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

July 1, 1967 – June 30, 1968

To the President of the University:

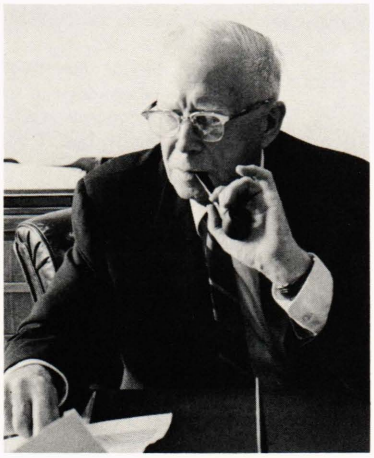
Technical Activities

The Laboratory's technical activities have continued with extensive and complementary programs in fleet air defense, evaluation of fleet ballistic missile systems, military and scientific satellites, and supporting research and exploratory developments. During the year the technical effort was distributed as follows: research—13%; exploratory and advanced development—20%; engineering—26%; system engineering and integration—17%; and technical evaluation of operational systems—24%. In each field the Laboratory has brought teams of scientists and engineers from a broad spectrum of disciplines to bear on the solution of problems of national significance.

Fleet Air Defense

Improvement of Operational Systems.—The Fleet Systems Division has recently undertaken a new high-priority program to improve the defense of existing naval ships against antiship missiles. The Laboratory serves as System Integrator for the Ship Anti-Missile Integrated Defense (SAMID) program. The main initial effort is to formulate the first increment of improved equipment and procedures for selected ship classes for early tests at sea.

The Ship Installation Group assists the Navy in the integration of the Basic Point Defense Surface Missile System aboard ships varying in size from destroyers to carriers. In support of this effort, the Group has studied the effects of ship motion on the performance of men and equipment. The Laboratory has also identified the new features



R.E. Gibson, Director

necessary for evolution of the Basic System into an Advanced Point Defense System, and has defined them in Performance and Compatibility Requirements for the radar, launcher, and weapon control systems.

A new type of test for system operability has been developed by the Weapon Direction Group to aid in maintaining a high state of weapon system readiness. The test, known as the Digital Daily System Operability Test (DDSOT), will be conducted routinely by shipboard personnel using a special digital program in one of the general purpose computers provided aboard ship.

The Laboratory has also prepared a comprehensive series of Performance and Compatibility Requirement documents for currently operational ship missile systems, with the overall objective of facilitating system integration and program management.

An operational data recording project was conducted at sea aboard a missile frigate by the Instrumentation Group using the APL-developed Radar Video Recorder (RAVIR), a device for recording and playing back radar data to reproduce displays of air traffic environments. This operation was the first at-sea recording of video representing major air operations, sea-air rescue, and combat air traffic under realistic combat conditions. It is now possible to evaluate such aspects of ship performance as target detection, tracking accuracy, reaction time and air-traffic-handling capability. The RAVIR equipment and tapes have also been used in training Fleet personnel in detecting and tracking targets, and the Laboratory is engaged in arranging for RAVIR equipment to be placed aboard combat ships as permanent training equipment.

Antiship capability of the Terrier, Talos, and Tartar missiles is being enhanced by analysis, engineering development, and tests. System modifications have been proposed and are being tested.

The Missile Systems Analysis Group is continuing a wide variety of analytical studies to provide a basis for realistic system tests and system integration programs. The analyses establish system capabilities and limitations, suitability of equipment application, evaluation of predicted effects, feasibility of intended procedures, definition and determination of required system tolerances, and evaluation of proposed modifications.

Missile Technology.—The Missile Systems Division is conducting programs to assess the capabilities of the Terrier, Tartar, Talos, and Standard Missiles, to provide design concepts and approaches for improving those capabilities, and to provide technical support to the Navy in the development, production, and deployment of these missiles.

Dynamic simulations by the Missile Performance Analysis Group and the Aerodynamics Group have been conducted to determine missile performance limitations for a variety of target tactics and environments and to establish the effectiveness of design improvements. An understanding of the nature and sources of target glint phenomena, a source of error in semiactive homing, has been developed by experimental measurements of target signatures by the Electronic Design Group and correlated with flight behavior through dynamic simulations. A design for reducing the effects of glint has been proposed.

