NATIONAL SCIENCE FOUNDATION

HEARINGS

BEFORE THE

SUBCOMMITTEE OF THE COMMITTEE ON APPROPRIATIONS HOUSE OF REPRESENTATIVES

EIGHTY-FIFTH CONGRESS

FIRST SESSION

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REPORT ON INTERNATIONAL GEOPHYSICAL YEAR

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NATIONAL SCIENCE FOUNDATION

REPORT ON INTERNATIONAL GEOPHYSICAL YEAR

WEDNESDAY, MAY 1, 1957.

WITNESSES

ALAN T. WATERMAN, DIRECTOR
JAMES M. MITCHELL, ASSOCIATE DIRECTOR
J. WALLACE JOYCE, HEAD, OFFICE OF THE INTERNATIONAL GEOPHYSICAL YEAR
JAMES B. ROBERTS, ASSISTANT TO THE COMPTROLLER

UNITED STATES NATIONAL COMMITTEE FOR THE INTERNATIONAL GEOPHYSICAL YEAR

L. V. BERKNER, VICE PRESIDENT, SPECIAL INTERNATIONAL COMMITTEE FOR THE INTERNATIONAL GEOPHYSICAL YEAR
JOSEPH KAPLAN, CHAIRMAN, UNITED STATES NATIONAL COMMITTEE FOR THE INTERNATIONAL GEOPHYSICAL YEAR
RICHARD W. PORTER, CHAIRMAN, USNC–IGY TECHNICAL PANEL ON THE EARTH SATELLITE PROGRAM
JAMES A. VAN ALLEN, CHAIRMAN, WORKING GROUP ON INTERNAL INSTRUMENTATION, USNC–IGY TECHNICAL PANEL ON THE EARTH SATELLITE PROGRAM
ROGER R. REVELLE, MEMBER, USNC–IGY TECHNICAL PANEL ON OCEANOGRAPHY
HARRY WEXLER, CHIEF SCIENTIST, USNC–IGY ANTARCTIC PROGRAM
HUGH ODISHAW, EXECUTIVE DIRECTOR, USNC–IGY
R. C. PEAVEY, ADMINISTRATIVE OFFICER, USNC–IGY

Mr. THOMAS. Gentlemen, will the committee please come to order? We have with us this morning some most distinguished gentlemen. The committee certainly is delighted and honored to have this opportunity of saying, "Hello," to so many of our distinguished friends again.

From the staff of the National Science Foundation, it is always nice to have with us our genial and able friend, Dr. Waterman, the director; Mr. Mitchell, associate director; Mr. Joyce, the head of the Office of the International Geophysical Year; and Mr. Roberts, assistant to the comptroller.

Of course, now we have so many distinguished faces here in the International Geophysical Year representatives—our old friend, Dr. Berkner, vice president of the Special International Committee for the International Geophysical Year; our very genial friend, Dr. Joseph Kaplan, chairman of the United States National Committee for the International Geophysical Year; Dr. Porter, chairman of the USNC–IGY Technical Panel on the Earth Satellite Program; Dr. James A. Van Allen, chairman of the Working Group on Internal Instrumentation, of the USNC–IGY Technical Panel on the Earth Satellite Program; Dr. Harry Wexler, chief scientist, USNC–IGY Antarctic program.

We also have with us Dr. Roger R. Revelle, a member of the USNC–IGY Technical Panel on Oceanography. We have been missing you around here, Doctor. We have been inquiring about you.

We have Mr. Odishaw, executive director, and Mr. R. C. Peavey, administrative officer, of the United States National Committee on the International Geophysical Year.

This is a great day for the committee. I repeat, we are delighted and honored to have you gentlemen with us. You do the committee a great honor, and we thank you for coming.

Dr. Waterman, do you or Dr. Berkner or any of the other gentlemen want to take over and run your part of the show and let us listen?

Introductory Remarks

Dr. Waterman. I want to make a few brief remarks, Mr. Chairman. We are very happy to have this opportunity for these scientists to make their presentation to you in response to your request about the status of the International Geophysical Year program.

This is a very impressive program, as you know, and I believe that it is especially extraordinary for the number of very capable scientists in this country that have taken a part in planning it. These scientists are doing so under the guidance and supervision of the gentlemen that are here today.

The program itself is dedicated to basic science, but I would like to point out that, as a result of the basic research accomplished during the International Geophysical Year, the practical benefits are certain to be very great, especially in such important practical fields as meteorology and weather forecasting, and also in the field of radio communications, to mention just two outstanding ones; so that this is another example where basic research is certain to pay off with this very impressive effort in which the nations of the world are cooperating.

I would like, then, Mr. Chairman, to ask Dr. Berkner to make the opening remarks, and then turn the program over to Dr. Kaplan, as Chairman of the United States National Committee.

Biographical Sketches

Mr. Thomas. Wonderful. That is a fine procedure.

If I may, let me interrupt you.

Mr. Reporter, someone has been kind enough to give us a biographical sketch of these distinguished scientists. I want to insert them at this point in the record.

(The biographical sketches referred to follow:)

Biographical Sketch of Lloyd V. Berkner, President of the International Council of Scientific Unions; Vice President of Comité Special de l'Année Géophysique Internationale, 1957–58

Lloyd V. Berkner is vice president of the Comité Special de l'Année Géophysique Internationale. Since 1951, he has been president and chairman of the executive committee of the Associated Universities, Inc., of New York.

Mr. Berkner received his B. S. degree in electrical engineering at the University of Minnesota in 1927 and subsequently did graduate work in physics at George Washington University. He acted as engineer for the Airways Division of the Department of Commerce from 1927 to 1928. From 1928 to 1930 he was a member of the first Byrd Antarctic Expedition, again acting in the capacity of an engineer. On his return in 1930, he joined the staff of the National Bureau of Standards as an electrical engineer, remaining until he became an engineer and physicist at the department of terrestrial magnetism of the Carnegie Institution of Washington in 1933 During his service as an officer in the United States Navy from 1941 to 1946, he served as head of the Radar Section of the Bureau of Aeronautics from 1941 to 1943, as Director of the Electronics Material Branch from 1943 to 1945, and as technical planning officer for future operations of the U. S. S. *Enterprise* from 1945 to 1946. From 1946 to 1947, he was executive secretary of the Research and Development Board of the Department of Defense, and from 1947 to 1951 he acted as head of the section on exploratory geophysics of the atmosphere of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington and has remained a research associate of the institution since 1951. Since 1947, he has acted as consultant for the Research and Development Board, and he was a consultant for the Massachusetts Institute of Technology from 1950 to 1952, and for the National Security Resources Board from 1952 to 1953. In 1949, he acted as special assistant to the Secretary of State in the organization and direction of the first military assistance program of the North Atlantic Pact, and from 1949 to 1950 he was chairman of the steering committee and author of the official State Department report, Science and Foreign Relations.

He has been the recipient of the United States Special Congressional Gold Medal, the Silver Medal of the Aeronautical Institute, the Gold Medal of the City of New York, the Science Award of the Washington Academy of Sciences, the Commendation Ribbon of the Secretary of the Navy, the Legion of Merit, the Naval Reserve Medal with 1 star, the American Defense Service Medal with 1 star, the American area of the Pacific campaign medals, the World War II Victory Medal, and the Outstanding Achievement Award of the University of Minnesota. He is an honorary officer of the Order of the British Empire.

