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Research in Space

Scientific opportunities, instrumentation problems, and sources of support are reviewed by the Space Science Board of the National Academy of Sciences.

A beginning has already been made in the exploration of the fringes of the atmosphere and of the regions of space outside the earth. The events of the past two years encourage the expectation that this exploration will proceed with increasing momentum.

The means now at hand, or soon to be available, for transporting instruments into space add immeasurably to the power and versatility of the tools of scientific investigation. Atmospheric attenuation limits the earthbound observer to the use of about 20 of the 60 octaves in the electromagnetic spectrum above 100 kilocycles per second: an additional 40 octaves are in principle accessible to instruments flown outside the earth's atmosphere. These opportunities are of the liveliest interest to physicists and astronomers. With the aid of artificial satellites and space probes, fields, radiation, and particles in interplanetary space and in the vicinity of the earth, the moon, and the nearer planets become accessible to direct observation for the first time. As space technology advances it will undoubtedly become possible not only to sample the matter in space but also to observe and perhaps to obtain samples of the material of the moon and planets: these prospects are manifestly of interest not only to the physical but also to the biological sciences.

In the conviction that the challenge posed by these unprecedented opportunities for scientific study deserves most serious attention, the National Academy of Sciences, through its Space Science Board, seeks to offer encouragement to those who wish to take part in space research programs. This article is addressed primarily to those scientists who may not yet have given serious consideration to the possibility of experimentation in space. It attempts to suggest the opportunities which are available and to outline some of the information which will be needed by those who wish to go further.

Opportunities

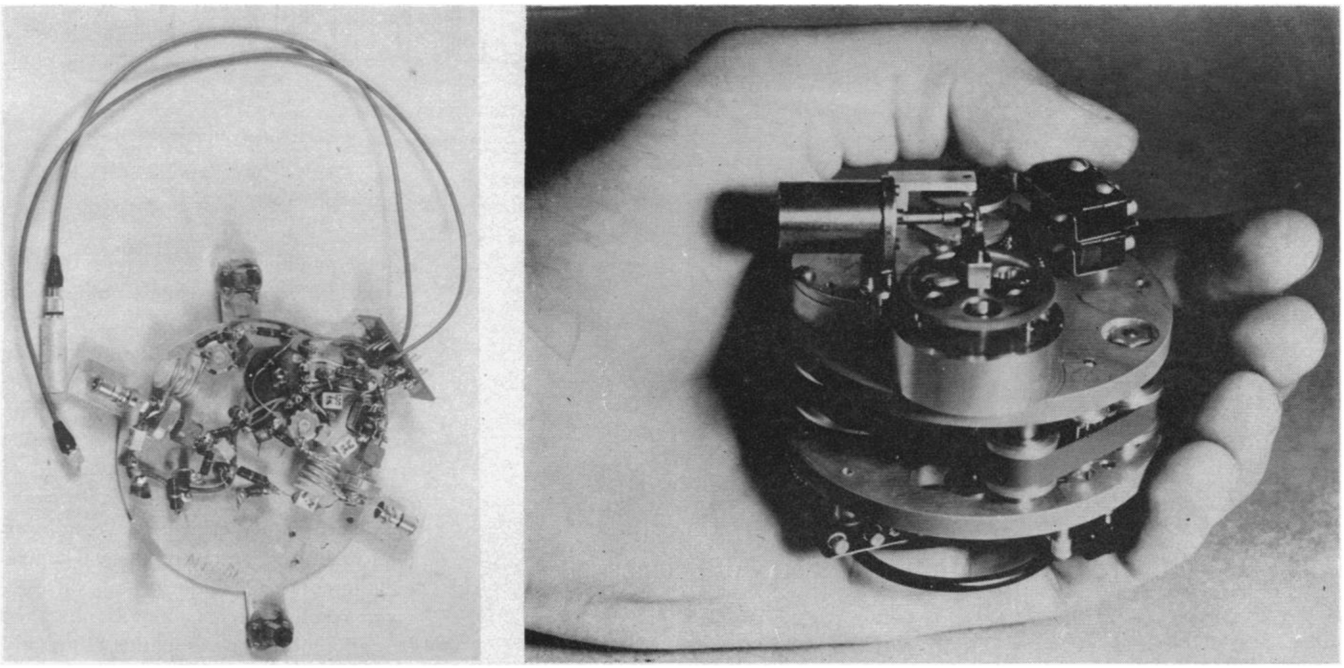
The establishment of the National Aeronautics and Space Administration provided the means for the continued development of a civilian program of space exploration. A major part of the tasks ahead is concerned with the development of more powerful, reliable, and versatile rockets, control systems, tracking and observing equipment, and instrumentation generally. Rapid technological progress in all of these is to be expected, and the attendant possibility that the supply of suitable experiments ready for flight will be outstripped is quite real.

Moreover, continued progress on the engineering side may be expected to lead to significant improvements in reliability, to permit simplification in the design of experimental apparatus, and to widen the variety of experiments which may be attempted. It is likely that there will be not only a rapid increase in the number of opportunities for conducting scientific experiments in space but also a corresponding improvement in the dispatch with which any given undertaking can be accomplished.

By the adaptation of the technology of rockets and space vehicles to scientific ends, it is at last becoming possible to study the universe free of interference from the absorptions and distortions of the earth's atmosphere and to investigate by direct experiment the conditions existing in interplanetary space. The new experimental techniques have already given results which cannot be matched by any other investigative methods. These circumstances, now in the process of evolution, challenge the ingenuity and enterprise of the scientific community as a whole.

