EXCERPTS from the

REPORT OF THE DIRECTOR

of the Applied Physics Laboratory

JULY 1, 1964 – JUNE 30, 1965

TO THE PRESIDENT OF THE UNIVERSITY:

Technical Activities

The work of the Laboratory continues to be focused on three classes of Naval systems, namely (1) shipborne surface-to-air guided missile systems, (2) submarine-borne fleet ballistic missile systems, and (3) satellite navigation systems. In scope, the technical activities connected with these programs extend from exploratory development and research in the various relevant fields of science and technology, through diagnosis of troubles in existing systems by means of systematic performance evaluation, to the development of new components and the engineering of systems improvements. Naturally, the impact of the research and exploratory development extends beyond the direct Naval requirements. A most important result is provision of the healthy, invigorating climate of innovation needed to bring out the best efforts of the entire staff.

SURFACE MISSILE SYSTEMS PROGRAM —In May 1965, the divisions and groups in the Laboratory concerned with surface-launched missile systems were consolidated into one department, headed by Dr. Kossiakoff, named the Surface Missile Systems (SMS) Department. Historically, the development of the Navy surface-ship capability in anti-air warfare has been the principal task of the Laboratory; most of our other developments stem from this base. In this Department, program managers act as focal points for communications with their Navy counterparts; the managers of the Talos, Tartar, Terrier, and the Advanced Surface Missile System programs, together with the Department's operating divisions, namely, the Missile Systems Division, the Fleet Systems Division, and the Advanced Techniques Division, carry out the Laboratory's assignments.

The Laboratory's efforts on Naval surface-launched missile systems fall into the general areas of test and evaluation, improvement of system effectiveness, new systems, technical staff support, and special technical tasks. Among the many noteworthy accomplishments of the past year, the following are selected for mention in this report.

Test and Evaluation.—Shipboard tests are a major function of the Surface Missile Systems Department. They provide realistic evaluations and valid demonstrations of the effectiveness of weapon-system modifications and improvements. During this year ten major shipboard test programs were in progress, all supported by APL personnel and by instrumentation designed and fabricated at the Laboratory. Many of these tests emphasized the increasing complexity of the environment in which weapon systems must operate. For example, intersystem compatibility between Tartar and Talos systems was studied by missile firings on the USS *Columbus*.

Improvement of System Effectiveness.—Another major area of SMS effort is system effectiveness. Included especially is work designed to improve operational readiness, in-flight missile reliability, and system performance. System deficiencies are corrected, better test procedures are devised, and operational efficiency is improved.

Using the data base accumulated over a two-year period by Fleet reporting of equipment failures, a standard procedure has been developed for indicating those units responsible for unduly large amounts of system down time. Studies aimed at increasing the effective range of the Terrier radar in an adverse environment have yielded excellent results.

Use of an airjet noise generator to blow air over an instrumented Talos missile has provided for the first time an adequate simulation of the three-dimensional vibrations which occur in flight and hence will aid in improving missile reliability. An engineering model of a digital fire control computer was developed for the Talos fire control system and was demonstrated successfully aboard the USS *Albany;* the use of digital techniques results in simpler, smoother, and more consistent operation.

New Systems.—The introduction of new classes of ships, improved missiles, electronic warfare innovations, and revised operational procedures requires the continual modification of the Navy's surface-to-air missile systems.

At BuWeps' request, a Weapon System Integration Task Group has been established for Standard Missile and Terrier/Tartar to establish functional interface parameters between equipment furnished by different contractors, to establish signal interfaces between the missiles

and the shipboard systems, and to evaluate actual hardware for its performance in the systems. Already this Task Group has prepared a definitive document defining the interfaces between the new Standard Missile and the older fire control systems.

Technical Staff Support.—Technical staff support embraces planning and coordination of programs and technical direction of Bureau of Naval Weapons contracts. This year's most notable contribution has been in the highly classified field of planning effective ways of coping with increasingly hostile operational environments.