Mr. Berkner is a fellow of the American Physical Society, the Institute of Radio Engineers, and the American Institute of Electrical Engineers. He is a member of the National Academy of Sciences, the National Research Council, the International Scientific Radio Union, the International Union of Geodesy and Geophysics, the American Geophysical Union, the American Association for the Advancement of Science, the Arctic Institute of North America, the Washington Academy, the New York Academy, the Philosophical Society of Washington, the Council on Foreign Relations, the Armed Forces Communications Association, the American Political Science Association, Theta Tau, Eta Kappa Nu, Acacia, Scabbard and Blade, Plumb Bob, the Cosmos Club, and the Explorers Club.

Biographical Sketch of Dr. Joseph Kaplan, Chairman, United States National Committee for the International Geophysical Year

Dr. Kaplan attended the Johns Hopkins University and received the B. S. degree in chemistry in 1924, and the M A. degree and Ph. D. degree in physics in 1926 and 1927 respectively. Dr. Kaplan spent 1 year (1927–28) at Princeton University as national research fellow in physics. During this period he worked under Dr. Karl T. Compton, and published several papers on the nature of active hydrogen and nitrogen and the excitation of the green auroral line in the laboratory. These two papers formed the foundation of much of his subsequent work on the laboratory production of upper atmospheric spectra.

Dr. Kaplan was apopinted assistant professor of physics at the University of California, Los Angeles, in 1928, associate professor in 1935, and professor in 1940. He served as chairman of the department of physics from 1938–44 and organized a war program in meteorology in 1940, directing it until 1944. He organized the Institute of Geophysics at UCLA and directed it during 1946–47. His academic activities have included the teaching of astrophysics in the department of astronomy in the period 1932–43.

From 1943 to 1945, Dr. Kaplan was on leave from UCLA as Chief of the Operations Analysis Section of the Second Air Force, and later of the Operations Analysis Section of the Air Weather Service. For this work he was awarded the War Department's decoration for exceptional civilian service in 1947.

Prior to this service with the Air Corps, he served as a member of the University Meteorological Committee established in 1942 to assist the military services in matters related to meteorology, and he participated actively in the development of the largely expanded weather services of both the Air Corps and the Navy. Following World War II, Dr. Kaplan was appointed to the Air Force Scientific Advisory Board and has been a member of this group since 1947, having served for several years as chairman of the Geophysics Research Panel.

Dr. Kaplan is currently, and has been in the past, active on a number of national and international committees Of these, the most active at present is the United States National Committee for the International Geophysical Year, of which he is Chairman This committee, established by the National Academy of Sciences, is responsible for the United States program of geophyiscal research which will be conducted during 1957–58 in cooperation with 55 other nations From January 1947 until the end of 1954, Dr. Kaplan served as local secretary of the American Physical Society for meetings which are held in the West. He has served as chairman of the Mixed Committee on the Upper Atmosphere of the International Union of Geodesy and Geophysics. He has served as chairman or as a member of the steering committee for several conferences sponsored by the National Science Foundation, and has been a member of the panel on physics of the NSF

Recent appointments include that of member at large of the United States of America National Committee of URSI (July 1, 1954, to June 30, 1958); membership in the National Academy of Sciences-National Research Council delegation to the 10th General Assembly of the International Union of Geodesy and Geophysics; member, commission 22, International Astronomical Union; member, executive committee, International Association of Terrestrial Magnetism and Electricity; and chairman, committee on the upper atmosphere, American Meterological Society. Currently, Dr. Kaplan is vice-president of the International Association of Geomagnetism and Aeronomy (the new name of the International Association of Terrestrial Magnetism and Electricity), and chairman of the committee on the high atmosphere of this association He is also a member of the United States National Committee for the International Union of Pure and Applied Physics.

Dr Kaplan is a fellow of the American Physical Society, and a member of the American Astronomical Society, the American Geophysical Union, the American Rocket Society, the Meteoritical Society, the American Meteorological Society, and the Institute of the Aeronautical Sciences. He was elected a fellow in the Institute of the Aeronautical Sciences in 1957. He received the astronautical award of the American Rocket Society in 1956, and the distinguished service award of Phi Delta Epsilon in 1956. He is a member of the National Academy of Sciences.

He has been active in civic and university affairs, having served as president of the West Los Angeles Rotary Club, chairman of the West Los Angeles Coordinating Council, president of the southern California chapter of the American Friends of the Hebrew University. He has served as a member of the Governor's special technical committee on air pollution and as chairman of the University of California committee on air pollution.

His research activities have been principally concerned with the spectra of diatomic molecules, and in particular with afterglows in nitrogen, oxygen, and their mixtures The applications of these laboratory results to the spectra of the aurora and airglow have also been emphasized in his studies, which have also directed attention to chemical processes in the upper atmosphere

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BIOGRAPHICAL SKETCH OF DR. R W PORTER, CHAIRMAN, TECHNICAL PANEL ON THE EARTH SATELLITE PROGRAM OF THE UNITED STATES NATIONAL COMMITTEE FOR THE INTERNATIONAL GEOPHYSICAL YEAR

Dr. Porter received his bachelor of science degree in electrical engineering in 1934 from the University of Kansas, where he was a Summerfield scholar for 4 years. He obtained the doctor of philosophy degree in electrical engineering in 1937 from Yale University, where he held a Coffin fellowship for 2 years

During his undergraduate days he worked as an engineer at radio station KFKU While at graduate school he acted as associate professor at New Haven Junior College. For the summers of 1935 and 1936 he was employed at General Electric; and he has been permanently affiliated with General Electric since 1937, working in such fields as voltage regulator engineering, aircraft equipment development, and, since 1945, rocketry. He is now consultant on communication and control equipment of the engineering services division. He developed and designed the first military and commercial applications of amplidyne generators; and he was responsible for the General Electric fire control system used on the B–29 and other aircraft and for automatic tracking equipment for early fire control radar. In 1940 he supervised the first year of the General Electric advanced course in engineering.

Dr. Porter is chairman of the Technical Panel on the Earth Satellite Program of the United States National Committee for the International Geophysical Year. This Committee has been established by the National Academy of Sciences to plan and direct the United States International Geophysical Year program.

Dr. Porter has been honored by Yale University with a doctor of science degree, by the University of Kansas with the alumni award, by General Electric with the Coffin award, by the American Rocket Society with the Goddard award, by Eta Kappa Nu with the outstanding young electrical engineer award. He was president of the American Rocket Society in 1955. He is a member of the Institute for the Aeronautical Sciences, the American Society for Engineering Education, National Aeronautical Association, Tau Beta Pi, Sigma Tau, Eta Kappa Nu, Sigma Xi, and others.

Biographical Sketch of Dr. James A. Van Allen, Chairman, Department of Physics, State University of Iowa. Chairman of the Working Group on Internal Instrumentation of the Earth Satellite Program

Dr James A. Van Allen is chairman of the Subcommittee on Internal Instrumentation of the USNC–IGY Technical Panel on the Earth Satellite Program, and a member of that technical panel, and he is a member of the Technical Panels on Cosmic Rays and on Rocketry.