Support for work in space research is provided by the National Aeronautics and Space Administration (1512 H St., NW, Washington 25, D.C.) and the National Science Foundation (1951 Constitution Ave., NW, Washington 25, D.C.). The Advanced Research Projects Agency (Department of Defense, Washington 25, D.C.) also supports work which pertains to its defense mission. Where special departmental interests exist, funds may also be available directly from other sources—for example, the research offices and establishments of the military services.

An individual scientist or a research institution seeking support for a project or program of research involving the use of rockets, artificial satellites, or space probes should make application to one or other of the agencies mentioned above. Besides discussing the scientific significance of the work proposed, it is desirable also to describe the experimental requirements for telemetry and any special problems involved in the reduction and analysis of data. The budgetary needs for the various principal stages of the project should also be presented. Applications to the National Science Foundation should follow the form prescribed in the leaflet "Grants for Scientific Research" which is available from that agency on request. When the other agencies are concerned it is preferable that the investigator apply informally in the first instance, giving at



Weight restrictions and environmental conditions have favored the application of miniaturization techniques to the design of apparatus for space vehicles. The minitrack transmitter (left) for a Vanguard satellite [Courtesy U.S. Navy]. A miniature magnetic tape recorder of the type which has been used in satellites for the storage of data (right). The stored information can be read out at will by command signal from the ground. [Courtesy U.S. Army]

least the information outlined above. (A leaflet "The Advanced Research Projects Agency," now available from the Department of Defense, Washington, D.C., summarizes information useful to those who may wish to make proposals to that agency.) Thereafter, discussion with appropriate members of these agencies will enable the proposal to be made in a form best suited to the particular case.

While some experiments require the use of satellites or space probes, high-altitude rockets will continue to find special application for many types of investigations. They are particularly useful for establishing the altitude dependence of phenomena of interest in regions below satellite altitudes. The National Aeronautics and Space Administration and the Department of Defense are actively interested in the support of research programs using rockets.

The nature and magnitude of the engineering effort which must accompany space science efforts make it necessary to pay much more attention than usual to the design and reliability of the experimental apparatus. As a general rule, space research projects proceed through a series of stages which may be enumerated as follows: (i) feasibility study leading to the design of experiments, (ii) development of experiments and instrumentation, (iii) development of flight packages, and (iv) launching operations, data reduction, and analysis.

The scale and complexity of the effort required in the third and fourth phases tend to be characteristic of the practical side of space research. This may give rise to some apprehension on the part of the scientist that his interests may become subordinated to those of engineering. While recognizing the importance of engineering to success in space experiments, the Space Science Board holds the view that throughout the course of the experiment the originator must participate actively to the maximum extent practicable. This view is shared by the responsible government agencies. The scientist engaged in a space research project may, therefore, expect to have close liaison with those responsible for the engineering design, construction, and environmental testing of the flight package and to have a voice in decisions affecting telemetry, the choice of orbit or trajectory, and the time of launch, insofar as these may affect the scientific aspects of the experiment. He may expect to participate actively in the instrumental testing of his apparatus before launching, and, of course, to have complete and immediate access to the results of the experiment.

As a practical matter, financial support is not limited to proposals which encompass all the stages mentioned above. In many cases, today's technology may be inadequate for an immediate realization of the experimental goals. Nevertheless, theoretical or preparatory investigations, in anticipation of future capabilities, may well elicit support. Here both the National Aeronautics and Space Administration and the National Science Foundation have genuine interests in sponsoring research.

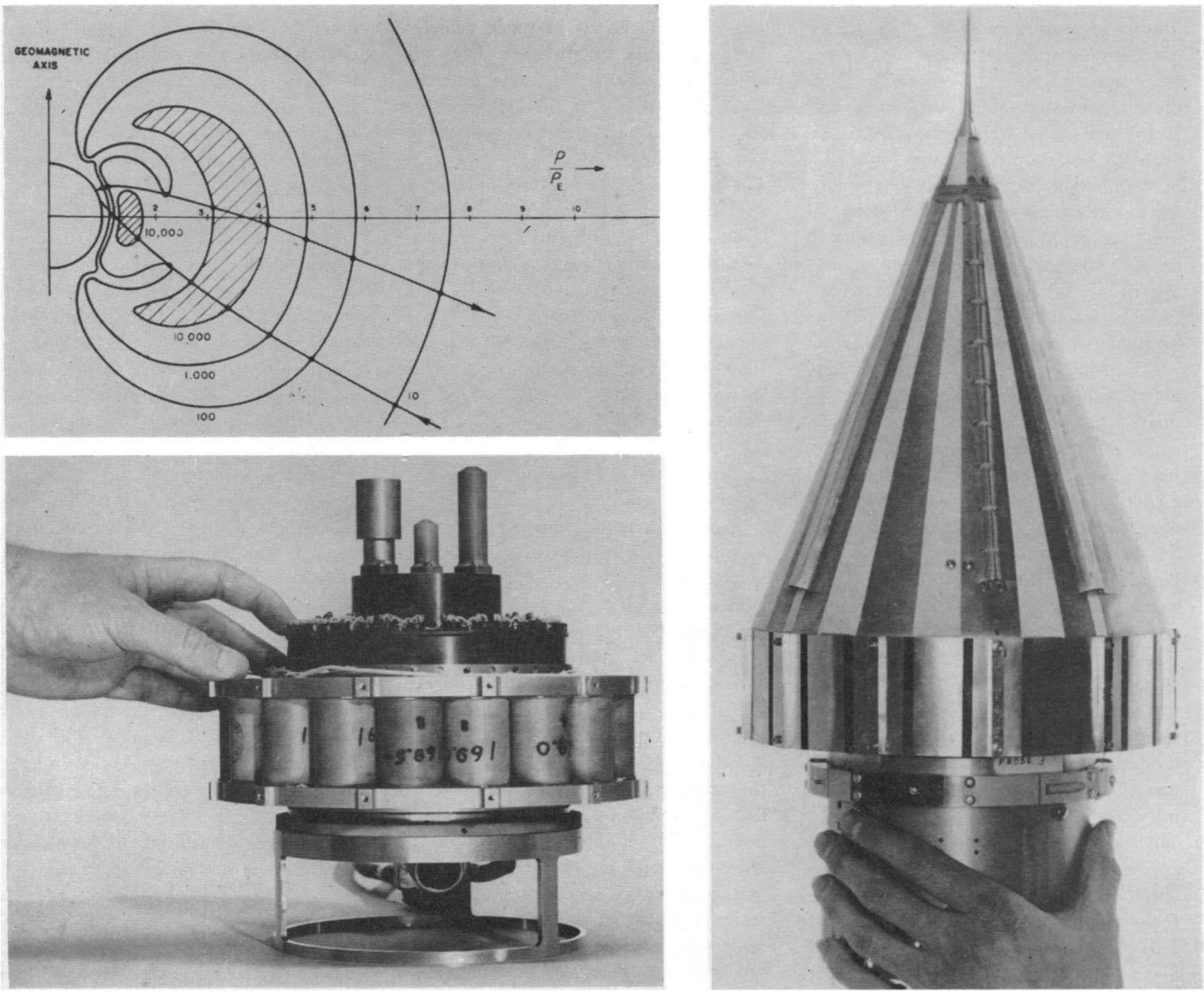
The launching of an experiment in a satellite or space probe involves a significant expenditure of time, effort, and engineering resources, Preparation of a suitable scientific flight package accordingly requires careful collaboration between the authors of experiments and the engineers and scientists conversant with flight package design. The nature of rocket propulsion and the usual reliance on radiotelemetry for the recovery of results impose some definite characteristics on the design of experiments. The discussion which follows is intended to be suggestive of the present state of the art and should not be taken as definitive.

