems, and advanced sensing techniques were used to measure each of the parameters. A number of flights have given a copious store of excellent data concerning the physical phenomena occurring in regions of the atmosphere that were simultaneously being observed by the Wallops Island radars. The gigantic task of extracting the maximum knowledge and understanding from these data is proceeding satisfactorily.

Information Activities

Reports and Papers—Approximately 125 unclassified and 100 classified formal technical reports were issued by the Technical Reports Group, about 200 formal Polaris, Poseidon, and Pershing classified reports were issued by the Polaris Division, and 102 papers were published in professional journals. In addition, several thousand informal documents on a wide variety of topics were issued, largely by the individual Groups. One hundred and twenty-one papers were presented by staff members before scientific, engineering, and lay societies, of which 24 were presented abroad.

Library—An increased use of microforms for the journal and report literature has limited the physical growth of the collections which now include 41,000 bound volumes and 300,000 technical reports. Equipment for reading microforms is located in the libraries and throughout the Laboratory. Special equipment has also been installed for producing full-size copies from microfiche and microfilm.

The information retrieval system, utilizing DDC and APL tapes, has been converted to the IBM-360/91. A computerized circulation control system has been developed and studies are in progress for automating acquisitions and serials control activities.

Twenty-four bibliographies were compiled and 166 technical translations, primarily Russian, were completed. A new, expanded edition of the *Journal Holdings in the Washington-Baltimore Area* was published. Listing over 5,000 titles, it now includes the holdings of 41 participating libraries, an increase of 14 from the previous edition.

Colloquia—The Colloquium series continued this year with twenty-eight programs, three of which were presented by members of the Laboratory staff.

Patents—During the year, 77 inventions were disclosed to the Department of the Navy, 29 patent applications were filed, and 31 patents were granted.

Chemical Propulsion Information Agency—Highlights during the past year include the initiation of analytical reports relating to significant phases of propulsion technology, the automation of the Agency's data base, and the addition of technical capability in the area of air-breathing propulsion.

In its regular complete information program, CPIA produced 18 publications covering all aspects of chemical propulsion. In addition, nine issues of *Chemical Propulsion Abstracts* and updating revisions of the four basic CPIA propulsion manuals were issued. As in the past, these publications were distributed to all of the major propulsion RDT&E organizations in the government and in industry.

Staff Activities

Evening College Program at APL

During the past academic year, the Evening College Center continued to expand. The number of courses offered has increased from six in the Fall of 1964 to 24 scheduled for Fall 1969. Summer courses, which began in the Summer of 1967, have been continued.

When the MSEE degree program began at the Laboratory in 1964, APL staff members constituted 65% of the student body, but since the Fall of 1966, the proportion of participants from outside the Laboratory has exceeded the number of APL staff members. In the Fall of 1968, three out of every four students at the APL Center came from outside the Laboratory. The total number of individuals enrolled increased from 116 in 1964 to 457 in 1968.

One hundred and four persons who attended classes at the APL Center have now received master's degrees; 55 have received the MS degree with a major in Numerical Science, and 49 have received the MS degree with a major in Electrical Engineering. No one yet has received the degree of Master of Science with a major in Applied Physics or Space Technology, initiated in the Fall of 1967, but two or three graduates are expected by June 1970.

Fellowship Program

Mr. I. Katz held the William S. Parsons Fellowship for the year 1968–69, and Mr. V. W. Pidgeon was awarded the Fellowship for 1969–70; Dr. E. P. Gray held the William S. Parsons Professorship for 1968–69.

Three Applied Physics Laboratory Fellows have worked on their programs this year. Mr. W. P. Widhelm completed the requirements for the Ph.D. degree in June 1969, and Mr. C. L. White and Mr. R. E. Keeler worked on their dissertations.

Personnel Changes

The Laboratory staff increased from 2519 as of June 30, 1968 to 2535 as of June 30, 1969. There was a gain of 30 in the Senior professional staff bringing the total to 674, and a loss of 14 in the Associate staff, making the new total 563.

