Excerpts from the REPORT of the DIRECTOR *of the Applied Physics Laboratory*

JULY 1, 1966—JUNE 30, 1967

TO THE PRESIDENT OF THE UNIVERSITY:

Technical Activities

The general pattern of the Laboratory's technical operations has not changed greatly from that described in my last report. The effort is concentrated in four principal areas: (1) Fleet Air Defense, (2) Evaluation of Fleet Ballistic Missile Systems, (3) Space Systems Development, and (4) Supporting Research and Exploratory Development. In each field the Laboratory seeks to bring to bear the scientific method and teamwork among experts in a broad spectrum of technical disciplines, to the solution of problems of national significance.

R. E. Gibson, Director

FLEET AIR DEFENSE

Since the founding of the Laboratory in World War II, the defense of ships from air attack has been a central objective. After the highly successful development and employment of the radio proximity fuze in 1944, the Laboratory undertook the broader task of developing guided missiles to surpass the effectiveness of guns by an order of magnitude. Following development of the Talos, Terrier, and Tartar missiles and their tactical deployment, the Laboratory was asked to assume technical responsibility for solving problems encountered in the associated shipboard fire-control systems.

Improvement of Operational Systems.—The program to bring the performance and reliability of shipboard systems and missiles to their inherent design capability has now been virtually completed and the resulting modifications installed in a substantial fraction of the Fleet. In the meantime, steps have been taken to meet new requirements imposed by advancing capability of potential enemy attack weapons. In particular, a program of near-term electronic counter-countermeasures development has been completed, resulting in a series of equipment modifications which will significantly improve the capabilities of ship systems. After test and evaluation in early 1968, these improvements will be available to the Fleet. Modification kits, incorporating a number of significant counter-countermeasures improvements into Tartar and Terrier homing missiles, have been produced in quantity and installed. Concurrently, we have assisted the Fleet by preparing special publications which enable maximum effectiveness in the use of equipment as it is currently configured. The Standard Missile, originally designed in large part by the Laboratory, is now in production and will eventually replace Terrier and Tartar missiles. A notable feature of the design is that no periodic tests aboard ship will be required to insure readiness.

Radar Technology.—Research in search radar technology, recently begun at the Laboratory, has resulted in two significant accomplishments. A video processor has been demonstrated to improve markedly the performance of conventional search radar in the presence of radar reflections from rain, clouds, land, and other types of clutter. The positive suppression of spurious radar noise effected by this device has made it possible to develop a simple, automatic, tracking program using a small general-purpose digital computer. Together, these developments promise significant enhancement of ship system effectiveness at modest cost. Natural clutter, a significant phenomenon in all radar applications, is being investigated in several fundamental ways. Extensive data have been acquired on sea surface clutter during tests in the unique environment available at Aruba in the Netherlands Antilles. The reflectivity and scattering effects of precipitation are the subject of continuing experimentation at Howard County.

Advanced Surface Missile System.—In connection with the Navy's Advanced Surface Missile System, the Laboratory has completed detailed definition of the "baseline system" which constitutes a standard or point of reference for system development by an industrial contractor. The Laboratory is pursuing the design to experimental demonstration stages in the areas of radar signal processing and missile guidance. The radar will employ a multifunction phased array system quite similar in function to the Typhon radar, but taking advantage of major reductions in weight and cost brought about by recently developed microwave components. The Laboratory will also be responsible for system simulation and for integration with other ship systems, particularly the command and control aspects.

FLEET BALLISTICS MISSILE SYSTEMS

The Laboratory's primary function in the Navy's Polaris program is technical evaluation of the operational weapon system, both before and during operational deployment. In order to insure the maximum possible effectiveness of this highly important system,

the Navy authorized the Laboratory to develop, define, and implement a testing program far more thorough than had ever been employed on any previous system. The effort required scientific analysis of all factors affecting system performance and reliability. It was necessary to quantify effects expected from environmental conditions, determine the system characteristics requiring measurement, and to develop practical techniques for measurement. It also required application of experience gained in the anti-air missile program on operator capabilities, conduct and analysis of shipboard tests, hardware reliability problems, and a host of other practical knowledge.