Vehicular Reliability

The problem of reliability has had a notable effect on early attempts to conduct research in space with high-performance rockets, both as satellite-launching devices and as space probes. The incidence of total failure or minor malfunction in samples of small size can lead to conclusions which are of negligible significance in statistical terms. Reliability in complex, multistage rockets—particularly those using liquid fuels—is achieved only by painstaking effort during development. Progress is constantly being made in this respect, and there is every reason to expect that experience in the future will be appreciably better than it has been in the past. Nevertheless, it is also likely that failures will continue for some time to be a part of the cost of experimentation with high-performance rockets. While the problems of the reliability of the rocket and its controls are not the direct concern of the scientist engaged in space research, their implications should be borne in mind during consideration of the design of experimental apparatus so that the value of the experiment may not be entirely lost if the rocket fails to achieve the planned trajectory. Of course, the reliability of the experimental equipment itself is of the most vital concern to the scientist; this aspect is discussed below.

Weight and Volume

Limitations in the propulsion available for purely scientific purposes have, up to the present, restricted the scope of research with artificial satellites and space probes in this country. Useful weights of experimental apparatus have been less than 10 kilograms. Within the year, the availability of improved booster and upper-stage rockets should make possible increases in payload to more than 50 kilograms. In 1960, a still larger booster should permit the orbiting of earth satellites weighing 1000 to 2000



Analysis of the readings, obtained by telemetry, of the particle counters of Pioneer III together with earlier satellite observation led to the discovery of the two Van Allen radiation belts (shared areas) shown in the cross section (top left). The contours are drawn through points where the number of counts was 10, 100, 1000, and 10,000 per second. The ascending and descending segments of the trajectory of Pioneer III are superimposed [Courtesy State University of Iowa]. A view of the outside of the instrumented payload of the lunar probe Pioneer IV (right). The pattern of light and dark areas serves to stabilize the internal temperature by regulating the absorption and loss of energy from the sun. The probe Pioneer III was of similar construction [Courtesy U.S. Army]. The instrumentation of Pioneer IV (bottom left). The cylinders at the top are cosmic ray counters. The ring of cylindrical batteries below surrounds the telemetry transmitter. This device, protected by a housing similar to that at the right, is now in orbit around the sun. The instrumentation of the probe Pioneer III was similar except for the omission of the shielding around the counter on the left [Courtesy U.S. Army]. Both were constructed by the Jet Propulsion Laboratory of the California Institute of Technology.

kilograms. Improvements in upper stages are expected to make possible, in about 3 or 4 years, the launching of weights of several thousand kilograms into orbits of co-rotation with the earth (altitude of about 5.6 earth radii) or other accomplishments of comparable magnitude. Later still, very powerful rockets are likely to be available and, as the competence of the technology improves in this fashion, the determining factor in our space research work will then be scientific justification rather than engineering limitations.

For the immediate future, weight rather than volume appears to impose the greater restriction on the design of scientific satellite packages. For example, both Explorer and Vanguard satellites have carried most of their scientific equipment in cylindrical instrument compartments about 15 centimeters in diameter located along the spin axis. Instrument assemblies have taken the form of disk-shaped modules or decks of various heights, arranged in a stack. In the early Pioneers, on the other hand, the instrument packages were disposed around the equator of a top-shaped shell. Only in the Explorers was a substantial fraction of the total volume available occupied by the instruments.

Components and fabrication techniques similar to those used in miniaturized airborne and rocket electronic equipment have proved satisfactory for space use. Instruments requiring exterior surface mounting or bulky units of nonmodular dimensions can probably be accepted when the more powerful launching vehicles come into use.

Power

The electrical power supply carried by a space vehicle ordinarily determines the total amount of scientific data which can be acquired, amplified, and transmitted to the earth. Thus far, satellite and space probes have depended almost entirely upon chemical batteries (for example, mercury or silver-zinc cells), and these have usually functioned satisfactorily. A performance of about 100 watt-hours per kilogram of batteries has been obtained. On the average, power supplies of this kind have taken up about a quarter of the disposable weight in Explorer and Vanguard satellites.