More than seventy Standard Missile flight tests have been analyzed through the cooperative efforts of the Standard Missile Office, the Aerodynamics Group, and the Test and Evaluation Group to determine the degree of success and the causes of flight anomalies. Missile design changes have been expedited to preclude additional failures and to provide early introduction of necessary modifications into production. Warhead designs and experiments have been carried out to explore the feasibility of particular concepts, including augmentation of the terminal effectiveness of the Terrier missile against surface targets.

Fuze-warhead effectiveness studies by the Missile Performance Analysis Group have included formulation of missile performance requirements and a design concept for an advanced ordnance section for Standard Missile.

The adaptation of new missile designs and new components to older missiles to improve Fleet air defense capability is a subject of continuing study.

Techniques for simplification of the mechanical design of missile seekers have been under investigation. A direct drive torque-motor antenna-stabilized platform has been developed by the Missile Control Systems Group to replace the motor-clutch gear train version currently used in Standard Missile. Engineering tests on this model indicate very good performance characteristics and potential for reducing production costs. The Missile Control Systems Group is also studying techniques for simplifying and improving missile autopilot systems. Modifications for improving missile response time have been designed for the Terrier HT-3A and Standard Missile autopilots.

Radar Technology.—The necessity of coping with targets in unfavorable environments has led to special studies and the development of new procedures and equipment. The need for determining the effects of land background clutter has resulted in a number of studies and simulations of the effects of such clutter.

An adaptive video processor that enhances the visibility of targets obscured by clutter has been developed by the Radar Development Group. The processor uses a scaled average of returned signals to establish a threshold below which all extended clutter returns are suppressed, while discrete targets become visible. This processor has been evaluated on various radars with considerable success, particularly in three-coordinate radar systems.

Advanced Surface Missile System.—Development of prototype units of an advanced radar signal processor suitable for use with the Navy's Advanced Surface Missile System (ASMS), which is planned as the successor to Terrier, Talos, and Tartar, have been completed during the past year by the Radar Development Group and the Missile Electronics Development Group. Experience with these prototype designs has enabled the Laboratory to define technical specifications for a complete system and to design a "Baseline" system which will constitute a point of departure for industrial team proposals during the coming year.

A new Laboratory role under the ASMS Project Office, which will continue throughout the development of the Advanced Surface Missile System by industrial contractors, is the design of a total ship combat system. Integration of several weapons systems, including the new antiair warfare system, an antisubmarine system, a gun system, and possibly other new weapons systems, is to be accomplished on a single, multipurpose ship.

Fleet Ballistic Missile Systems

The Polaris Division continued its function as evaluator of the FBM Weapon System. This effort includes the analysis and evaluation of FBM submarine weapon system performance during Demonstration and Shakedown Operations (DASO) at Cape Kennedy, on tactical patrols, and in operational tests. Highlighting the DASO program during the year was the deployment of the USS *Will Rogers* which marked the last of the total fleet of 41 Polaris submarines. This readiness program is a continuing one, however, with the earlier-built submarines going through DASO again after having been refitted with more advanced missiles and equipment during shipyard overhauls. In addition, the Laboratory conducted the DASO and special studies for the first United Kingdom Polaris submarine, HMS *Resolution*.

An increasingly larger measure of effort was devoted to special studies and preliminary design and testing to solve technical problems affecting the performance of the total weapon system. Of special significance was sonar development work and investigation of sound propagation characteristics. To support the field testing of these new developments and techniques, the Laboratory acquired a larger sound boat during the year and equipped it with an underwater acoustic instrumentation system.

The Pershing Analysis Staff is continuing its analysis and evaluation of the U.S. Army Pershing Weapon System. This work includes planning, monitoring, data collection, analysis, and detailed reporting of test and firing operations.

Space Systems Development

The Space Systems Department continues a broadly-based research, development, and engineering program, including exploration of the upper atmosphere, design of satellites, and development of associated ground equipment.

Navy Navigation Satellite System.—The Space Radio Frequency Group has been active in development of new applications for the Navy Navigation Satellite System.

A portable high-accuracy receiver called "Geoceiver," applicable to gravity field measurements and worldwide precision surveying, is also under development by the Space Radio Frequency Systems Group. The Geoceiver can receive signals from both Navy navigation satellites and the

***White Cirrus II*, which is equipped with an underwater acoustic instrumentation system.**

NASA geodetic satellite GEOS. It can also be employed within the Navy's world-wide satellite tracking network.