Planning and analysis of system tests provide invaluable insight into technical and military problems encountered under operational conditions. The Navy has encouraged the Laboratory to seek solutions to such problems, particularly where we can conceive promising approaches. A recent area of interest is that of submarine defense. Applying experience gained in missile and radar systems, improvements have been developed and introduced into one type of sonar set to greatly enhance bearing accuracy. Several other new ideas in the sonar area are being explored experimentally.

At the request of the Department of Defense a similar, though more limited, evaluation program has been organized by the Laboratory for the Army's Pershing Missile System. System Demonstration and Shakedown Operations, Operational Tests, and Weapon System Readiness Tests have been developed and conducted, patterned on techniques used for the Polaris System. Data have been accumulated from such tests and Field Alert Status Reports have been prepared comparable to the Polaris patrol reports. Many of our recommendations are being incorporated to improve the reliability and readiness of the deployed operational systems.

Space Systems Development

The Laboratory's program in Space technology originated with its invention and development of the doppler system of navigation by space satellites. This resulted in the successful development by the Laboratory of an operational Navy Satellite Navigation System. The system has been in full operation for the past three years. Development involved the establishment of a worldwide satellite tracking system, major advances in geodesy, invention of new techniques for passive attitude stabilization, thermal control, ultra-precise frequency standards, a new packaging technique for integrated circuits, and development and construction of receiving equipment for a variety of applications. The experience and facilities built up in the development of the Navigational Satellite System have been applied more recently to several programs for the National Aeronautics and Space Administration and to the design and construction of a satellite to demonstrate gravity gradient stabilization at synchronous altitudes.

Navigational Satellite System.—The effort in support of the Navy Navigational Satellite System this year has consisted mainly in helping the Navy establish an industrial source for producing satellites, and building four operational satellites (OSCARs 11, 12, 13, and 14) to maintain the system at full capability until the new contractor (RCA) begins production. Both of these tasks have proceeded successfully. The system itself is performing in a gratifying manner. The users at sea report enthusiastically on the accuracy and reliability of navigation. The Navy is contracting for equipment for additional Fleet installations, and the government has released the technical data for commercial use. At the Laboratory, work is proceeding on development of items for the second-generation satellite, a new configuration with longer life and improved performance.

Work is being done on the aircraft application of the Navigation Satellite System. Flight tests showed that navigation fixes obtained from satellite passes in flight can be used to correct a large part of the error accumulated in flight by an inertial navigation system. In another area of application manportable battery-operated receiving equipment has been successfully demonstrated with prototypes developed at the Laboratory. Using a pair of "Backpack" equipments, the distance between two points (based on simultaneous reception of a satellite pass) has been determined with an accuracy comparable with, or superior to, that obtainable by current field-survey methods, and in a small fraction of the time required for conventional survey.

NASA Satellites.—The Laboratory has continued work for the National Aeronautics and Space Administration in two fields, spacecraft and space science. The Beacon Explorer, Direct Measurement Explorer, and the Geodetic Satellite, GEOS-A, are in orbit and performing their design missions. GEOS-B is complete and scheduled for launching next year. A new satellite development has been started with the objective of carrying an X-ray telescope for making the first satellite mapping of X-ray sources. The American Science and Engineering Inc. is building the telescope, while the Laboratory is designing the spacecraft and communications. This is expected to be the first of a series of Small Astronomy Satellites to serve as platforms for a variety of experiments.

The DODGE Satellite (Department of Defense Gravity Experiment).—The objective of the DODGE program is to make a complete investigation of the feasibility and performance of gravity-gradient stabilization of a satellite at near-synchronous altitudes (upward to 18,000 miles). Attitude stabilization is important for communication, weather, and other satellite systems where antennas or cameras need to be pointed toward the earth. The DODGE satellite has been built to test two alternative configurations of controllable booms and two different and controllable damping systems. Two cameras are provided to give accurate directional data by televising the earth, and precise magnetometers are installed for measuring variations in the earth's field to calibrate the functioning of the magnetic damping. The results of this experiment should lay the basis for future application of gravity gradient stabilization. This satellite was completed and launched successfully on July 1, 1967.