Special Technical Tasks.—The advent of digitally controlled weapon direction equipment in the Fleet required establishment of an on-shore test site where operational problems and new digital techniques could be examined, so a reduced-scale, general-purpose, digital weapon direction system has been set up at the APL System Evaluation Laboratory. This equipment can be used to simulate or analyze almost any digital weapon direction system, including those used in point defense systems, advanced missile systems, or anti-submarine warfare systems. The equipment may also be used in connection with the design of the automated digital daily system operability tests for shipboard fire control systems.

In support of the Standard Missile and Terrier programs a Guidance System Evaluation Laboratory has been installed at APL to provide a controlled environment for assessing existing systems and their subsequent modifications and for experimenting with new guidance designs. Closed-loop guidance-system performance may be determined by using the missile guidance hardware together with the analog computers and simulated functions that the laboratory provides.

POLARIS PROGRAM — The second major area of Laboratory support of the Navy's mission is the work in assessment and improvement of the Fleet Ballistic Missile (FBM) system.

The Polaris Division has continued its analysis of the predeployment System Demonstration and

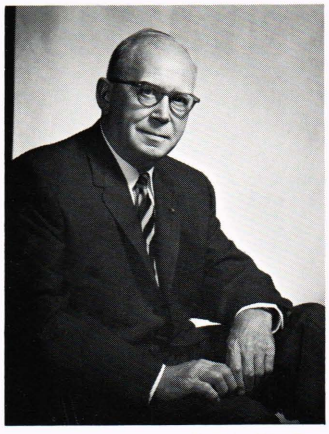


Photo by Udel Bros.

R.E. Gibson, Director

Shakedown Operation (DASO) testing of FBM submarines at Cape Kennedy, Florida, at the rate of approximately one a month. Analysis of data from tactical patrols of FBM submarines increased approximately 100% compared to 1963-64. In addition, the division has written and published for the Navy the official tactical procedures to be used aboard the four classes of operational submarines.

Weapon system effectiveness studies for both A2 and A3 missiles have been continued and expanded. Unique methods developed by APL have resulted in significant improvements in sonar technology.

SPACE DEVELOPMENT PROGRAM—The use of spacecraft for providing additional or improved naval capabilities has achieved considerable success. This has led the Laboratory to undertake similar work for other agencies as will be noted below. Early this year the internal organization of the Space Development Division was realigned to increase its effectiveness in undertaking the Laboratory's space programs.

Satellite Launchings.—The Laboratory designed, fabricated, and launched four satellites into orbit during this period. One was an operational satellite for the Navy's satellite navigation system; one was an experimental satellite (5E–5) with instrumentation for ultraviolet-light and rubidium-magnetometer measurements and particle detectors; the other two were Beacon Explorer Satellites for NASA to permit exploration of the ionosphere by numerous stations throughout the world.

Satellite Navigation System Operational.—With the satisfactory performance of the first operational navigation satellites and the deployment of associated surface equipment, the technical evaluation of the APL-developed navigation satellite system was conducted in the fall of 1964. As a result of this evaluation, the system was placed in operational use, its operation was transferred to the Navy astronautics Group, and satellite production was assigned to the Naval Avionics Facility at Indianapolis, with APL providing technical assistance to both agencies.

Satellite Data Analysis.—From analysis of doppler tracking of APL-designed satellites, terms of higher degree and order in the analytic expression of the earth's gravitational field have been determined. These terms, up to the 15th degree and 14th order, have provided a refined definition of the shape of the geoid. Analysis of perturbations in the inclinations of two nearly polar satellites has yielded a reasonable value for the total of earth and ocean tides for the semidiurnal solar tide, but the amount of tidal friction has not yet been found accurately. Studies of the earth's outer radiation zone have revealed a striking correlation between the trapped electron intensities in the outer radiation zone and the solar rotation period of about 27 days. The ultraviolet instrumentation aboard the 5E–5 satellite has thus far provided unique identification of 100 stellar sources of ultraviolet light.