A compact "backpack" navigation receiver was fabricated for installation aboard the Navy oceanographic ship USNS *Kane* to provide position fixes during continental drift studies. Design studies for the Bureau of Commercial Fisheries have demonstrated the feasibility of equipping free floating buoys with low-power receivers capable of measuring doppler shift and relaying the data to shore for computer determination of the buoy's positions.

Timing signals from the Navy navigation satellites have been used by stations of the operation and tracking networks as a means of setting clocks. In view of the interest expressed by the United States Coast and Geodetic Survey (USC & GS), a receiver was developed by the Space Operations Control Group for clock-setting especially for this purpose. Tests of the prototype were made at Wallops Island, Virginia, and demonstrated capability for timing precision better than 50 microseconds. A model unit is under construction at APL to the order of USC & GS; additional units are expected to be deployed to remote sites including Antarctica.

A design study has confirmed the feasibility of a microelectronics briefcase-sized dual-channel receiver for recovering time and doppler data from the Navy navigation satellites. Investigations of navigation satellite timing measurements indicate the feasibility of recovery of time data to better than a microsecond.

Scientific Satellites.—The Space Data and Control Branch is designing and developing a Small Astronomy Satellite (SAS) that will be adaptable to future scientific missions outlined by NASA. The design will be such as to require minimal changes to accommodate a variety of experiments. The first Small Astronomy Satellite (SAS-A) will include an X-ray experiment. The satellite will be launched by a Scout vehicle in early 1970 from the San Marco Launch Platform off the coast of Kenya. The Launch Platform is operated by the Italian Government.

The Space Data and Control Branch has also begun a study to provide a design for the SAS-B satellite. This will be the second satellite in the SAS Program and will support a gamma ray experiment. The experiment will provide a complete celestial survey for gamma ray sources and locate them with a precision of ± 0.25 degree.

The GEOS-2 satellite, the third geodetic satellite designed by the Space Development Department for NASA, was launched on January 11, 1968. The satellite has six different geodetic instruments: a doppler system; a flashing light system; C-band transponders; a range-and-range-rate transponder; a range transponder; and a laser reflector. APL transferred operational control of the satellite to NASA on February 20, 1968.

An experiment to determine the effects of prolonged weightlessness on sense of balance was developed for NASA Ames Research Center. Frogs will be used in the test. The experiment will be launched by a Scout vehicle from Wallops Island, Va., in early 1969 under the project title, "Orbiting Frog Otolith."

Satellite Technology.—A continuing program of engineering development on satellite technology has produced an important set of new techniques and equipments.

On July 1, 1967 the DODGE (Department of Defense Gravity Experiments) satellite was launched into a near-synchronous, equatorial orbit at an altitude of 22,000 miles. The objective of this experimental satellite was to determine whether the exceedingly small gradient of the earth's gravity field at this high altitude was sufficient to sustain vertical stabilization. It carried a number of instruments and methods of stabilization.

The Space Control Group was responsible for the design and instrumentation of the satellite. A first success was achieved with the satellite when its initial spin was removed by an enhanced magnetic despin system. The satellite was then placed in a magnetic stabilization mode with one of its axes aligned along the local magnetic field direction. Four long, extendible booms were then deployed and DODGE became the first satellite to be three-axis gravity-gradient stabilized at this high altitude. The enhanced magnetic damping system was shown to be most effective in damping satellite oscillations about the vertical direction. The best stabilization achieved with this system, without the aid of an angular momentum flywheel, gave peak angles in pitch, roll, and yaw of 2.5, 3.5, and 15 degrees respectively. Three-axis stabilization was achieved using four short booms and a flywheel with its angular momentum vector parallel to the satellite's orbital angular momentum vector. The best stabilization achieved to date using the flywheel provided peak angles in roll, pitch, and yaw of 2, 3, and 5 degrees respectively. Attitude control experiments are continuing using a large variety of inertial configurations and damping system parameters.