Supporting Research and Exploratory Development

Aeronautics.—The work in aeronautics has continued to be concentrated on development of advanced air-breathing propulsion systems. Special effort has been devoted to improving the efficiency of solid propellant rocket motors by air augmentation techniques. The achievable range and speed of tactical missiles may be significantly enhanced by mixing air with boron-rich exhaust gases. The Laboratory has compounded a new fuel which can be used in such a burning mode, and it has yielded predicted gains in efficiency on a test model basis. This work is expected to permit dramatic improvement in the capability of the next generation of tactical missiles.

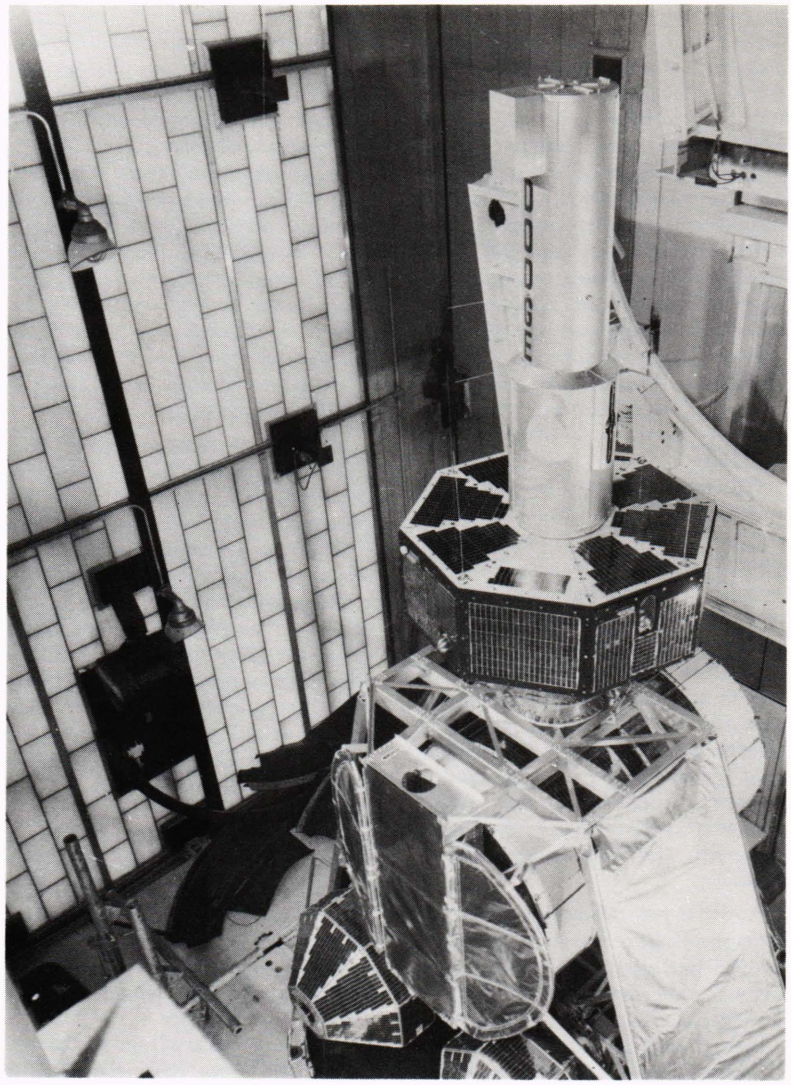
The Laboratory is exploring advanced missile technology in a number of additional ways. Ramjet technology has been refined through studies of transverse injection in supersonic flow, modelling the thermodynamic cycle of ramjet operation, and research and experimentation on external burning in supersonic streams. The test facilities have been steadily improved through various innovations in equipment and instrumentation.

Research Center.—The application of electron spin resonance techniques to the study of chemical reactions involving free radicals has continued. An extensive invited review paper has been written on the theoretical interpretation of electron spin resonance spectra of paramagnetic species trapped in solid matrices or absorbed on surfaces.