Dr. Van Allen received the bachelor of science degree from Iowa Wesleyan College in 1935, the master of science (1936) and doctor of philosophy in physics from the State University of Iowa in 1939. He was a Carnegie research fellow in the Department of Terrestrial Magnetism of the Carnegie Institution from 1939 to 1941. In 1941–42 he was associated with the John Hopkins Applied Physics Labortory in Washington, where he worked on the development of the radio proximity fuse. He was again associated with the laboratory in 1946 to 1950, and was in charge of the high altitude research group there. Dr Van Allen was a Guggenheim Foundation fellow in 1951 and a research associate at Princeton University (1953–54). From 1942 to 1946 he served as a lieutenant commander in the United States Navy. Dr. Van Allen joined the teaching staff of Iowa State University as professor and head of the department of physics in 1951.

Dr. Van Allen has been a pioneer in high-altitude research with rockets, serving as a member of the subcommittee on upper atmosphere of the National Advisory Committee for Aeronautics (1948–52) ; a member of the Upper-Atmosphere Rocket Research Panel since 1946, and its chairman since 1947. In 1952 Dr. Van Allen developed the balloon-launched rocket (rockoon) technique which is now widely used in upper-atmosphere research, and he supervised the development of the Aerobee rocket. In 1949 he was awarded the American Rocket Society's Hickman medal, and the physics award of the Washington Academy of Sciences.

He is a fellow of the American Physical Society, member of the American Geophysical Union, Washington Academy of Sciences, Sigma Xi, and Gamma Alpha. He is the author of Physics and Medicine of the Upper Atmosphere (1952) and has contributed a number of articles on cosmic rays and upper atmosphere research to scientific journals. He is the editor of Scientific Uses of Earth Satellites (1957).

Biographical Sketch of Dr. Roger Revelle, Director, Scripps Institution of Oceanography, Member, Technical Panels on Oceanography and Geomagnetism

Dr. Roger Revelle is director of the Scripps Institution of Oceanography of the University of California and chief campus administrative officer of the La Jolla Campus of the University of California. During the past few years, Dr. Revelle has played a key role in planning the USNC–IGY program, particularly those aspects relating to oceanography and to operations in the equatorial regions. He is a member of both the USNC–IGY Technical Panel on Oceanography and the USNC–IGY Technical Panel on Geomagnetism. He is chairman of the USNG–IGY ad hoc equatorial committee.

Dr. Revelle received his bachelor of arts degree in 1929 from Pomona College and did graduate work at Claremont College from 1929 to 1930, at the University of California at Berkeley from 1930 to 1931, and at the Scripps Institution of Oceanography at La Jolla from 1931 to 1936, when he received his doctor of philosophy degree. He served as a teaching assistant at both Pomona College and the University of California at Berkeley and as research assistant at the Scripps Institute of Oceanography.

In 1936 he joined the teaching staff of the Scripps Institution of Oceanography, serving as an instructor. From 1941 to 1946 he was an assistant professor. He also served as a lieutenant (junior grade) in the United States Naval Reserve, stationed at the San Diego Radio and Sound Laboratory from 1941 to 1942 and was promoted to the rank of commander during his service as officer in charge of the Oceanographic Section of the Navy Bureau of Ships from 1942 to 1946 In 1946 he acted as officer in charge of the Oceanographic Section of the Staff Joint Task Force No. 1, and from 1946 to 1947 he headed the Geophysics Branch of the Office of Naval Research. Since 1948 he has been a consultant of the Office of Naval Research.

In 1948 he returned to the University of California as associate director of the Scripps Institution of Oceanography and professor of oceanography. He became acting director in 1950 and director in 1951. He acted as leader of the University of California-Navy Electronics Laboratory mid-Pacific expedition to the central Pacific and of the University of California Capricorn expedition to the South Pacific in 1952–53.

Dr. Revelle belongs to a number of scientific organizations, including the National Research Council, the National Academy of Sciences, the American Association for the Advancement of Science, the American Meteorological Society, Sigma Xi, Society of Limnology and Oceanography, American Association of Petroleum Geologists and Cosmos Club He is president of the Section on Oceanography of the American Geophysical Union and chairman of the Special Committee on Oceanographic Research of the International Council of Scientific Unions. He is a fellow of the Geological Society of America. Dr. Revelle is chairman of the board of trustees of the La Jolla town council and member of the advisory board of the Musical Arts Society of La Jolla.

As an internationally recognized authority on oceanography, Dr. Revelle has published some three dozen articles on the physical and chemical characteristics of the seas in both American and foreign scientific journals. He is author of a book on geophysical exploration under the ocean, The Earth Beneath the Sea, published in 1954 by McGraw-Hill.

Biographical Sketch of Dr. Harry Wexler, Chief Scientist, IGY Antarctic Program

Dr. Harry Wexler is chief scientist of the USNC-IGY Antarctic program and is responsible for its entire scientific effort to be undertaken in 1957 and 1958 in Antarctica. He is a member of the USNC-IGY Antarctic Committee, the USNC-IGY Technical Panel on Meteorology, the ad hoc Arctic Committee and the ad hoc Equatorial Committee. He is also an alternate member of the United States National Committee for the International Geophysical Year and its Executive Committee.

Dr. Wexler received his bachelor of science degree in mathematics from Harvard University in 1932 He did graduate work at the Massachusetts Institute of Technology from 1932 to 1934 and from 1937 to 1938 and obtained his doctor of science in meteorology in 1939. During the intervening period, 1934 to 1937, he worked at the United States Weather Bureau in Chicago, Ill., and Washington, D. C. He was appointed assistant professor of meteorology at the Institute of Meteorology of the University of Chicago in 1940 and left this position in late 1941 to return to defense work at the Weather Bureau in Washington. In November 1942 he joined the Army Air Force's Weather Service as a captain and was appointed senior instructor in meteorology to the Army Air Force Aviation Cadet School in Grand Rapids, Mich. While there he served as a member of the wartime university meteorological committee established to assist the military services in matters related to meteorological training.

In late 1943 Dr. Wexler was transferred to the Weather Division of the Army Air Forces in Washington, where he served as research executive and initiated and fostered a program of research in weather which later developed into the large Air Force program in geophysics. In September 1944, Dr. Wexler, with Col. Floyd Wood as pilot, made the first penetration of an Atlantic hurricane, which because of its unusual intensity became known as the "Great Atlantic Hurricane." In 1946 Dr. Wexler became Chief of the United States Weather Bureau's Science Services Division. In 1955 he was named Director of Meteorological Research. The Weather Bureau has made Dr. Wexler available to the USNC-IGY for scientific direction of the Antarctic program.

In 1945 the Institute of Aeronautical Sciences presented Dr. Wexler the Losey Award in recognition of his outstanding contributions to the science of meteorology as applied to aeronautics.