In addition to the stabilization results achieved with DODGE, this satellite

produced the first color picture of the full earth disc. The satellite has now produced over 10,000 television pictures. The extendible booms have been operated more than 200 times in orbit, and the satellite has responded to over 15,000 radio commands from ground stations at APL and in Australia.

In the first year in orbit the satellite provided more than 20 million discrete engineering measurements by means of its sophisticated telemetry system.

A variety of optical image processing techniques potentially applicable to the DODGE pictures are under study using an experimental coherent optical system based on Fourier transform methods rather than computer processing methods.

Other optical sensor developments by the Space Radio Frequency Systems Group include an experimental low-light-level TV camera based on secondary electron conduction. Field evaluation indicates that stars of magnitude 7 are clearly detectable with reasonable exposure times. Both satellite astronomy and attitude determination applications are currently under consideration.

APL developed an advanced capability in the design and production of microelectronic devices during the past year. The Microelectronics Laboratory is equipped to produce limited numbers of thin-film and monolithic devices, and the output has already been extremely helpful to the production of certain satellites. A number of new items are under development including micropower logic components. Micropower connotes power dissipation at the microwatt level as distinguished from the usual milliwatt levels in microelectronic devices. Micropower will permit greater packaging density and lower power requirements.

Perturbations in the inclination and longitude of the node of four nearly polar satellites were used to find values for the tidal numbers and phases of the lunar and solar semidiurnal tides. Values found in this way represent the average displacement for the total of ocean and body tides. The deceleration of the earth's rotation deduced from the studies agrees well with deductions obtained from data on ancient eclipses and is lower than other recent estimates.

The solar proton events of May 1967 have been studied by the Space Physics and Instrumentation Group using data from Explorer 34 and the APL satellite 1963 38C. The objective was to compare the intensity and spectrum of protons in the interplanetary medium with those observed in the near-earth polar regions in order to better understand the propagation of particles into the magnetosphere. Preliminary conclusions are that protons with energy greater than 1 Mev generally have ready access to the polar caps, but that exceptions do occur. Spatial variations in proton flux in the polar regions and occasional significant differences in intensity inside and outside the magnetosphere indicate that access may be a function of the interplanetary magnetic field configuration. Analysis of solar proton data acquired by satellite 1963 38C established that the geomagnetic cutoff for 1 to 100 Mev solar protons is independent of particle energy but depends on magnetic activity and moves towards the equator during the main phase of a magnetic storm. These findings are of interest in studies in the distortion by the solar wind of the geomagnetic field in the auroral and polar regions. In this case, five years of data from one satellite are being put into a form where the effects of time on the various aeronomic phenomena become available for detailed study.

The Time and Frequency Standards Laboratory has continuously monitored signals from several VLF transmitters located in the western hemisphere, and VLF phase perturbations have been quantitatively related to satellite observations of solar protons in three events. The analyses of VLF phase perturbations have led the Electronic Physics Group to an examination of the production and loss processes of ionization in the D-Region of the ionosphere.

SUPPORTING RESEARCH AND EXPLORATORY DEVELOPMENT

Aeronautics Division.—Exploratory development of supersonic combustion ramjet (Scramjet) propulsion for

Lift-off of GEOS-2 launch vehicle at Western Test Range, January 11, 1968.

possible application to high-performance missiles is continuing in the Hypersonic Propulsion Group. A full-scale engine was tested at the Ordnance Aerophysics Laboratory and functioned well on the first test.

The Aerodynamics Group has completed a study of slender missile configurations at hypersonic Mach numbers to discover potential stability and control problems prior to the actual design of such missiles. This study has pointed up the significance of aerodynamic interference effects at these Mach numbers. Of special importance is the dominating influence of the hypersonic body flow field which differs both qualitatively and quantitatively from that at lower speeds and which largely determines the behavior of lifting and control surfaces. A collection of useful design principles for hypersonic aerodynamic missile configurations is evolving from this research study.

A compact propulsion system is being developed for advanced missile systems using the booster rocket chamber as a ramjet combustion chamber. Air inlets are located on the sides of the missile body. Ground tests on a full-scale combustor over a wide range of simulated flight conditions have confirmed predicted combustion efficiency. Development of an air inlet system spatially compatible with existing missile launching systems is under way, as is the development of an aerodynamically suitable missile configuration which would use such a propulsion system.