In another theoretical effort a free-flight theory of gas transport properties has been developed which, in its most accurate form, agrees essentially with the Chapman-Enskog theory. The initial approximations are much superior to the old mean-free-path theory. In particular, a thermal diffusion effect is predicted in the zero'th approximation. This is made possible by an accurate historical accounting of the possible trajectories of molecules traversing a gas.

A method has been developed using electron spin resonance detection of atoms and free radicals for the precise measurement of atom-molecule reaction rates over a wide temperature range (250–1000°K). A number of important elementary reactions have been studied in this way. This method is now refined to the point where these difficult measurements are quite reliable and precise. This improvement in the measurement technique has allowed theoretical interpretation of the experimental results to be made with considerably more meaning than before.

Results were obtained from a series of experiments on the detection of microwave emission from semiconductors under the influence of externally applied electric and magnetic fields. The semiconductor sample used was a rectangular bar of n-type indium antimonide (InSb) mounted in a rectangular waveguide. Under the influence of an electric field in the range of 100-200 V/cm and a magnetic field up to several kilogauss, microwave emission in the frequency range of 6-100 GHz could be detected at various sample temperatures. While this type of microwave-emission phenomenon has been generally known for several years, the present work contributes a number of observations which are significantly different from previously published results. It is shown here that the emission spectrum of InSb has a much wider temperature range than reported before (up to 250°K instead of 77°K). It has also been observed in this Laboratory that there is a delayed microwave emission after the removal of electric field pulse in an axial magnetic field or at liquid helium temperatures.



The DODGE satellite is shown at Cape Kennedy, mated to a Titan III-C vehicle and being prepared for its launching July 1, 1967.

Cooperation with The Johns Hopkins Medical Institutions.—The collaborative effort of the Laboratory and the Medical Divisions has matured by the establishment of an active program in ophthalmology and in study of further areas for cooperation. Joint programs in biomedical image processing and heart pressure instrumentation have been formulated, and a program in cardiovascular system and instrumentation research is being explored.

Several of the efforts already have produced results. A device is now in use for investigating the compliance of the heart by means of a balloon-tipped catheter inflated by a fast hydraulic servo to control chamber volume. A new instrument has been constructed which will measure the inflow and outflow of fluid to the eye while maintaining a predetermined pressure or pressure variation. Data on the pressure-volume

relationship of the rabbit eye in vivo and in vitro are being analyzed and prepared for publication. An optical device for generating a three-dimensional display of a volume from a set of X-ray pictures has been demonstrated. This latter device has potential for providing high resolution X-ray examination of volumes for which present techniques have inadequate resolution or require excessive X-ray exposure.

In another area, theoretical and experimental studies of nuclear medicine scanning systems have resulted in a capability for examining variation of performance as a function of scanning system design parameters. First measurements, varying administered radioactivity and scan time, are being prepared for publication.

Satellite Explorations in Astrophysics and Geophysics.—Two studies designed to improve the determination and prediction of the orbits of Navy Navigation Satellites have yielded interesting results this year. Analysis of the results of the tracking of satellites using the doppler shift effects from stations distributed all over the world has resulted in a significant refinement of the model of the earth's gravitational field, sometimes called the "figure of the earth." Some 240 coefficients in the spherical harmonics of the earth's field have been determined. This gives a three-fold increase in tracking accuracy and consequently in position determining.

In order to obtain the most accuracy possible in this system, it is necessary to know the refraction of radio waves in the troposphere. A more refined model of tropospheric refraction has been developed. A model of the ionosphere also has been developed which, although admittedly over-simplified, does give good correlation of the variations in the ionosphere observed during the pass of a satellite.

The large 60 ft. reflecting telescope at the Laboratory has been used in conjunction with a swept frequency receiver working between 400 and 900 MHz to obtain emission spectra from the sun. A number of significant events have been noted and correlated with photographs of the sun taken with Hα radiation.