In 1958 β, the small Vanguard test sphere, sufficient power was developed by banks of solar cells to operate a transistor transmitter at about 12 milliwatts. That this power supply has continued to operate satisfactorily since 17 March 1958 indicates that silicon solar cells are not rapidly damaged by the space environment. More extensive use of these cells in the future is expected. For the range of variation of aspect in an uncontrolled satellite, for storage of energy during periods when the cells may be in shadow, and for regulation and voltage conversion, about 2.5 kilograms are presently required for the supply of 1 watt. This is equivalent to more than 3000 watt-hours per kilogram, if a 1-year life is assumed. A 2.5 watt power system of this type will be used in a late IGY satellite.

Nuclear-powered devices are expected to provide efficiencies approaching 4000 watt-hours per kilogram for high-power, long-life applications in space vehicles. Although such systems are well advanced in development, some problems in application, in particular radiation shielding and heat dissipation, may present difficulties.

Recent American satellites have operated on batteries at a fractional watt level with lifetimes up to a few months (and one on solar cells for more than a year). Prospective space vehicles may operate at a few watts for periods up to a year. It may be expected that the 1960–62 period will see power levels of 50 to 100 watts.

Environmental Temperatures

The approximate solution of the problem of the temperature of a satellite or space vehicle was worked out prior to launching both for the Explorers and for Vanguard I. In both cases, temperature range reported from the satellite agreed with predictions within design limits. The temperature of the vehicle represents a balance between radiation absorbed by or heat generated within the satellite and the heat lost by radiation or latent heat exchange within the satellite. By suitable adjustment of the absorption and emission characteristics of the various portions of satellite surfaces, and with due consideration of the orbit, the shell temperature for Explorer I was held within a range of −25° to about 90°C. The corresponding temperatures within the shell are believed to have been 0° and 40°C. In Vanguard I, a stable temperature of about 40°C appears to have been reached within 1 day after launching.

Present techniques appear to be generally adequate for the design of instrument containers capable of maintaining temperature within tolerable limits. With some sacrifice of payload weight and diversion of power, more refined regulation of the temperature of the instrument compartment can be achieved.

Shock and Vibration

Once an instrument package has achieved orbit or a condition of coasting flight in space, it is essentially in a force-free condition except for the effects of residual spin, attitude control, or possible meteoritic impacts. In this environment, light-weight structures of large size may be erected—for example, by inflation. However, before this free-flight condition is attained the instrument package must withstand a great deal of shock and vibration. This occurs to some extent during shipment and preparation for flight but is more severe during the propulsive phases of launching when acceleration forces of both set-back and spin are encountered, together with random vibration over a wide spectrum along all three axes.

For establishing flight dependability of the payload package, a program of shock and vibration testing has been developed in the IGY satellite program. Test limits are dictated in large measure by the shock and vibration characteristics of the payload itself. Specific test routines have been worked out for the Vanguard launching system, the Jupiter-C, the Pioneer, and the Juno II. These have included dynamic balancing, acceleration, spin tests, and triaxial vibration tests.

Although the severity of the tests differs somewhat for the various launching systems, the following, taken from the type approval tests for the Juno II prototype payloads, is illustrative of the conditions which some of the earlier experimental apparatus has had to withstand. These examples apply particularly to the lighter payloads; the requirements for resistance to shock and acceleration are likely to be somewhat less when heavier payloads are concerned.

1) Shock. The complete payload is subjected to about four 100*g* shocks parallel to the axis of the launching thrust.

2) Vibration. Random noise, 15*g* root-mean-square, parallel to the thrust axis for 2 minutes. Random noise, 12*g* root-mean-square, along two planes mutually orthogonal and perpendicular to the thrust axis for 2 minutes in each plane.

3) Static acceleration. The payload is

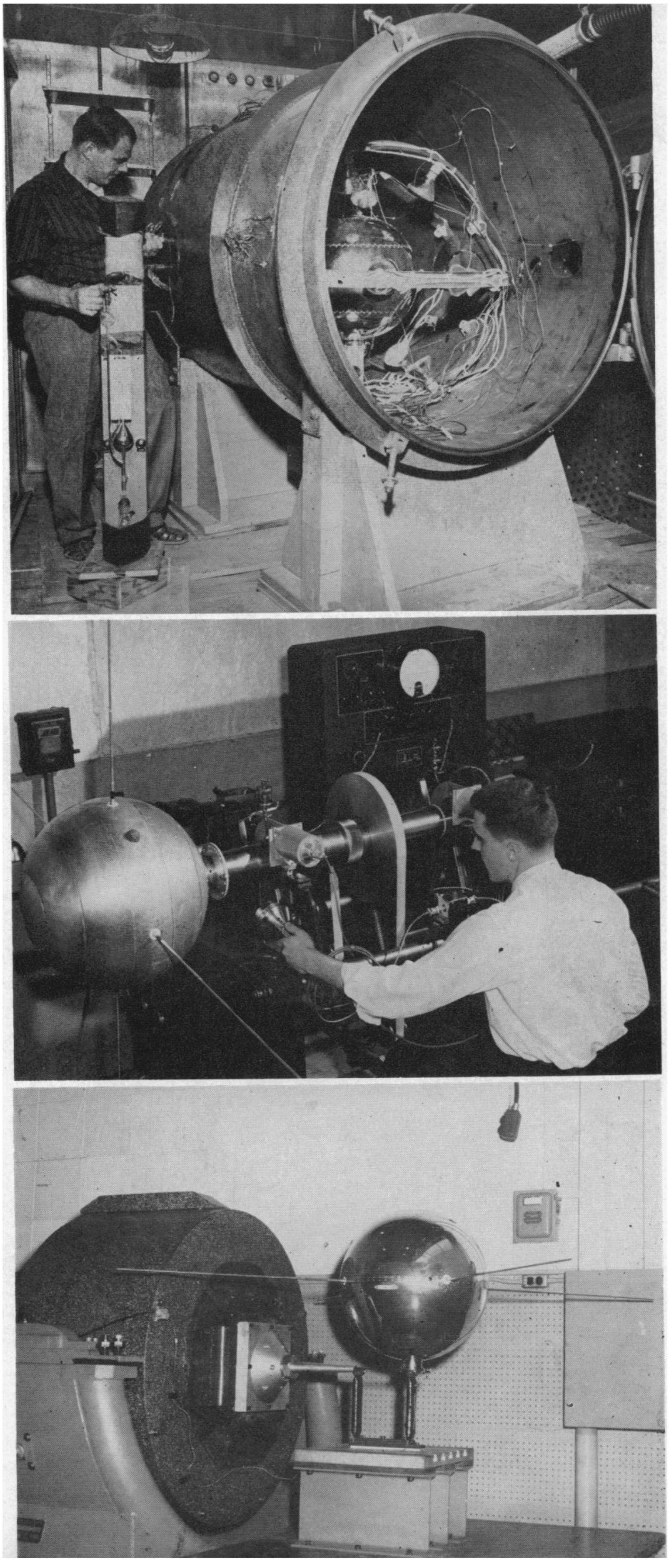
held at 75g for 2 minutes by centrifuging.