New Satellites.—Three satellites are currently being designed and built at APL for NASA: a Direct Measurement Explorer Satellite (DME-A) and two Geodetic Satellites (GEOS-A and GEOS-B). The DME-A experiment packages are being supplied by NASA, NRL, and University College, London; APL has designed the high-data-rate telemetry system that will transmit the experimental outputs. In addition to including geodetic instrumentation similar to that used in the successful ANNA satellite which APL built and launched in 1962, each GEOS satel-

lite will contain a laser reflector and a NASA transponder.

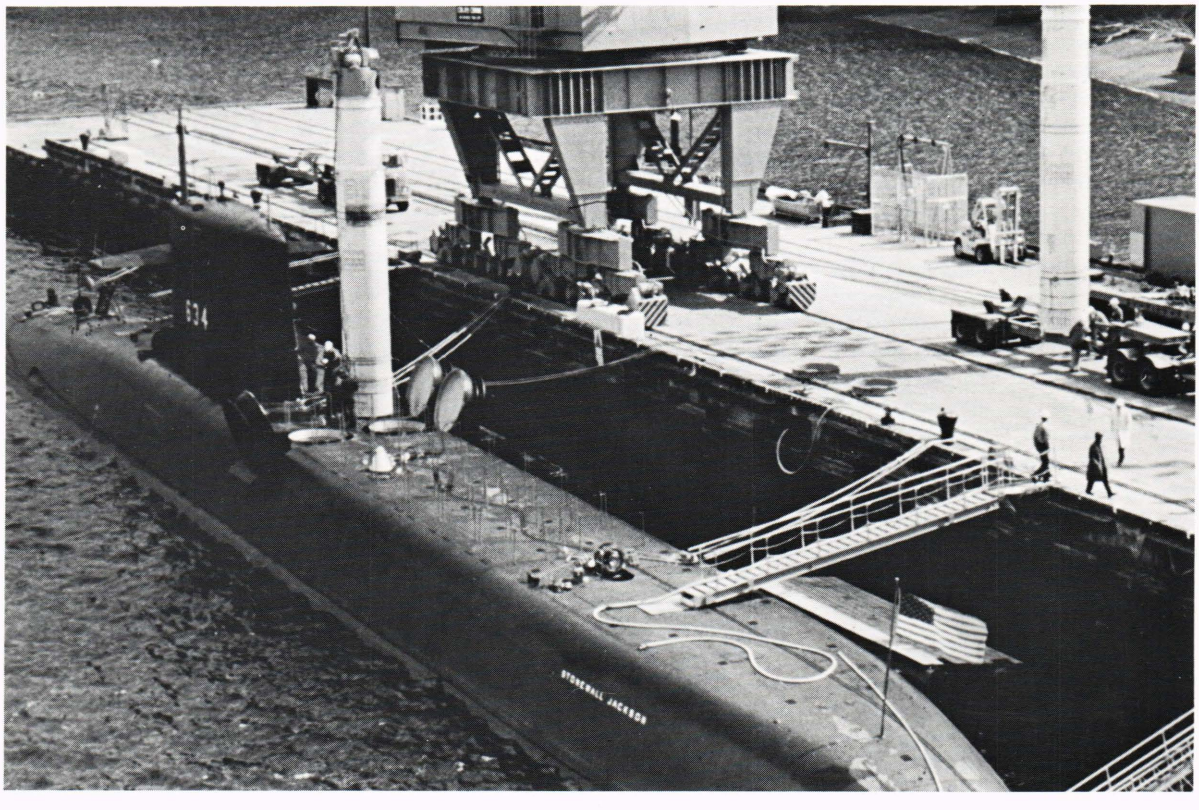
AN/SRN–9 Navigation Sets.—Twelve prototype AN/SRN–9 navigation sets, consisting of receivers and special-purpose computers, were fabricated by the Laboratory and installed aboard a variety of ships, including oceanographic research vessels, Coast Guard cutters, and Navy cruisers and aircraft carriers. The navigation accuracy achieved at sea with the AN/SRN–9 has measured up to every expectation. Indeed, the sets loaned to the Woods Hole Oceanographic Institution and the Lamont Geological Observatory and used aboard their research vessels produced position fixes of an accuracy so much greater than those previously obtained that the directors of these organizations have stated that the development of the AN/SRN–9 provides a tool for major advances in oceanography.