Dr. Wexler is a member of the Advisory Committee on Reactor Safeguards for the Atomic Energy Commission; Chairman, Committee on the Meteorological Aspects of the Effects of Atomic Radiation, of the National Academy of Sciences; a member of the Meteorological Operations Subcommittee of the National Advisory Committee for Aeronautics. He is a councilor of the American Meteorological Society, a fellow of the American Academy of Arts and Sciences, a member of the Royal Meteorological Society and the Washington Academy of Sciences. He is a member of the American Geophysical Union. In August 1955, Dr. Wexler was a member of the United States delegation to the Atoms for Peace Conference in Geneva, Switzerland.

As an internationally recognized authority on meteorology, Dr. Wexler has published some 50 papers in scientific journals, treating such subjects as the radiative cooling of the air, polar anticyclones, atmospheric turbidity, structure of hurricanes, and upper atmosphere temperatures and dynamic connections with the lower atmosphere.

Statement of Dr. Lloyd V. Berkner

Mr. Thomas. We will place the statement you have prepared in the record at this point, Dr. Berkner, and you can tell us in your own words what progress you are making in the International Geophysical Year program.

(The statement is as follows:)

Statement of Dr. L. V. Berkner, Vice President, Comité Spécial de l'Année Géophysique Internationale, National Academy of Sciences

General Remarks

The opportunity to appear before this committee again, shortly before the actual opening of the IGY, is particularly gratifying to me. The interest which the Congress, and in particular your committee, has continually shown in the IGY scientific program is most heartening, and is also representative of the attention which the program is now drawing throughout the world. There is no doubt but that this effort stands as the greatest cooperative venture in science the world has ever known—a peaceful effort which I believe is of particular importance in these troubled times, and which promises immeasurable benefits to all. During the past year we have directed our efforts to the final coordination of all of the international program aspects, some of which I should like to bring to your attention now.

In previous testimony, you will recall, I mentioned the third meeting of the Special Committee for the International Geophysical Year (CSAGI). This meeting was held in Brussels, September 8–14, 1955, and it served to coordinate the new and enlarged national programs into an integrated plan, as well as to provide a critical review of the various national technical programs developed since the Rome meeting of the CSAGI a year before.

RECENT CSAGI MEETINGS

A fourth meeting of the CSAGI was held in Barcelona, September 10–16, 1956, at which time the international program was reviewed in the light of the new programs and the revisions of the programs announced at Brussels in 1955. At the request of the United States National Committee, one full day of this meeting was devoted to the several phases of the International Geophysical Year earth satellite tracking programs. Special emphasis was placed on the need for wide international cooperation in tracking the satellite to develop its full scientific potential. Many nations indicated a willingness to set up satellite observation stations, both on the professional and volunteer level.

The U. S. S. R. National Committee announced at this meeting that it too was proceeding with an earth satellite program and would launch its satellite during the International Geophysical Year; the U. S. S. R. delegates to the Barcelona Conference advised us that further details of their satellite program would be made available through CSAGI and we have recently received word that we can expect these details within the next 2 months. It is interesting to note that resolutions adopted unanimously at Barcelona call for both the United States and U. S. S. R. satellites to have compatible transmitters, in accordance with the announced United States plans, thus, assuring that United States scientists will be able to track the U. S. S. R. satellite.

The Barcelona meeting also continued the earlier discussion of the problem of handling the vast quantities of raw data which the IGY investigation will produce. It was decided that there would be three world data centers: One in the United States, a second in the U. S S. R., and a third center, which would in fact be a number of centers in different countries (largely in Western Europe), to collect data by scientific discipline. As you know, each national IGY committee participating in the IGY program is under obligation to supply at its own cost, and in accordance with a time schedule established by the CSAGI, all of its IGY data to one of the world data centers. Each center will then copy the data which reaches its center, and interchange with the other two centers. Thus the international IGY data will be available throughout the world for long-range, post-IGY research.

ESTIMATED COST OF IGY PROGRAM

At the hearings before this subcommittee in 1954 the cost of the total IGY program was estimated to be about $150 million Since then the worldwide program has expanded both in the number of participating countries—the total investment in the worldwide program is now perhaps something like $500 million—and in an intensification of the studies in a number of fields. Another important addition was the adoption of a program to study atmospheric circulation by means of natural and artificial radiations in the atmosphere. The addition of this last program was sponsored by the Netherlands National Committee. One of the primary purposes of this program is to take advantage of the potentialities of radioactive tracers as a research tool in the many fields of the earth sciencies and to encourage the establishment of worldwide studies using tracer techniques during the International Geophysical Year A CSAGI meeting on this subject was held in Utrecht in January 1957, at which time a program was set up and recommendations for its implementation were made.

INTERNATIONAL PARTICIPATION

When the United States IGY program was first presented to the Congress, 29 nations had indicated that they would participate in the program. Last year 45 nations were full-fledged participants. At the present time the number has increased to a total of 58: Argentina, Australia, Austria, Belgium, Bolivia, Brazil, Bulgaria, Canada, Ceylon, Chile, Chinese Peoples Republic, Colombia, Cuba, Czechoslovakia, Denmark, Dominican Republic, Ecuador, Egypt, Ethiopia, Finland, France, Germany (East), Germany (West), Great Britain, Greece, Guatemala, Hungary, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Japan, Mexico, Morocco, Netherlands, New Zealand, Norway, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Rhodesia and Nyasaland, Rumania, Spain, Sweden, Switzerland, Tunisia, Union of South Africa, Union of Soviet Socialist Republics, United States, Uruguay, Venzuela, and Yugoslavia.

EXPANSION OF PROGRAM

The intensification of the IGY program is exemplified most clearly, as it was last year, by the expanded program in the Antarctic region. In 1954, 5 nations proposed some 12 stations in Antarctica; last year 10 nations planned 39 stations. At the present time 12 nations have already set up or are in the process of setting up 63 stations. Representatives of the Argentine and U. S. S. R. National Committees have joined the scientists at the IGY Little America station, working there in the meteorological program and thereby helping to coordinate the work of the Little America Weather Central As a cooperative arrangement, a representative of the United States National Committee is at the main Soviet base at Mirny. These exchanges are extremely valuable in coordinating the scientific work.

The largest overall programs are still those of the United States and the U. S. S. R. The magnitude of a nation's program, as I indicated in previous testimony, depends on many factors· geographic territory possessed or held in trust is one of the most important because the IGY calls for adequate geographic coverage of the world. The large land masses of the United States and its possessions, and United States practical interests in communications, transportation, and so forth, are pertinent aspects of United States interests in the IGY effort.

REGIONAL CSAGI MEETINGS

In addition to the CSAGI Barcelona meeting discussed earlier, CSAGI has held a number of special meetings devoted to the coordination of the work in the specific regions and particular scientific disciplines. These meetings were as follows

Arctic Conference, May 1956 (Stockholm)
Western Hemisphere Conference, July 1956 (Rio de Janeiro)
Antarctic Conference, July 1956 (Paris).
Oceanography Conference, January 1957 (Göteborg).
Atmospheric Radiation Conference, January 1957 (Utrecht).
Western Pacific Regional Conference, February 1957 (Tokyo).
Data Center Conference, April 1957 (Brussels).

IGY technical manuals for each discipline are in the process of publication and distribution. These manuals accurately describe the scientific work to be done and the instrumentation to be used. They also set up minimum standards of performance and standardize the scientific procedures so that the data gained from the experiments will prove internationally meaningful.