4) Spin. After dynamic balancing, the payload is spun at 900 revolutions per minute for 10 minutes.

The foregoing tests are applied to the flight prototype sample. Somewhat less rigorous flight acceptance tests are then applicable to identical payloads scheduled for actual flight.

The development of the payload instrument package for withstanding these and other physical conditions it is expected to encounter is the responsibility of an expert space-package design group having familiarity with the launch in question. Ideally, this group should begin to work with the scientist carrying out the experiment at an early phase of his instrument development, even before the completion of a laboratory bench model of the apparatus. After the individual components and the complete apparatus have been tested successfully for flight readiness, the flight-package engineers assume responsibility for adapting the approved instrumentation into a flight-prototype package which will meet environmental test requirements and which will be suitable for accommodation in the shell of the vehicle and, at the same time, functionally acceptable to the responsible scientists.

Massive test equipment is required for carrying out the full range of environmental tests for payload instrument packages, particularly for payloads of 50 kilograms or more. Adequate installations of test equipment are located at laboratories engaged in the development and design of airborne or space-vehicle instrumentation. These include NASA facilities at the Naval Research Laboratory, Washington, D.C.; the Jet Propulsion Laboratory at California Institute of Technology, Pasa-



Accelerations, vibrations, heating, and extremes of low pressure to which satellites and space probes are subjected during launch and free flight are severe. Preliminary systematic testing of the instrumented payloads under conditions which resemble those to be encountered later is essential. Examples of test equipment for this purpose are shown. (Top) A satellite is prepared for test in a vacuum chamber. The lamps visible inside the chamber are used to heat the satellite during the test cycle [Courtesy U.S. Navy]. (Middle) A satellite is observed while being rotated about its spin axis so that any residual dynamic unbalance can be found and corrected. [Courtesy U.S. Navy]. (Bottom) A satellite is mounted on a vibrational testing machine [Courtesy U. S. Navy].

dena; the Army Ballistic Missile Agency in Huntsville, Ala.; and the Air Force Ballistic Missile Division, Inglewood, Calif. Such test facilities have also been established by a number of major commercial contractors of NASA and the Department of Defense.

Telemetry

The transmission back to earth of instrument readings has been accomplished both with continuous transmissions and with storage of data and subsequent periodic "read-out" by radio command. Both phase and amplitude modulation have been used. Reception of a complete record for a satellite employing continuous telemetry requires an extensive network of receiving stations placed so that at least one is always within the line of sight of the satellite. Despite the severity of this requirement, excellent though not complete records have been obtained for U.S.-IGY satellites by this method.

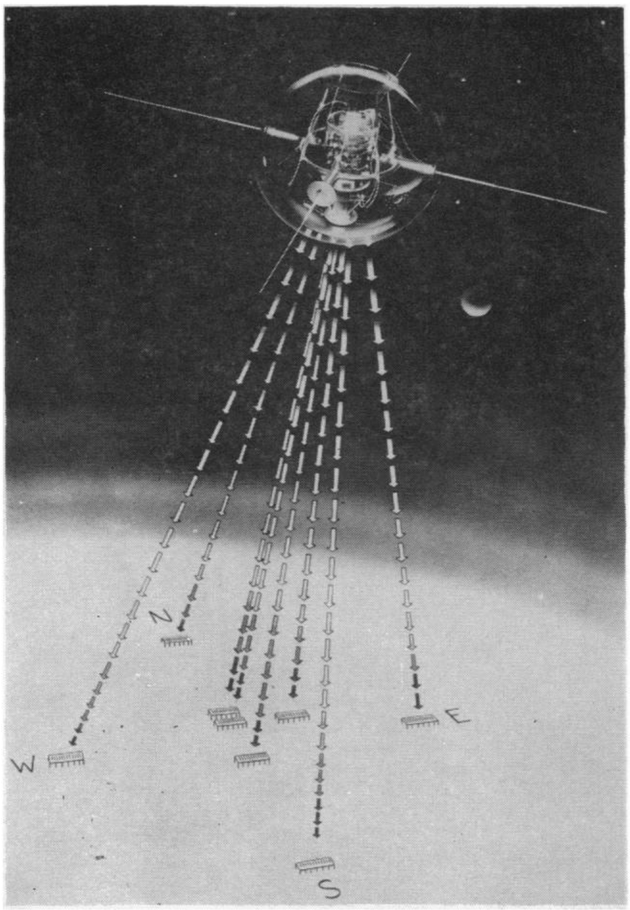
The alternate scheme, involving read-out of data upon command, was planned originally for the Vanguard satellites and was used successfully in Explorer III and Vanguard II. With the satellites containing a data-storage system sufficient for one orbit, it is possible for a complete record to be obtained from read-outs made once each orbit as the satellite passes over the "picket fence" array of tracking stations.