In the investigation of the effects of ablation or transpiration products on high-velocity wake characteristics, the Fluid Mechanics Group has carried out a series of hypersonic wind-tunnel tests. An infrared scanning and recording spectrometer, developed in rocket tunnel research tests, has been used for evaluation of species and static temperature level determinations in both the arc-jet and near-wake flows.

During this year the Fluid Mechanics Group also conducted experimental work in evaluating materials and cooling designs for sharp leading edge structures, and several approaches now appear feasible for flight at speeds up to about Mach 6.5 at sea level. Analytical work on heat transfer, stress relaxation by plastic yielding, and thermal creep of materials was also accomplished.

For hypersonic flight at low altitudes, the thermal environment is such that some means of protection is essential. Generally this thermal protection is provided by an ablation material, but in some applications it is necessary to retain a fixed geometry. One such application is the leading edge of a ramjet inlet where drag must be minimized by maintaining a sharp leading edge. Use of a transpiration cooling system integral with the structure can provide the stable geometry required. A theoretical method for predicting cooling flow and heat transfer has been developed. Also, experimental determinations have been made of the coolant friction coefficient and heat transfer coefficient with suction in a porous tube.

A system for making dynamic drag measurements in the APL hypersonic gun tunnel has been developed. This system employs a hydraulic coupling between the model and a piezoelectric pressure transducer.

A joint effort with the Georgia Institute of Technology to develop and evaluate a radome and attachment assembly suitable for flight at hypersonic speeds has been in progress. Four radomes were fabricated using slip-cast fused silica and fitted with specially developed attachments. Tests have demonstrated the capability of the radome assembly design to withstand the hypersonic flight environment for adequate periods.

During the past year, the Engineering Group made considerable progress on theoretical developments in radome thermal stress analysis. Results were distributed to scientists at more than forty universities and national defense establishments. Procedures have also been developed to yield estimates of structural frequencies for airframes and also a measure of accuracy of these estimates. Computer programs which accept missile stiffness and mass data and calculate rigorous upper and lower bounds to bending frequencies have been written.

The Propulsion Research Laboratory augmented its instrument and control capability by the installation of a new Digital Data Acquisition and Control System (DIDACS), electronic signal conditioning, and an electronic test-control unit. The new system will provide capability for recording wide-band signals associated with supersonic combustion and reentry experiments.

A study of the performance criteria and technical feasibility of a specific high-speed ground transportation system, i.e., the Urban Gravity-Vacuum-Transit (GVT) System, has been conducted by the Aeronautics Division for the Department of Housing and Urban Development. The study examined certain potential problem areas such as gas dynamics, systems tolerances, train-tube-suspension dynamics, wheel-rail interaction, and noise control. The general conclusion of the study is that, except for uncertainty regarding the requirements for the wheel-rail interface, development and operation of a GVT system for stage lengths up to 5 miles appear technically feasible.

Research Center.—The past year has seen APL enter the new field of Fourier transform spectroscopy, a technique that offers several orders of magnitude improvement in signal detection over the conventional spectrometer. A Michelson interferometer spectrometer, adaptable to the 1 to 1000 micron wavelength region, was designed and built by the Excitation Mechanisms Group.

Extensive studies have been made by the Microwave Physics Group and Plasma Dynamics Research Group on the operating mechanisms of HCN and H_2O lasers emitting far-infrared radiation. Several new emission lines in both lasers were discovered during the past year. Using a number of submillimeter wavelength emission lines from these lasers as radiation sources, a far-infrared laser interferometer suitable for measuring electron densities over a range from 10^{14} to 10^{17} cm^{-3} has been developed. Several projects on the structure of free radicals trapped in various solids were completed during the past year. Using results obtained from the electron spin resonance of HO_2 in argon at 4°K, it was possible to interpret the more complex spectrum of HO_2 in ice at 77°K obtained by British workers. In another investigation, the resonant spectra of the radical ion HCN^- in KCl crystals were interpreted.

Mass spectrometric studies have been extended to the analysis of very fast chemical reactions by the Electronic Physics Group. Free radicals found in atomic hydrogenation, oxidation, and chlorination reactions have been identified, and an unusual reaction has been observed in which an oxygen

atom, apparently in a single reaction step, removes two hydrogen atoms from opposite ends of a hydrazine molecule to form diimide.