WORLD DAYS COMMUNICATIONS NETWORK

A final world-days calendar has been printed and distributed to all the IGY countries, copies of which I have with me if you are interested. I should like to discuss briefly the world-days program and the international communications network associated with it both because the program itself should prove extremely valuable for experiments in upper atmosphere physics and also because the program is emblematic of the international cooperation and interdependence of the IGY.

A series of tests of the worldwide communications network was held January 10–16, February 10–16, March 10–16, and April 10–16 There will be other tests on May 10–16, and the entire month of June will be devoted to advance trials of the whole IGY program. The network has its focal point at the National Bureau of Standards ionospheric field station located at Fort Belvoir. From this point warnings will be flashed to scientists throughout the world to redouble their efforts in anticipation of unusual geophysical activity. The network consists of the meteorological radio teletype net of the World Meteorological Organization, virtually all the commercial communications facilities throughout the world, Government facilities, such as military channels and in the United States the CAA and special messages broadcast by stations WWV and WWVH—the National Bureau of Standards communications predictions channels—and their counterparts in other countries.

Scientists at the National Bureau of Standards field station, with the advice of ionospheric and solar observatories and communications forecasting centers both in the United States and abroad, will make a decision by 1600 u. t. (universal time) every day as to whether to call an alert for 0001 u. t. the following day. If solar conditions are such as to warrant the calling of an alert, the NBS field station will issue messages to regional warning centers in the U. S. S. R., the Netherlands, France, Germany, and Japan and then to the associate warning centers in Australia, Antarctica, and Alaska. From these centers the warnings will be flashed to every IGY field station throughout the world.

The NBS field station in Virginia will also serve as the Western Hemisphere regional warning center. In the United States itself, messages will be put on the United States Weather Bureau communications system, so that all United States Weather Bureau stations will be alerted. It is then the task of each station to inform all the other IGY field stations in its locality

The special communications forecasting stations—WWV and WWHV in the United States, LOL in Argentina, and JJY in Japan—are expected to serve as a secondary method of informing the world IGY stations of alerts and special world intervals.

During the International Geophysical Year there will be four types of specially designated world days or series of days on which special observing programs will be conducted.

1 Regular world days will consist of 2 consecutive days at new moon and others near the quarter phase and at times of expected prominent meteor showers. On these days there will be increased activity in ionospheric physics, geomagnetism, and other IGY disciplines.

2 Alerts will be issued from the National Bureau of Standards radio forecasting center at Fort Belvoir, Va., after consultation with the forecasting centers of other countries. Generally alerts will be issued when there is an unusually active region on the solar disk indicating a high probability of ensuing solar flares and geomagnetic disturbance.

3. The alert will also serve as notice to scientists that a special world interval may be called in a few days The special world interval will be called by the IGY World Warning Agency on 8 hours' notice when there is a strong possibility that a significant geomagnetic disturbance will begin within 24 hours after the start of the interval. The interval will end when the disturbance subsides or in about 48 hours should the predicted disturbance not materialize.

Programs in ionospheric physics, geomagnetism, solar activity, cosmic rays, and aurora will be intensified during alerts and special world intervals. Some special cosmic ray balloon flights and rocket launchings may be made during these periods, with experiments on a standby basis, awaiting notification of special conditions from the world warning center.

4. World meteorological intervals are series of 10 consecutive days each quarter including the solstice and equinox days and 3 regular world days when upper air soundings will be increased and special attention will be given to the gathering of data from the upper atmosphere. IGY scientific rocket launchings are almost all scheduled for these intervals.

CONCLUSION

I have not tried to be all inclusive in this brief description, but I feel that even from these few comments one can get a picture of a cooperative, international scientific program moving and developing rapidly toward its goal. It is significant that the international program, or even our own national program, is not the work of an individual but rather of hundreds of individuals. The geophysical sciences are different from some other sciences in that synoptic data is what is needed—data from all over the world taken at the same time. Weather has no boundaries, neither does the aurora, nor the ionosphere; they are worldwide and cosmic events. And so it is with the International Geophysical Year program: It is necessarily worldwide if we are to understand our physical environment, and the results of the program cannot fail to be widely beneficial to all mankind. I am personally pleased that the United States has been and is playing a large and vital role in this endeavor. I would also feel remiss in not stating another conviction: That the Congress has shown, and this committee in particular, great imagination and vision in its warm and understanding interest and support of the United States effort, which have made that effort possible.

PROGRESS OF INTERNATIONAL IGY PROGRAM

Dr. BERKNER. Mr. Chairman and members of the committee, I am very happy to be able to report on behalf of the International Committee this morning that the planning for the IGY is going very well; that not only is a substantial portion of the program already in operation, but it will be essentially in complete operation by July 1.

Mr. THOMAS. Congratulations. That is quite an undertaking; well done.

Dr. BERKNER. I think it is an example of effort which is carried out collaboratively by governments and scientists, in which the governments are the catalyst agency, supplying those missing elements that the scientists could not possibly supply in order to provide the cooperative opportunity for looking at our own earth as a planet.

Curiously enough, we can look into the sky and see Venus as a planet, or Mercury as a planet, or Mars as a planet, but our hardest job is to see the Earth as a planet, because we are confined to this sandwich between the atmosphere on the one hand and the solid earth underneath.

Mr. THOMAS. Will you permit another interruption, Doctor?

At this point in the record, will you insert, when you revise and extend your remarks, the governments that are participating, and you might give some little description of their efforts.

COUNTRIES PARTICIPATING IN PROGRAM

Dr. BERKNER. I would be very happy to do so.

As of today there are now 58 national committees formed and some additional countries, which have not formed national committees, but which are now participating in the program, so there is a total of about 70 countries cooperating in the program actively.

(The additional material concerning the programs of other nations follows:)

SUMMARY OF NATIONAL PARTICIPATION

At the present time there are 58 nations with formal national committees and programs participating in the IGY. They are: Argentina, Australia, Austria, Belgium, Bolivia, Brazil, Bulgaria, Canada, Ceylon, Chile, Chinese People's Republic, Colombia, Cuba, Czechoslovakia, Denmark, Dominican Republic, Ecuador, Egypt, Ethiopia, Finland, France, Germany (East), Germany (West), Great Britain, Greece, Guatemala, Hungary, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Japan, Mexico, Morocco, Netherlands, New Zealand, Norway, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Rhodesia and Nyasaland, Rumania, Spain, Sweden, Switzerland, Tunisia, Union of South Africa, Union of Soviet Socialist Republics, United States, Uruguay, Venezuela, and Yugoslavia. At least 12 other nations are participating in a less formal manner, bringing total participation to about 70, or almost the entire community of nations.

IGY stations are located over all land and water areas of the earth but many stations were arranged to give coverage in meridional lines that run from the North Pole to the South Pole, and around the earth in the Arctic, equatorial, and Antarctic regions. There are about 1,200 stations and observation sites engaged in the IGY program, and at least 8,000 geophysicists and other scientists, observers, engineers, and technicians devoting most of their time to establishing stations, constructing and installing instrumentation, and taking part in the observational program.