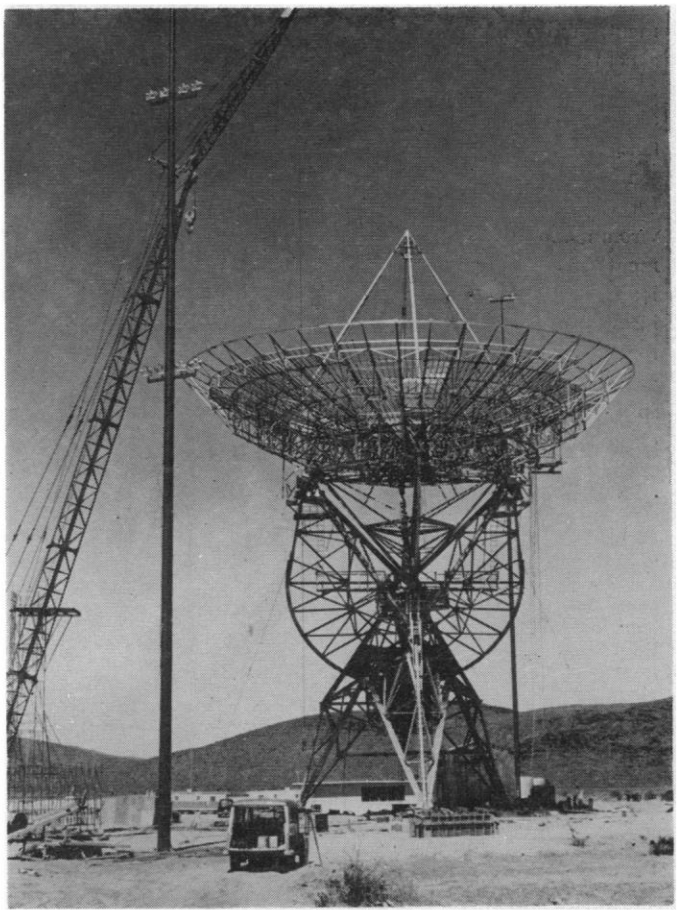
Satellite experiments in the U.S.-IGY effort have so far involved a communication rate of only a few cycles per second. Even when data gathered during a full revolution have been compressed for read-out transmission during passage over a tracking station, the communications bandwidth has not exceeded 15 kilocycles per second. Design of experiments for narrow-band signals was considered preferable not only because less power is required for such communication but also because the simpler design increases reliability.

As space science experiments become more complex, increased demands upon and improvements of telemetry capabilities may be expected. With the present state of the art, communications capabilities approach video bandwidths for ranges of several hundred miles. Limitations are of an engineering rather than a basic nature. Capability also exists for maintaining signal bandwidths of a few tens of cycles out to distances of the order of 100 earth radii and, according to the Jet Propulsion Laboratory, it should be possible by 1962 to communicate at 30-cycles-per-second bandwidth to a distance of about 1000 earth radii or to about one-tenth of that distance with a voice channel of 3 kilocycles per second.

Tracking

Facilities for tracking satellites by radio and optical means and for the computation of orbital position as a function of time have been established as a part of the U.S.-IGY program. These facilities are now being operated





IGY satellites are tracked by a network of radio interferometer stations. This diagram shows a typical arrangement of antenna pairs at such a station (left). Comparison of the phase differences between signals received at the various antennas from the satellite's transmitter establishes the position of the satellite [Courtesy Bendix Radio Corporation]. The 85-foot diameter trainable antenna of the Goldstone Tracking Station of the Jet Propulsion Laboratory is one of a group of radio telescopes used for tracking deep space probes (right). Devices of this sort are suitable for tracking objects in space so long as their angular rates are low. The same high-gain antennas also serve for receiving telemetry signals [Courtesy U.S. Army].