Life Support in Space.—Life-support studies nearing completion include the development of a breathing simulator for use in tests of atmosphere-control systems, goggles to protect against flash blindness, and a life-support capsule for frogs to fly in Apollo spacecraft. The frogs will be instrumented to supply information relevant to astronaut dizziness.

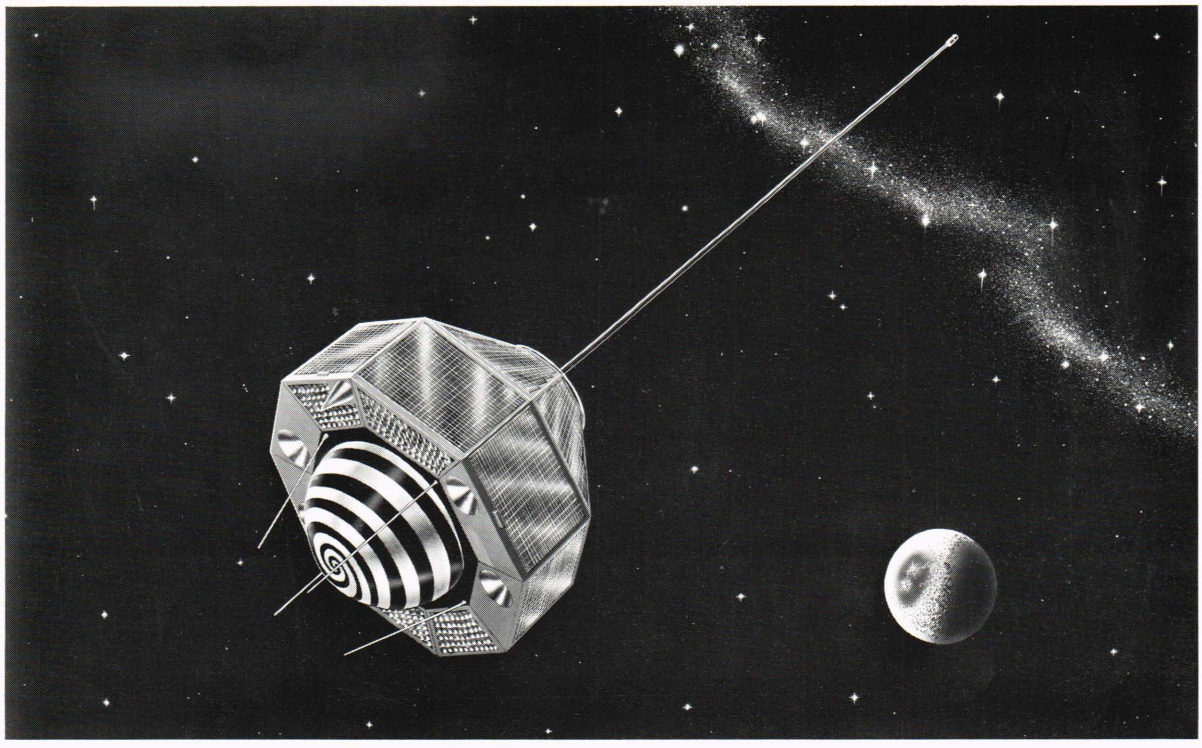
Supporting Programs of Research and Exploratory Development — While I have thus far stressed the three major programs of the Laboratory to underline the basic unity in what might appear to be widely diverse undertakings, I must now summarize some other activities, no less important and no less worthy in accomplishment. By and large, these activities are directed toward longer range objectives and enable the Laboratory better to support the Navy in its broad mission. They are not, however, so completely directed towards immediate operational problems as are those already mentioned.