Summarized briefly below are the fields of research and the number and disposition of stations of the 58 nations formally participating in the IGY:

Argentina: Fields of activity: Aurora and airglow, geomagnetism, glaciology, gravity, inospheric physics, longitudes and latitudes, meterology, oceanography, satellite observations, seismology, solar activity, world days. Number of stations: 35. Included in these stations are 11 in the Antarctic.

Australia: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionspheric physics, longitudes and latitudes, meteorolgy, oceanography, rockets and satellite observations, seismology, solar activity, world days. Number of stations: 52. Included in these stations are 4 in the Antarctic

Austria: Fields of activity. Aurora and airglow, cosmic rays, geomagnetism, ionospheric physics, longitudes and latitudes, meteorology, seismology, solar activity, world days. Number of stations: 12.

Belgium: Fields of activity: Aurora and airglow, geomagnetism, ionospheric physics, longitudes and latitudes, meteorology, oceanography, seismology, solar activity, world days. Number of stations: 16. Included in these stations is 1 in the Antarctic, and 6 in the Belgian Congo.

Bolivia: Fields of activity: Cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitudes and latitudes, meteorology, seismology, solar activity, world days. Number of stations: 45

Brazil: Fields of activity: Cosmic rays, geomagnetism, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, seismology, world days. Number of stations 5.

Bulgaria: Fields of activity: Cosmic rays, geomagnetism, longitudes and latitudes, meteorology, seismology. Number of stations 8.

Canada: Fields of activity Aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, seismology, solar activity, world days. Number of stations: 55.

Ceylon: Fields of activity: Meteorology. Number of stations: 7.

Chile: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, gravity, glaciology, ionospheric physics, longitudes and latitudes, meteorology, oceanography, seismology, solar activity, satellite observations, world days. Number of stations: 22. Included in these stations are 9 in the Antarctic and 2 in the South Pacific.

Chinese People's Republic: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, ionospheric physics, longitudes and latitudes, meteorology, seismology, solar activity. Number of stations: 35.

Colombia: Fields of activity: Glaciology, ionospheric physics, meteorology, seismology, world days. Number of stations: 8.

Cuba: Fields of activity: Meteorology, satellite observations. Number of stations: 2.

Czechoslovakia: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, gravity, ionospheric physics, longitudes and latitudes, meteorology, satellite observations, seismology, solar activity. Number of stations: 6.

Denmark: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, ionospheric physics, meterology, oceannography, world days. Number of stations: 14 Included in these stations are 6 in Greenland.

Dominican Republic: Fields of activity: Meteorology. Number of stations: 1.

Ecuador: Fields of activity: Geomagnetism, glaciology, ionospheric physics, meteorology, oceanography, satellite observations, seismology. Number of stations: 6. Included in these stations are 2 in the South Pacific.

Egypt Fields of activity: Geomagnetism, gravity, ionospheric physics, longitudes and latitudes, meteorolgy, satellite observations, seismology, solar activity, world days. Number of stations: 4.

Ethiopia: Fields of activity: Geomagnetism Number of stations: 1.

Finland: Fields of activity: Aurora and airglow, ionospheric physics, longitudes and latitudes, meteorolgy, oceanography, seismology, world days. Number of stations: 7.

France: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, rockets, seismology, solar activity, world days. Number of stations: 41. Included in these stations are 6 in French Equatorial Africa, 1 in Madagascar, 2 in French Pacific Oceania, 2 in the South Indian Ocean, and 3 in the Antarctic.

Germany (East): Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, longitudes and latitudes, meteorology, oceanography, seismology, solar activity, world days. Number of stations: 17.

Germany (West): Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, seismology, solar activity, world days. Number of stations: 15.

Great Britain: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, rockets and satellite observations, seismology, solar activity, world days. Number of stations: 50. Included in these stations are 14 in the Atlantic, 2 in the Pacific Ocean, 4 in Africa, 2 in the Indian Ocean, and 16 in the Antarctic.

Greece: Fields of activity: Ionospheric physics, meteorology. Number of stations: 1.

Guatemala: Fields of activity: Aurora and airglow, geomagnetism, glaciology, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, seismology, world days Number of stations: 5.

Hungary: Fields of activity: Aurora and airglow, cosmic rays, gravity, geomagnetism, ionospheric physics, longitudes and latitudes, meteorology, seismology, solar activity, world days. Number of stations: 7.

Iceland: Fields of activity: Aurora and airgrow, geomagnetism, glaciology, ionospheric physics, meteorology, oceanography, seismology, world days. Number of stations: 25.

India: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitudes and latitudes, meteorology, satellite observations, seismology, solar activity, world days. Number of stations: 58.

Indonesia: Fields of activity: Geomagnetism, meteorology, seismology, world days. Number of stations: 7.

Iran: Fields of activity: Cosmic rays, geomagnetism, meteorology, seismology, satellite observations. Number of stations: 2.

Ireland: Fields of activity. Aurora and airglow, geomagnetism, meteorology, seismology, solar activity, world days. Number of stations: 14.

Israel: Fields of activity: Ionospheric physics, meteorology, oceanography, seismology. Number of stations: 5.

Italy: Fields activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, seismology, solar activity, world days. Number of stations: 60.

Japan: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, rockets and statellite observations, seismology, solar activity, world days. Number of stations: 87. Included in these stations is 1 in the Antarctic.

Mexico: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, seismology, solar activity, world days. Number of stations: 30.

Morocco: Fields of activity: Geomagnetism, ionospheric physics, meteorology. Number of stations: 6.

Netherlands: Fields of activity: Aurora and airglow, geomagnetism, ionospheric physics, meteorology, oceanography, satellite observations, solar activity, world days Number of stations: 16. Included in these stations is 1 in Surinam, South America.

New Zealand: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, seismology, solar activity, world days. Number of stations: 44. Included in these stations are 7 at Pacific Islands and 5 in the Antarctic.

Norway: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, ionospheric physics, longitudes and latitudes, meteorology, oceanography, seismology, solar activity, world days Number of stations: 16. Included in these stations is 1 in the Barents Sea and 1 in Antarctica.

Pakistan: Fields of activity: Cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, seismology, solar activity, world days. Number of stations: 8.

Panama: Fields of activity: meteorology, oceanography. Number of stations: 2.

Peru: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitudes and latitudes, meteorology, satellite observations, seismology, solar activity, world days. Number of stations: 10.

Philippines: Fields of activity: cosmic rays, geomagnetism, ionospheric physics, longitudes and latitudes, meteorology, oceanography, seismology, solar activity, world days. Number of stations: 12.

Poland: Fields of activity: Aurora and airglow, geomagnetism, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, seismology, solar activity, world days. Number of stations: 35.

Portugal: Fields of activity: Geomagnetism, meteorology, oceanography, seismology Number of stations: 11. Included in these stations are 1 in the Azores, and 1 in Africa

Rhodesia and Nyasaland: Fields of activity: Meteorology. Number of stations: 4.

Rumania: Fields of activity: Geomagnetism, gravity, ionospheric physics, longitudes and latitudes, meteorology, seismology, solar activity. Number of stations: 6

Spain: Fields of activity: Cosmic rays, geomagnetism, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, satellite observations, seismology, solar activity, world days. Number of stations: 27. Included in these stations are 3 at Atlantic island locations and 1 in Africa.