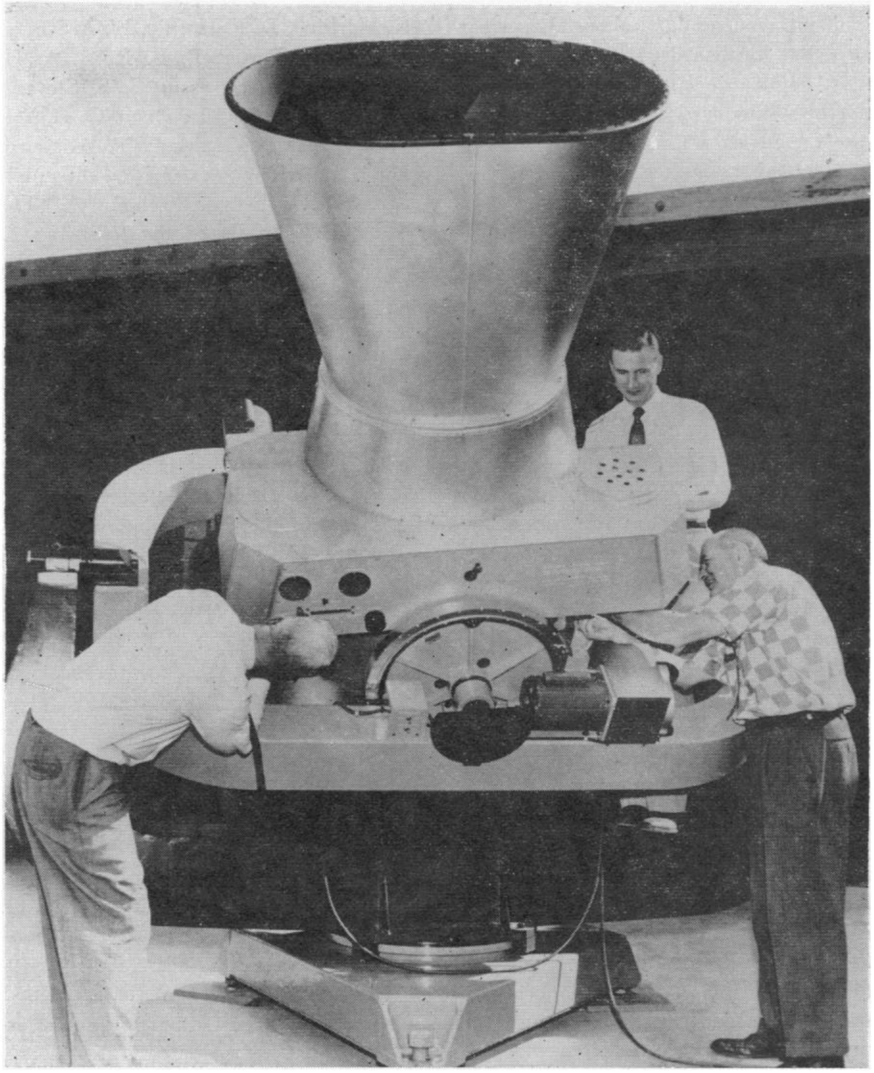
and expanded by the National Aeronautics and Space Administration.

The radio tracking network consists of interferometer stations, operating at 108 megacycles per second, at Blossom Point, Md.; Fort Myers, Fla.; Mt. Cotopaxi, near Quito, Ecuador; Lima, Peru; Antofagasta and Santiago, Chile; San Diego, Calif.; Woomera, Australia; Antigua, British West Indies; and Esselen Park, South Africa. These stations are also equipped for command read-out of telemetry. Some are also equipped for tracking at 40 megacycles per second. Another group of stations, primarily for reception of telemetry and disposed for wider longitudinal coverage, includes sites at San Gabriel and Earthquake Valley, California.; Cape Cañaveral, Fla.; Huntsville, Ala.; White Sands, N.M.; Ibadan, Nigeria; and Singapore. Arrangements have been made for enlisting the aid of the Jodrell Bank Experimental Station in England for the tracking of deep space probes, and three smaller radio telescopes, to operate as a group, are also being set up for this purpose. The first of these is at Goldstone, California. A number of additional radar and space vehicle reception stations has also been put in operation by the Department of Defense.

Precise observations suitable for the computation of definitive orbits for satellites are made by the IGY optical tracking network, now operated by the National Aeronautics and Space Administration and the Smithsonian Astrophysical Observatory. This network includes the following stations, each equipped with an F: 1, 20-inch photo telescope: White Sands, N.M.; Florida, near Palm Beach; Curacao, Netherlands West Indies; Arequipa, Peru; Villa Dolores, Argentina; Olifantsfontein, South Africa; Cadiz, Spain; Shiraz, Iran; Naini Tal, India; Woomera, Australia; Mitaka, Japan; Haleakala, Maui, Hawaii.

Plans for the centralized reduction and compilation of both telemetry and orbital data are under study by the National Aeronautics and Space Administration. In the meantime, it is customary to provide the experimenter with magnetic tape records of the telemetry signals in the form in which they are received.

Orbital data provide a correlation of scientific data with the position of the instrument package in space. These data can be furnished to the scientist as a tabulation of co-ordinates or orbital subpoints and vehicle altitude, given at specified instants of time. At present, the uncertainty of the positions in space so defined is somewhat less than 10 kilometers. For experiments requiring higher precision, improvement is undoubtedly possible.



The Baker-Nunn IGY satellite tracking camera shown here is one of 12 installed on a world-wide basis for photographing artificial satellites against the star background. Accurately timed photographs from these cameras, collated and reduced by the Smithsonian Astrophysical Observatory, have assisted in establishing definitive orbits for even the smallest satellites. The 15-centimeter sphere 1958β2 has been photographed repeatedly at various distances and by the Australian station at Woomera at the extreme range of nearly 4000 kilometers. [Courtesy Smithsonian Astrophysical Observatory]

Space Science Board

The establishment of the Space Science Board of the National Academy of Sciences was announced on 2 August 1958, by Detlev W. Bronk, president of the Academy. The purpose of this board is, in the broadest terms, to ensure the constructive support of the scientific community for a sound and imaginative program of scientific research in space. On the domestic scene, its functions in this regard are to be the focus of the interests and advisory responsibilities of the Academy-Research Council in space science; to draw the attention of scientists to the problems and opportunities in space research, and to provide advice as they may require. In international scientific affairs, the board acts as the instrument for collaboration with the International Council of Scientific Unions and serves thereby to promote the cooperation of American scientists with international programs of space research.

It was noted at the time of its establishment that, in conformity with the academy's tradition, the Space Science Board would function solely in an advisory capacity. Provision for the operational aspects of the conduct and support of space research has been made by law in the establishment of the government agencies cited above. It is clear also that the board's advisory functions must be of a dual nature: it must serve not only the needs of government but also the needs of the scientific community by giving audience to and advice on the problems and suggestions of individual scientists and research institutions.