After more than four years, APL Satellite 5E-1 (1963-38-C) still continues to give out reliable data concerning the earth's trapped radiation in the inner and outer zones, solar radiation and geomagnetic phenomena. The long life of this satellite is enabling us to compile a time history which grows more valuable as time goes on. During this year, a study of the decay in the artificial radiation belt produced by the Starfish explosion in July 1962 has been continued with quantitative results. In addition, an increase in the lower energy particles (less than 1 mev) has been observed in the inner radiation zones. A particularly sharp increase has been correlated to the solar flares of September 1966.

The frictional forces that cause the earth to slow down also affect the apparent motion of the node of a satellite orbit. By study of the behavior of the nodes of polar satellites in the Navy Navigational Satellite System, the friction forces have been estimated by members of the Laboratory. As determined in this way these forces appear to be somewhat smaller than those estimated from the times of ancient eclipses, though the difference is not great.

In addition, by combining these estimates with figures for the earth's rotational velocity during the past 400 million years, found by study of the growth lines in fossils, it is concluded tentatively that the earth is expanding and the universal gravitational constant is decreasing.

Research Projects for ARPA.—The relationship with the Advanced Research Projects Agency (ARPA) in the Office of the Secretary of Defense has continued with considerable mutual benefit. Activities of note are the Laboratory's participation in underground nuclear testing of the vulnerability of certain vital strategic system components. In this area, APL has taken a leading position by virtue of coordination of its own work with that of the Army, Navy, and Air Force. The Laboratory has continued with its work on the national over-the-horizon experimental radar installation and has recommended (and had accepted) a site in Florida. It is now in the process of recommending a long-term experimental program. The Laboratory participated in the Technical Steering Group of a summer study on Advanced Surface to Air Warfare Systems (ASAWS) for the 1975-85 era. Efforts continued on acoustical methods of tunnel detection, on ablation by high speed particles, and on the further development of ferrite-switched phased subarrays.

Information Activities

Reports, Papers, and Patents.—Approximately 150 unclassified and 125 classified formal technical reports were issued by the Technical Reports Group, about 250 formal Polaris and Pershing reports were issued by the Polaris Division, and 79 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.

The *APL Technical Digest* continued into its sixth year of successful publication. The May-June 1967 issue (Vol. VI No. 5) was devoted entirely to a discussion of the DODGE satellite with particular emphasis on the camera system. This Department of Defense satellite was launched successfully on July 1 and the cover picture of the May-June *Digest* was a photograph of the earth taken by the APL-developed cameras from a distance of 18,000 nautical miles.

Ninety-six papers were presented by staff members before scientific, engineering, and lay socieites. Of these, 16 were presented abroad.

The APL Colloquia continued this year with 23 meetings. All of the speakers except two were from outside the Laboratory.

During the year 101 inventions were disclosed to the Department of the Navy, 22 patent applications were filed, and 34 patents were granted.

Library.—The APL Library service is furnished by a Reference Library and a Document Library. Both are making extensive use of the APL computing facilities, not only in routine record keeping but also in research efforts.

Especially noteworthy during the past year was the establishment of a Computing Science Information Center last January in the Computer Building as a branch of the Document Library. This is partly in anticipation of future broadening needs for computer information throughout the Laboratory.

Chemical Propulsion Information Agency.—During the year, in its regular information program, CPIA produced 52 publications covering all aspects of chemical propulsion. Also nine editions of the Chemical Propulsion Abstracts and updating revisions of the four basic CPIA propulsion manuals were issued. CPIA also assisted the Interagency Chemical Rocket Propulsion Group (ICRPG) in conducting two

major annual propulsion meetings and 18 specialized meetings.

CPIA is continuing to submit structural formulas for inclusion in the U. S. Army Chemical Information and Data System (CIDS). The CIDS and the "chemical typewriter" program hold great promise as a mechanized, time-saving combination that will improve our ability to provide in-depth indexes, informative abstracts, and retrospective searches to the chemical propulsion industry.

Staff Activities

EVENING COLLEGE PROGRAM AT APL

The University Evening College Center at the Laboratory continued the strong growth it has shown in the past. The number of courses offered has increased from six in academic year 1964-65 to nineteen scheduled for 1967-68.