Sweden: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, ionospheric physics, longitudes and latitudes, meteorology, seismology, solar activity, world days. Number of stations: 20. Included in these stations is 1 in the Arctic Ocean.

Switzerland: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, ionospheric physics, longitudes and latitudes, meteorology, satellite observations, seismology, solar activity, world days. Number of stations: 4.

Tunisia: Fields of activity: Meteorology. Number of stations: 1.

Union of South Africa: Fields of activity: Cosmic rays, geomagnetism, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, satellite observations, seismology, solar activity, world days. Number of stations: 29.

Union of Soviet Socialist Republics: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, rockets and satellites, seismology, solar activity, world days. Number of stations: 150. Included in these stations are 10 in the Arctic Ocean and 6 in the Antarctic.

United States: Fields of activity: Aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitudes and latitudes, meteorology, oceanography, rockets and satellites, seismology, solar activity, world days. Number of stations: 240. Included in these stations are 5 in the Atlantic, 2 in the Arctic Ocean, about 22 in Alaska, 23 in the Pacific, and 7 in the Antarctic.

Uruguay: Fields of activity: Meteorology. Number of stations: 1.

Venezuela: Fields of activity: Meteorology. Number of stations: 1.

Yugoslavia: Fields of activity: Aurora and airglow, geomagnetism, meteorology, oceanography, seismology, solar activity, world days. Number of stations: 11.

INTERNATIONAL MEETING AT BARCELONA

In just a moment I would like to describe to you a trip I have made out through the Far East in which we looked into the program in some of the countries that were a little slower in getting started. I should mention to you the fact that since I reported the last time, the Special Committee for the International Geophysical Year which has the international responsibility for planning the scientific program had its meeting at Barcelona in September of last year, and this was a very successful meeting.

PLANS FOR U. S. S. R. SATELLITE PROGRAM

Perhaps there are two points that I should particularly mention. One is the fact that the Soviet Union at that time announced its intention of launching an earth satellite. I have since been in communication with Professor Bardin, who is head of the Soviet National

Committee, and he has advised me that the details of the Soviet program will be available to us shortly. But of perhaps special interest is the fact that at that time, at Barcelona, the Soviet Union decided to adopt the same standards for their satellite which had already been adopted by the United States, so that the same ground apparatus can be used to observe either the Soviet satellite or the United States satellite.

Just what their launching schedule is, I do not know at the moment, but I hope to know more about this within the next 30 to 60 days.

ESTIMATED VALUE OF INTERNATIONAL PROGRAM

I had reported to you before that it was my estimate that the total world effort on this program amounted to about $250 or $300 million. I must now revise that estimate upward. It is coming much closer to $500 million.

Mr. YATES. What compels that revision—are there more countries which have come in?

Dr. BERKNER. Not only more countries coming in, but their effort has increased. The effort of many nations has been substantially enhanced.

PROGRAM OF ATMOSPHERIC RADIATION STUDIES

In addition, one program was added which was not previously included in the IGY. That is the program of the study of natural and artificial radioactivity in the atmosphere as a tool for the measurement of the circulation of the atmosphere. This is a new program that had been under discussion, but for which we could not see clearly the character of coooperation and instrumentation. At Barcelona it was decided that the experimental work had proceeded far enough so that this program could be adopted. It has now been adopted as a program.

Mr. YATES. If I may be excused for interrupting, Mr. Chairman, will this last program you spoke about bear upon the question of radioactive fallout?

Dr. BERKNER. It will, indeed, have some bearing on the program. I should really say that it looks at the problem of fallout in reverse. There are, as you know, six natural radioactive elements in the atmosphere.

These include beryllium, two forms of phosphorous, sulfur, and so on, radioactive nuclei which are formed by the action of cosmic rays on the atmosphere itself. These can be used as tracers in the atmosphere, to learn something of atmospheric circulation.

In addition to that, of course, there are artificial radioactive products introduced in the atmosphere because of bomb explosions and wisdom dictated that as long as these bomb explosions were occurring, that we should use these tools as quickly as possible to exhaust their potentialities in finding what the atmospheric circulation really was.

Mr. YATES. Thank you.

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INTERNATIONAL IGY MEETINGS

Dr. BERKNER. There have been a whole series of meetings in various parts of the world to stimulate certain activities and to come to agreements; I should mention the Arctic Conference in Stockholm in May 1956; the Western Hemispheric Conference which was held in Rio de Janiero in July 1956, particularly to asist our Latin American colleagues; the Antarctic Conference which was held in Paris in July 1956; the Oceanographic Conference in January 1957 at Goteberg, Sweden, of which I think perhaps Dr. Revelle will have something more to say, since he was one of the leaders of that conference; Atmospheric Radiation Conference, the one that finally sewed down the details of this program of artificial and natural radioactivity in the atmosphere, at Utrecht in January 1957; a very important Western Pacific Regional Conference at Tokyo in February 1957; and finally, the conference at Brussels, in April 1957, which is just over, on the organization of the world data centers where the information will be collected and distributed.

Mr. THOMAS. You have been on the run, have you not?

Dr. BERKNER. I have not been at all of these, Mr. Chairman.

STANDARDIZATION OF IGY MEASUREMENT

I might say the work of standardization, which is, of course, terribly important since in order to get a picture of the earth as a planet there must be international agreement on the standard of measurements and on the synchronization, has been completed, and there are 37 manuals that either have been published or are in the process.

Some of these had to be prepublished to get them into the Antarctic in time, but they are now rolling off the presses in final form and are being distributed.

I might add that this standardization was forced by the IGY. In many cases it should have been done years ago. Since there is a deadline, the nations got together and the standardization will not only have benefit to the IGY, but will benefit science for many years to come.

WORLD DAYS CALENDAR

The world calendar of regular world days has now been completed and published and issued and there may be such a calendar in the room here.

Would you show the committee the calendar? We do not have one here. This calendar is now available throughout the world so that everyone is agreed on the dates that will be the regular world days; but as you recall, for the special world days, days when we have these enormous solar eruptions, these will have to be predicted.

Mr. THOMAS. It may be well to insert a calendar of world days in the record at this point.