Administrative Activities

Approval of New Trust Agreement

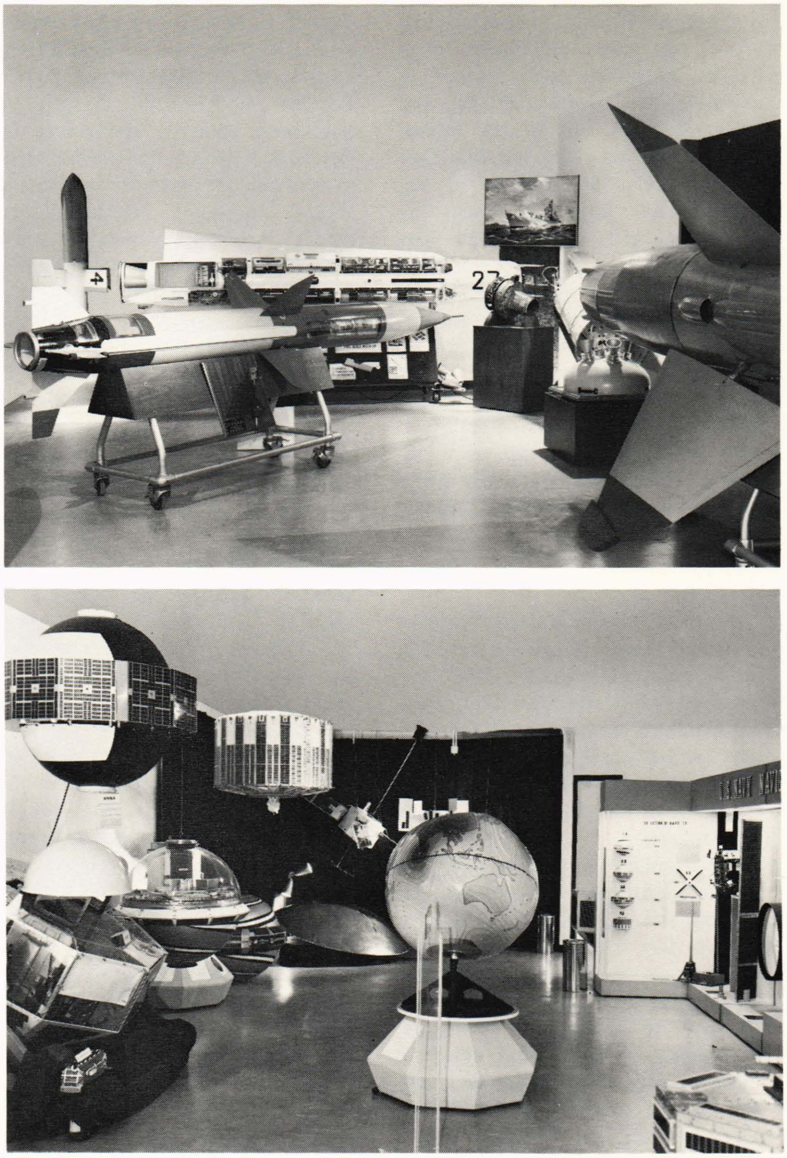
After many months of careful consideration by representatives of the Ordnance Systems Command and the Laboratory, and after authorization by the Office of the Secretary of the Navy and the Executive Committee of the Board of Trustees, Admiral Gralla and Dr. Gordon, on December 13, 1968, signed an historic agreement providing for the continuation of the Applied Physics Laboratory as a national resource.

Building Program

The new extension to the Director's Wing was completed and occupied. The additional 1900 square feet provide space for a larger conference room, several additional offices, and improved access to the West Wing of Building 1.

A 2000-square-foot extension to the Satellite Command Injection Station was completed and equipment installation is in progress.

A large Anechoic Chamber was completed and is in full operation in support of radio frequency research and associated hardware design.



Some of the exhibits featured at the Open House.

APL Family Open House

On Saturday, October 26, 1968, nearly 7,000 APL staff members, their families, and friends attended an open house that featured 95 exhibits on the Laboratory's past accomplishments and present work. There were satellites, missiles, electronic games, a show of scientific wizardry for the children, and displays covering the Laboratory research in such areas as lasers, plasma physics, and biomedical and satellite engineering. Refreshments were served at three locations throughout the day and afforded a chance for families to relax, meet, and renew acquaintances. Many Navy and University people took advantage of the opportunity to see the various areas of the Laboratory and the exhibits which had been assembled.

This is the last report that I shall have the pleasure of writing to you as Director of the Applied Physics Laboratory. I retire at the end of the year and I am delighted that Dr. Alexander Kossiakoff has accepted the responsibilities I now relinquish.

R. E. Gibson
Director

June 30, 1969