A new field of microwave-optical investigation into the paramagnetic properties of atoms of molecules in crystalline solids was initiated in the Research Center about two years ago. Various experiments have been done at liquid helium temperatures below the λ point on a ruby crystal (Cr^{3+} ion in Al_2O_3), using its fluorescent light for detection. Very strong magnetic resonances have been observed for the excited and ground states of the Cr^{3+} ion pairs as well as for isolated ions.

Research continued during the year on the exploitation of various uses of electron spin resonance spectroscopy in the chemical kinetics of gas reactions. As pioneered by the Chemical Physics Group, this technique proves to be a tool of great power and versatility in the detection and quantitative measurement of many atoms and free radicals, these being the significant reactive species in essentially all reactions in the gas phase. Emphasis has been centered recently on the precise measurement of a number of simple atom-molecule reactions.

In another area, the first nonzero eigenvalues of Stekloff eigenvalue problems are being studied by the Applied Mathematics Group since they are the optimal constants in a priori inequalities that have applications in bounding solutions of elliptic and parabolic partial differential equations. The present work aims to find lower bounds to these eigenvalues; this is of considerable interest to engineers.

Clear air turbulence investigations were continued with the Wallops Island multiwavelength high-power radar system. Jet aircraft making vertical ascents provided a check on the actual presence of turbulence over the radar. The most significant result was that every clear-air radar echo above about 3 km was associated with at least some degree of turbulence. Between the altitudes of 3 and 7 km almost all reported occurrences of clear-air turbulence were detected with the radars; however, the ability of the radars to detect weak turbulence decreased with increasing altitudes. The results of the experiment suggest that an improvement in radar sensitivity should make it possible to detect most of the significant turbulence in clear air up to 15 km.

Cooperation with The Johns Hopkins Medical Institutions.—The active collaboration with the Medical Division enters its third year with substantial results in the established programs in radioisotope scanning and ophthalmology. Further pilot studies have led to improvements in the three-dimensional radiography technique and to the formulation of a collaborative program of basic science and engineering to develop a related series of devices aimed at measuring and alleviating cardiac insufficiencies.

Theoretical work on data processing to achieve optimum fidelity in the radioisotope scanning problem has been mainly concerned with effects due to the form of the collimator response function, which were reported at the Fifteenth Annual Meeting of the Society of Nuclear Medicine. Also reported was the analysis of the application of methods of decision theory to the problem of detection of regions of abnormality of isotope concentration.

Theoretical analysis of the rate of formation of aqueous humor in the untouched eye using more realistic assumptions than have been previously used by other investigators has yielded results that explain the principal experimental features as determined by tracer techniques. A theoretical analysis of the relationship between the microstructure of the normal cornea and its transparency has been carried out by calculating the scattering to be expected from the actual quasi-random distribution of collagen fibrils as revealed by the electron microscope. This work was a cooperative effort by the Theoretical Problems Group and the Wilmer Institute.

The study of the static and dynamic regulation of intraocular pressure has been concerned primarily with improving the precision and reliability of tonometric and tonographic measurements. These measurements are important in clinical practice for the detection, diagnosis, and treatment of glaucoma. The clinical instruments produce a small deformation of the outer surface of the eye for the purpose of measuring intraocular pressure, aqueous outflow, and the flow resistance of the outflow channel. To improve the precision and accuracy of clinical instruments, a more accurate knowledge is required of the fluid-mechanical and viscoelastic properties of the eye. These properties are being measured by means of special instrumentation built by the Adaptive Machines Group. Further animal experiments are being conducted to gather sufficient data to support and verify concurrent mathematical analysis of the action of various tonometers.

High-frequency flicker studies are concerned primarily with the possibility that perception ability may provide a diagnostic tool, perhaps for the early detection of glaucoma. The initial study phase, directed toward establishing norms for a healthy population, is now essentially complete. Progress has been made in the construction of a theoretical model of retinal function to explain the ability of observers to detect high-frequency flicker.

A relatively unique facility has been designed and constructed for high-pressure studies on small animals. It allows operation at pressures up to 4 atmospheres, variation of the breathing gas mixture, mechanical respiration of the subject, monitoring of basic physiological parameters, injection of drugs and fluids as desired, and ophthalmoscopic visualization of eye grounds. These latter efforts were also done cooperatively by APL groups and members of the Wilmer Insitute.