The new M.S. degree program (with a major in Numerical Science) attracted 102 candidates in its first year. At the same time interest continued in the M.S. program with a major in Electrical Engineering; 72 candidates enrolled for that degree. Two additional M.S. degree programs were approved for 1967-68. One is with a major in Applied Physics and the other is with a major in Space Technology.

The first summer courses in the Evening College were offered at the Laboratory during the summer of 1967 with a total enrollment of 58. It is planned to continue summer sessions because such offerings can materially shorten the length of time required for a degree.

FELLOWSHIP PROGRAMS

Dr. Ernest P. Gray, a physicist on the Principal Professional staff and Chairman of the APL Colloquia, was named to the second William S. Parsons Professorship at the University and Dr. Vivian O'Brien and Mr. John R. Apel were awarded the William S. Parsons Fellowships. These appointments are for the 1967-68 academic year. Five graduate students from the University are working toward the Ph.D. degree on APL Fellowships. It is expected that one of these Fellows will complete his work in September 1967.

Administrative Operations

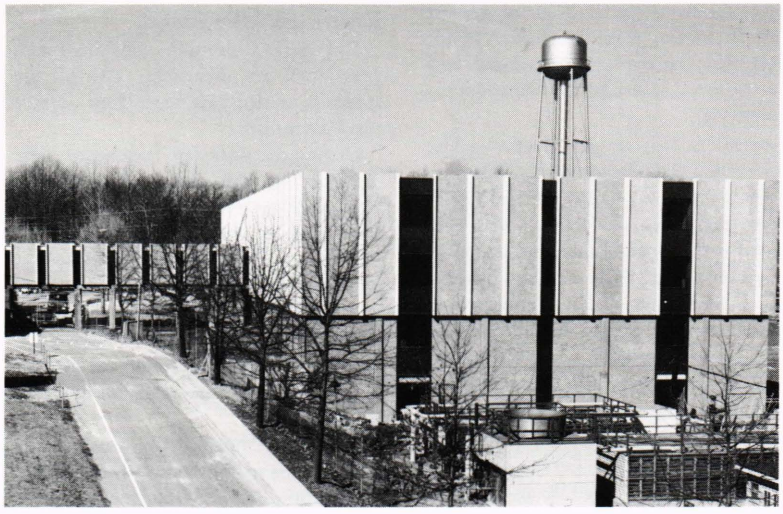
ORGANIZATIONAL CHANGES

There were no significant changes in the administrative organization of the Laboratory during the fiscal year. The Administrative Systems Office, which is under the cognizance of the Administrative Services Manager, continued the task of reviewing administrative procedures with the aim of improving and codifying them. Over the past year a number of procedural manuals have been issued including manuals on Safety, Purchasing, Subcontracting, and Stockroom Operations. To simplify administrative controls, the Teletype Project was transferred from the Office Services Group to the Space Development Department which utilizes approximately 90% of the Project's efforts. Cognizance of the Laboratory's stockrooms was transferred to the Plant Services Group to centralize under one administrative head all of the Laboratory's stockroom activities.

BUILDING PROGRAM

A major laboratory and office building has been under construction as noted in the report for last year. Construction has proceeded on schedule and it is expected that occupancy will begin in late February 1968, and will permit the release of rented space in Silver Spring as well as relieving current overcrowding at the Howard County Laboratory.

R. E. GIBSON
Director



New laboratory and office building (Building 6) that was completed on schedule in February 1968.

APL COLLOQUIA

Jan. 5—"Stimulated Raman Effect," by Nicolaas Bloembergen, Harvard University.

Jan. 12—"Ablation Cooling," by Edward W. Ungar, Battelle Memorial Institute.

Jan. 19—"Biomedical Engineering from Different Viewpoints," by Richard J. Johns, The Johns Hopkins University.

Jan. 26—"The Use of Technology for Solving Urban Problems," by Robert C. Wood, Department of Housing and Urban Development.

Feb. 2—"The Puzzling Radio Signals from Interstellar Hydroxyl Radicals," by Alan H. Barrett, Massachusetts Institute of Technology.

Feb. 16—"Explosive Production of Multi-Megagauss Fields and their Application," by Clarence M. Fowler, Los Alamos Scientific Laboratory.