At the time of the board's formation, the National Aeronautics and Space Administration had not yet come formally into existence. In order to assist in the formulation of the beginnings of a sound research program the board took the initiative of soliciting proposals and suggestions for research in space, a task which had already been recognized and begun by the Satellite Panel of the academy's IGY Committee. The widespread response to these requests provided the basis for a series of recommendations for a beginning research program. It is gratifying to note that these recommendations have, essentially in their entirety, been incorporated into the research program of the National Aeronautics and Space Administration. In view of the success of these initial endeavors and the rapidly developing strength and competence of the National Aeronautics and Space Administration, the board now feels free to devote its efforts more particularly to the consideration of the longer-term problems in space research, to study the support which space research may require in the future from other related branches of fundamental scientific enquiry, and to examine the problems of individual research workers in universities and elsewhere.

In the discharge of these responsibilities the board expects, in addition to its regular meetings and those of its component committees, to arrange and sponsor a series of open meetings and symposia on special problems in space research. The first of these was held in Washington during the meeting of the National Academy of Sciences in April of this year under joint sponsorship with the American Physical Society and the National Aeronautics and Space Administration. Special reports on scientific aspects of space exploration will also be published from time to time; the first of these is due for publication in a few months.

The board's membership consists of the following: L. V. Berkner (chairman), H. S. Brown, Leo Goldberg, H. K. Hartline, D. F. Hornig, W. A. Noyes, Jr., R. W. Porter, B. B. Rossi, A. H. Shapley, J. A. Simpson, S. S. Stevens, H. C. Urey, J. A. Van Allen, O. G. Villard, Jr., Harry Wexler, G. P. Woollard, Hugh Odishaw (executive director), and R. C. Peavey (secretary). The board has established the following 12 committees to deal with particular aspects of space science.

Committee 1, Chemistry of Space and Exploration of Moon and Planets: H. C. Urey (chairman), H. S. Brown (vice-chairman), Harmon Craig, Mark Inghram, Frank Press, G. de Vaucouleurs, F. L. Whipple, H. F. York, H. H. Hess, G. A. Derbyshire (secretary)

Committee 2, Optical and Radio Astronomy: Leo Goldberg (chairman), L. H. Aller, H. W. Babcock, A. D. Code, J. W. Evans, John Findlay, Herbert Friedman, Roger Gallet, F. T. Haddock, Jr., Lyman Spitzer, Jr., Martin Schwarzschild (Alt.), Otto Struve, E. R. Dyer (secretary)

Committee 3, Future Vehicular Development: D. F. Hornig (chairman), Abe Silverstein, J. P. T. Pearman (secretary)

Committee 4, International Relations: R. W. Porter (chairman), W. O. Fenn, H. E. Newell, Jr., H. P. Robertson, A. W. Frutkin (secretary)

Committee 5, Immediate Problems: R. W. Porter (chairman), G. A. Derbyshire (secretary)

Committee 6, Space Projects: B. B. Rossi (chairman), Thomas Gold, S. E. Luria, Philip Morrison, J. P. T. Pearman (secretary)

Committee 7, The Ionospheres of the Earth and Planets: A. H. Shapley (chairman), H. G. Booker, J. W. Chamberlain, Robert Jastrow, C. G. Little, Laurence A. Manning, R. C. Peavey (secretary)

Committee 8, Physics of Fields and Particles in Space: J. A. Simpson (chairman), J. A. Van Allen (vice-chairman), J. W. Chamberlain, William Kraushaar, E. N. Parker, E. H. Vestine, John Winckler, Stanley Ruttenberg (secretary)

Committee 9, General Engineering Service and Co-ordination: O. G. Villard, Jr (chairman), E. C. Buckley, J. P. T. Pearman (secretary)

Committee 10, Meteorological Aspects of Satellites: H. W. Wexler (chairman), C. C. Bates, George Benton, E. M. Cortright, Sigmund Fritz, W. W. Kellogg, Norman Phillips, Ernst Stuhlinger, V. E. Suomi, W. K. Widger, Jr., E. R. Dyer (secretary)

Committee 11, Psychological and Biological Research: H. K. Hartline (chairman), S. S. Stevens (vice-chairman), H. J. Curtis, L. E. Farr, Joshua Lederberg, E. F. MacNichol, Otto Schmitt, E. L. Tatum, G. A. Derbyshire (secretary)

Committee 12, Geodesy: G. P. Woollard (chairman), Paul Herget, R. K. C. Johns, D. A. Lautman, William Markowitz, J. A. O'Keefe, W. J. O'Sullivan, D. A. Rice, Hellmut Schmid, C. A. Whitten, E. R. Dyer (secretary)

International Cooperation

On the international scene, the Committee on Space Research (COSPAR) was established by resolution of the International Council of Scientific Unions in October of 1958. The function of this committee is to assist in the advancement on an international scale of fundamental research carried out with the use of rockets or rocket propelled vehicles. The membership includes representatives of the appropriate international scientific unions, the scientific institutions of those countries having satellite or other space research programs, and others having special interests in space science. The Space Science Board, in its international role, represents the interests of the Academy and the American scientific community on COSPAR.

Three working groups have been established by COSPAR to study, respectively, (i) tracking and telemetry, (ii) proposals for scientific experiments and research programs, and (iii) arrangements and methods for exchange and publication of data. In addition, the functions of the ICSU Committee on Contamination by Extra-terrestrial Exploration (CETEX), which had been established before COSPAR came into existence, have now been transferred to COSPAR.

In essence, COSPAR provides a means for continuation of the cooperative IGY programs of rocket and satellite research. It is to be hoped that this committee will be able not only to carry on but also to broaden and intensify the fruitful scientific relations which characterized the IGY programs.