The plans for work on the cardiovascular system now provide for carrying through the development of cardiac bypass systems, implantable artificial heart systems, and rechargeable pacemakers to clinical use. The concept of a skin tunnel transformer which solved the problem of transmitting large amounts of power through intact skin offers promise for application to an artificial implantable heart. Closed-loop feedback control technology is being applied to the control of an artificial heart. An engineering model of a controllable heart bypass pump is currently under development at the Laboratory and will be evaluated at The Johns Hopkins Medical Institution. Capitalizing on the microminiaturized electronics and battery power systems developed within the stringent requirements of the operational Navy navigation satellites, a series of rechargeable, long-lived, controllable cardiac pacemakers is being designed and engineered by the Space Power, Thermal and Attitude Control Systems Group and the Medical Institute.

Apparatus capable of reconstructing

a three-dimensional X-ray image has been demonstrated. A set of 20 separate radiographs of a subject is taken, each corresponding to a different angle. This apparatus is arranged so that the images superimpose in space and there reconstruct the original object. By passing a viewing screen through the display volume, structures lying in any plane cross section can be viewed.

A study has been undertaken to develop a working model of a myoelectrically controlled artificial hand. The Laboratory design incorporates the latest electronic and mechanical concepts to achieve a reliable working model.

Projects for the Advanced Research Projects Agency. — The ARPA Program Office has continued nuclear effects research, conducting experiments in underground tests and performing the required supporting analysis on behalf of ARPA.

Work has been resumed on radar cross-section measurements of large size vehicles, and a study was completed on the feasibility of using naval antiair systems in terminal defense against short-range ballistic missiles, and the first phase of a novel method for rapid and accurate counter-fire against artillery emplacements was concluded.

Work continued in support of ARPA's over-the-horizon (OTH) radar program, primarily in two areas: (1) design of an OTH radar calibrator; and (2) experiments on the reciprocity of the ionosphere over a Florida-Maryland path.

Special Studies.—A study by the Space Communications Group is currently examining data compression techniques for the worldwide Apollo ground communication and tracking data network which can significantly increase the information received at the Houston Center during manned missions. The data rate from the space vehicle is more than twenty times the rate that can currently be transmitted via the worldwide network. Recognition of redundancy in the high-speed link must be made at each ground station where the data are to be compressed to a rate compatible with the ground system capabilities before retransmission to Houston. The results have aided in elimination of unnecessary equipment, simpler and less expensive equipment modifications, and more efficient operation of the system.

Information Activities

Reports and Papers.—Approximately 150 unclassified and 125 classified formal technical reports were issued by the Technical Reports Group, about 318 formal Polaris and Pershing reports were issued by the Polaris Division, and 90 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. Seventy-nine papers were presented by staff members before scientific, engineering, and lay societies, of which 22 were presented abroad.

Library.—The collections have grown to include 40,000 bound volumes, 1,000 journal titles, and over 250,000 technical reports. This latter collection is growing at the rate of 5,000 per month in the form of microfiche, and microfiche comprises about half of the entire report collection. Microfiche readers will be located throughout the Laboratory. Access to this large mass of information will be achieved through the DDC and NASA computer information retrieval tapes that are now being sent to the library. Both systems are also being used for selective dissemination of technical information to APL staff members.

Twenty-two bibliographies were compiled and 134 technical translations, primarily Russian, were completed. A new edition of the *Union List of Scientific-Technical Titles and Holdings in the Washington-Baltimore Area* was published. In addition to the 27 participating libraries, this tool is used by many other libraries in the area for interlibrary loans.

APL Technical Digest.—The APL Technical Digest continued into its seventh year of successful operation. One of the highlights of the year was the use for the first time of four-color process printing on photographs used in a paper on "Orchids and Photography" published in the May-June 1968 issue.

Colloquia.—The Colloquium series continued as in past years. Of the twenty-seven colloquia presented this year, three were given by members of the Laboratory.

Patents.—During the year 111 inventions were disclosed to the Department of the Navy, 27 patent applications were filed, and 24 patents were granted.