Aeronautics Division.—A most significant accomplishment of this division is the quantitative demonstration that the thrust of a rocket can be augmented appreciably by supersonic after-burning, with added air, of the unconsumed portion of the rocket fuel. Such air augmentation has the effect of raising the fuel specific impulse from about 270 to about 500 lb-sec/lb during a significant portion of a rocket's trajectory.

One unit of the Propulsion Research Laboratory has been modified to simulate the atmospheric entry or re-entry conditions of ballistic missiles, satellites, and meteors. By use of an arc heater, velocity-altitude simulation can be achieved from a speed of 10,000 ft/sec at an altitude of 30,000 feet to a speed of 13,000 ft/sec at an altitude of 90,000 feet. This tunnel is expected to make its main contribution in the design of missile re-entry components. In this connection, recent experiments have yielded valuable data on the heat-shielding properties of pyrolytic graphite.



Polaris A3 missile loadout aboard SSBN–634. The missile, encased in a protective liner, is being lowered over tube 1. Today's Polaris fleet is one of the nation's top deterrents.



Artist's conception of GEOS–A satellite in space. The GEOS–A was designed and built for NASA.

The concept of a supersonic combustion ramjet has continued to undergo tests. Refinement of the design has progressed, and experimental tests of combustor and inlet performance have confirmed predicted behavior. A combined experimental and theoretical study has already been undertaken to investigate the importance of the various factors that might influence the stability and control characteristics of a shipborne interceptor-type missile at hypersonic speeds, and a hypersonic gun tunnel that will simulate a flight environment of Mach 10 at an altitude of 85,000 feet has been placed in operation.

Assessment Division.—During the fall semester of 1964, at the request of the Director, U. S. Naval Postgraduate School, Monterey, California, several members of the Assessment Division presented a course in tactical analysis to members of the second-year group in operations research. The course was prepared by the Assessment Division with assistance from several other technical groups. The course covered the fundamentals of tactical analysis for naval anti-air warfare, naval antiship warfare, and naval bombardment of shore targets. The schedule included lectures, demonstrations of the APL-developed Air Battle Analyzer, and student participation in simulated battles.

Research Center.—During the year, a number of research investigations were published or submitted for publication. A few of these will be given brief mention here. The pyrolytic conversion of an aromatic polypyromellitimide into a semiconductor was studied, and its electronic and physical properties were found to be stable, even at a high temperature. The magnetic dipolar energy of antiferromagnetic Fe_2O_3 was calculated and was combined with anti-ferromagnetic resonance data to explain the origin of the "spin-flip" transition. The theoretical relations necessary for determining quantitatively free (OH) radical concentrations by the electron spin resonance technique have been worked out and their usefulness demonstrated in the laboratory. Nuclear magnetic resonance studies of Xe^{131} in gaseous xenon have indicated that relaxation occurs during interatomic collisions as a consequence of the interaction of the electric quadrupole moment of the atom. Studies were made to determine the principal populating mechanism for the neon $2s_2$ level in a helium-neon gas-discharge laser operating at 6328Å since violation of the conservation of total spin selection rule presumably rendered appreciable resonant energy transfers from the He (2^3S) to the Ne ($2s_2$) state unlikely. The results of the measurements indicate, however, that the principal populating mechanism *is* by resonant energy transfer. A new approach to computing the forms of the far-field diffraction patterns of circular apertures illuminated with coherent radiation of fixed wavelength has been devised and has been used to solve diffraction problems which do not lend themselves to direct Kirchhoff integration.

Microelectronics.—Two significant advances have been achieved in the microelectronic component field. A unique design technique has resulted in construction of C- and X-band tunnel-diode amplifiers with good gain and bandwidth characteristics and with particularly low noise outputs. An all-diffused monolithic multivibrator circuit consisting of two transistors, three multiple-tap resistors, and three junction capacitors, with isolation diffusion between elements, was successfully fabricated and packaged. Volume I of the Microelectronics Handbook has been prepared and is being published.