Cooperation between the Laboratory and The Johns Hopkins School of Medicine was reflected by the production of several inventions in the biomedical field by APL staff members. Inventions in the radar, satellite, and solid-state physics fields, as usual, constituted the majority of the other inventions produced at the Laboratory.

Chemical Propulsion Information Agency.—During the year, in its regular information program, CPIA produced 32 publications covering all aspects of chemical propulsion. Also fourteen editions of the Chemical Propulsion Abstracts and updating revisions of the four basic CPIA propulsion manuals were issued. The CPIA assisted the Interagency Chemical Rocket Propulsion Group (ICRPG) in conducting two major meetings devoted to presentation of papers and discussions on recent progress in solid and liquid propellant rocket technology.

Special Laboratory Visits

Board of Visitors.—The Board of Visitors met at the Laboratory on November 15 and 16, 1967. This meeting was unusual in being coincident with a regular meeting of the Trustees Committee for the Applied Physics Laboratory.

Aside from the joint session with the Trustees, the Board had separate business meetings with the Laboratory management and with Navy officials. Program presentations and other data were provided to inform the Board in areas of expressed interest.

Congressional Visit.—On Friday, March 15, 1968, members of the Maryland delegation to Congress visited the Applied Physics Laboratory. Senator Daniel B. Brewster and Congressmen George H. Fallon, Samuel Friedel, Charles McC. Mathias, and Hervey G. Machen, Jr. were received by Dr. Gordon. During a short ceremony Dr. Gordon, Rear Admiral Arthur R. Gralla, Dr. Gibson, and Mr. Fallon addressed the group of assembled Principal Professional Staff members. Mr. Fallon presented a Maryland flag to the Laboratory.

The Congressmen were given an opportunity to learn of the work of the Laboratory, inspect its facilities, and discuss administrative problems.

Staff Activities

Evening College Program at APL

The Evening College Center at the Laboratory continued the vigorous growth which has been reported previously. The number of course offerings has increased from 6 in the Fall of 1964 to 22 scheduled for Fall 1968.

Summer Session courses were successfully introduced at the Laboratory in the summer of 1967 and continued in 1968.

In 1966-67 the proportion of non-Laboratory participants exceeded the number of APL staff members for the first time. This trend has continued and the ratio of non-Laboratory to APL staff members increased to 2 to 1 in 1968-69 and 3 to 1 in the summer of 1968.

The degree program of Master of Science (with a major in Numerical Science) was first announced in 1966-67 and attracted 102 candidates. Twenty persons have now received that degree.

Twelve APL staff members received the degree of Master of Science (with a major in Electrical Engineering) at the June 1968 Commencement. A check of the 31 other individuals who received the degree at that time showed that 27 of these had taken a substantial part of their program at the APL Center.

The evening College added two additional Master of Science programs at the Laboratory, commencing in September 1967, in Space Technology and in Applied Physics. The program in Space Technology provides a specialized training in space environment and spacecraft systems. The master's degree in Applied Physics is designed to provide the background for the development and implementation of advanced complex systems.

PERSONNEL CHANGES

The Laboratory staff decreased from 2566 as of June 30, 1967 to 2519 as of June 30, 1968. There was a gain of 32 in the professional senior staff, bringing the number to 644, and in the associate staff a net loss of 41 reduced the total to 577.

R.E. GIBSON
Director

ADDRESSES

Principal recent addresses made by APL staff members to groups and organizations outside the Laboratory.

G. M. Starken, "Science of the Sea," *American Society of Mechanical Engineers, Ohio Section,* Parkersburg, West Virginia, December 10, 1968.

A. N. Jette, "Comments on the Hyperfine Interactions of V_K Centers," *American Physical Society,* San Diego, California, December 19, 1968.

R.M. Fristrom, "Fire Research and Chemistry," *American Chemical Society, Texas Section,* San Antonio, Texas, January 7, 1969.

R.M. Fristrom, "The Chemistry of Flames," *American Chemical Society, El Paso Section,* El Paso, Texas, January 8, 1969.

R.M. Fristrom, "Molecular Beams—A Tool for Chemical Research," *University of Texas, Department of Chemistry Colloquium,* El Paso, Texas, January 8, 1969.

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Feb. 7—"An Open-Ended Discussion on Human Settlements," by C.A. Doxiadis, Doxiadis Associates, Athens, Greece.

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