Research Projects for ARPA.—The initial APL study of ballistic missile defense (ALBIS) for the Advanced Research Projects Agency has been completed and was well received. This has been followed by the Advanced ALBIS study which has already led to operational tests of some of the concepts involved. With Laboratory support in planning, analysis, and special instrumentation, the first operational phase was completed, and a second, more advanced, phase is in progress. As the Laboratory's work for ARPA expands, and the Advanced ALBIS study has advanced, a major conference on the Defense Against Sea-Launched Ballistic Missiles was held at the Laboratory.

Research Projects for NASA and USAF.—Both NASA and the AEC undertook to support selected areas of the Laboratory's plasma dynamics research with their funds. APL is now working for NASA in two fields in addition to our satellite programs, namely, work in support of the ground communication network for the Gemini and Apollo projects, and experimental studies of the supersonic combustion of hydrogen.

On June 1, 1965, the Laboratory inaugurated a new program, supported by the Department of the Air Force, on clear air turbulence, using the Air Force-NASA radars at Wallops Island.

A major conference on Oceanographic Research was held at the Laboratory this year.

Information Activities

Reports, Papers, and Patents.—The greater portion of the work of the Laboratory results in technical reports, papers presented before scientific societies, papers published in the scientific literature, and patent disclosures. This year has seen, in general, an increase in these categories.

Approximately 200 unclassified and 135 classified formal technical reports were issued by the Reports Office. One hundred and fifty formal Polaris reports were issued by that division. Eighty-six publications appeared in the open literature, and one in a classified journal.

Fifty-six staff members presented 104 papers before scientific, engineering, and lay societies. Of these, 20 were presented at meetings held abroad.

In addition, well over 1500 informal reports on a variety of topics were issued, the exact total being virtually impossible to ascertain. A good deal of documentation, both written and filmed, was prepared by various groups for circulation within the defense establishment. Noteworthy among these is a countermeasures training film prepared for the Bureau of Naval Weapons.

During the year, 88 inventions were disclosed to the Department of the Navy, 23 patent applications were filed, and 28 patents were granted.

The Chemical Propulsion Information Agency.—The CPIA has completed another year of stable operation as the national information exchange activity for Government-funded chemical propulsion research, development, test, and evaluation programs. This information exchange has been accomplished in publications, meetings, and personal contacts with investigators in the subject area. Significant progress has been made in the growth from this type of operation into the analysis functions required of CPIA as a Department-of-Defense-sponsored Information Analysis Center. The Agency has prepared a five-year plan for future operations which has been forwarded to the DOD by the Navy as written. The complete expansion is expected to approximately double the FY 65 CPIA budget by the end of the five-year period.

Administrative Operations

The significant changes in the Laboratory's structure have already been mentioned, namely, the consolidation of activities in support of the Surface Missile Systems Office of the Navy into the Surface Missile Systems Department and the internal reorganization of the Space Development Division. Other structural changes during the year were only nominal and represent no departure from previously established custom. The total staff has remained essentially constant at approximately 2450.

Educational Program

Evening College Program at APL.—Seventy-five APL staff members and 41 persons from outside the Laboratory enrolled in the Evening College courses taught at the Laboratory in 1964-65. Sixteen APL staff members and 16 persons from outside the Laboratory were accepted as candidates for the Master's degree in Electrical Engineering. The 11 courses that will be taught at the Laboratory during the 1965-66 academic year are listed in the University's Evening College Catalog.

APL Fellowship Program.—Four graduate students of the Department of Electrical Engineering, The Johns Hopkins University, have received APL Fellowships. Morgan Mallory Buchner completed his research at the Applied Physics Laboratory in July of 1965 and is now at the Bell Telephone Laboratories. He will be awarded his Ph.D. degree in the fall of 1965. Richard Dooley, Charles White, and Arthur Hochberg are currently conducting research in residence at APL.

R. E. Gibson
Director