(The calendar of regular world days is as follows:)

Final Calendar of Regular World Days (RWD) and World Meteorological Intervals (WMI) during the International Geophysical Year 1957-1958

(Adopted by CSAGI, September 1956 and edited by CSAGI SECRETARIAT - 3, AVENUE CIRCULAIRE, UCCLE-BELGIUM)

World Meteorological Interval 20 21 22 / 23 24 25 26 27 28 29

Regular world day 11

Regular world day at new moon 10

Unusual meteoric activity 8 (but not world day)

Regular world day with unusual meteoric activity 17

Day of total eclipse 12

June 1957 (Advance Trial)

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

July 1957

Sun.	Mon.	Tue.	Wed	Thu	Fri.	Sat.
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

August 1957

Sun.	Mon	Tue.	Wed.	Thu.	Fri.	Sat.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

September 1957

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

October 1957

Sun	Mon.	Tue.	Wed	Thu.	Fri.	Sat.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

November 1957

Sun	Mon.	Tue.	Wed.	Thu.	Fri	Sat.
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

December 1957

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

January 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

February 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	

March 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
2	3	4	5	6	7	1/8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

April 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

May 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

June 1958

Sun.	Mon	Tue.	Wed.	Thu.	Fri.	Sat.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

July 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

August 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24/31	25	26	27	28	29	30

September 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

October 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

November 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23/30	24	25	26	27	28	29

December 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

January 1959

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

INTERNATIONAL COMMUNICATIONS NETWORK

This work is now being done on a test basis, by the National Bureau of Standards at Fort Belvoir, with information already coming in from points all over the world to make possible these predictions. This is a new service. It will be a very interesting test of our ability to predict these things. We expect that predictions will be about 50 percent correct. This will make possible observations throughout the world, when these great hemispheric eruptions occur. You recall one already occurred February 23 last year, which was the largest that we have observed in modern times, so large that the cosmic rays from the sun were apparent even at the Equator.

I might add also that the intensity of cosmic radiation as a result of that eruption was so high that if maintained over a long period of time it might have an effect on biology on the earth. This was a very interesting observation.

STIMULATION OF INTERNATIONAL GEOPHYSICAL YEAR PARTICIPATION IN FAR EAST

I have just returned from a 3-month trip through the Far East. I thought I might mention 1 or 2 highlights of this trip. I had an opportunity to meet with the science councils and with the International Geophysical Year committees of the countries of the Far East. One very interesting sidelight to this trip was a long conversation that I had with Mr. Nehru one evening at a dinner party, a very intimate dinner party, in which he discussed with me for more than an hour the earth satellite.

As you know, Mr. Nehru is a scientist. I think he is a natural scientist, educated at Oxford. He was intensely interested in the satellite, particularly the scientific experiments that had begun. He asked if India could play any part in it. He was fascinated by the addition to knowledge that the satellite would be able to produce.

The second thing that impressed me is probably best illustrated by the position of Indonesia, which had felt rather out of things before and had not had an active program. I had a long meeting, first with the Science Council of Indonesia, whose president is Dr. Sarwono, and later with the IGY Committee, whose leader is Dr. Geonarso.

They are now becoming very excited by the IGY. They have rehabilitated some of the old observatories that had gone out of commission. They have started an extensive program in high-altitude balloon launching for meteorology, and are producing a strong program.

The effect of the IGY on countries like Indonesia was to renew their interest in science where politics had drawn their interest away from it. I found this in more than one place. I might add our friends in Australia, of course, are going to play a very strong part in observing the satellite.

Australia is planning a very active observation program and has been cooperating with our national committee in this regard. I think Dr. Van Allen will say more of this later.

The result of my observation is, as I said at the start, that the IGY is on schedule, that observations have already started, and I think we are beginning to have a completely new kind of look at our earth as a planet.

Mr. JONAS. You say the International Geophysical Year is on schedule?

Dr. BERKNER. The whole planning.

Mr. JONAS. What about the earth satellite program?

Dr. BERKNER. The satellite, as far as I know, is on schedule. I think Dr. Porter will be able to give us more up-to-date information.

Mr. THOMAS. That was a very nice statement, Dr. Berkner. Thank you very much.

Dr. KAPLAN. Since we have quite a number of us who are reporting today, I will be somewhat brief. You thanked us for being here, Mr. Chairman. I want to tell you we are grateful to have been invited.

Since Dr. Waterman told me about your desire to have this meeting, I know all of us have looked forward to it for many personal reasons as well as the friendship of the committee and because we are happy to report on the way in which this program has been progressing.

Mr. THOMAS. Doctor, will you pardon a little interruption? I think this is a very rare meeting, historical in one sense of the word.

If you do not object, I would like to have our Capitol Hill cameramen take a picture of these very eminent scientists.

(After a brief recess.)

Mr. THOMAS. Dr. Kaplan, we humbly apologize for this interruption, but after all, we think so highly of this meeting we want to have some evidence besides words.

STATEMENT OF DR. JOSEPH KAPLAN

If you will insert your statement first, then you may proceed in your own words. Go ahead, Doctor.

(The statement is as follows:)

STATEMENT OF DR. JOSEPH KAPLAN, CHAIRMAN, UNITED STATES COMMITTEE FOR THE INTERNATIONAL GEOPHYSICAL YEAR NATIONAL ACADEMY OF SCIENCES

GENERAL STATEMENT

It is a pleasure to appear before this committee again, and I appreciate this opportunity to report on the progress which has been made during the past year in carrying out the United States program for the International Geophysical Year. When we appeared before the committee in March 1956, several witnesses discussed recent international developments which had affected our planning for the United States program. I have brought some of these gentlemen back with me because I believe they have a very interesting story to tell of what has been done during the past year, and I should like you to hear their firsthand accounts about our progress

At the last meeting I reported on how the United States program had been developed by the United States National Committee and on the functions of the technical panels which we had established for each of the scientific disciplines I am pleased to report that the efforts of these panels of specialists, and of our National Committee, now offer the certainty that the program we presented to you during our past meeting is assured of accomplishment, and we all believe that the United States program for the International Geophysical Year will be one of the most successful scientific efforts which this Nation has ever undertaken.

INTERNATIONAL MEETINGS

Last September the nations participating in the International Geophysical Year met again in Barcelona. Delegates of our National Committee have also participated in IGY regional conferences on the Arctic in Stockholm in May 1956, on the Western Hemisphere in July in Rio de Janeiro, and on the Antarctic in Paris in August. More recently we have worked with a Western Pacific Conference in Tokyo which convened February 28 to March 2, and in a Data Center Conference in Brussels a month ago. It is interesting to note that none of these conferences has required major readjustment to the United States plans. Our participation in each of these conferences has been fruitful in coordinating regional aspects and in serving to present the United States interests and objectives before the international groups The Barcelona Conference in particular served to develop international plans for world data centers, which were defined in more precise detail at the recent Brussels conference to which I have just alluded. I might add that one of the most interesting events at the Barcelona meeting was the announcement by the U. S. S. R. that they also would have a program in earth satellites for the International Geophysical Year

UNITED STATES IGY PROGRAM

I should like to turn now to a somewhat more specific consideration of some of the significant aspects of the United States program. I shall not enter into a detailed presentation of our activities in the Antarctic, nor in implementing the earth satellite program.

Dr Harry Wexler, chief scientist for the USNC–IGY Antarctic program, has only recently returned from a survey of United States stations in the Antarctic, and I am sure that you gentlemen would much prefer to hear from him. I should like merely to add here my words of commendation and admiration for the outstanding job which the Department of the Navy and the other services have performed on our behalf in successfully establishing our planned stations complete with all of the scientific equipment and complement of staff which we had originally contemplated. This is a significant achievement considering the rigors and environment in which they had to work, and all of us on the National Committee are exceedingly gratified with the accomplishments of the Department of Defense on our behalf. The Nation may well take pride in this achievement.

Very great strides have been made in the earth satellite program Dr. Richard W. Porter, Chairman of our Panel for the Earth Satellite Program, and Dr. J. A. Van Allen, Chairman of the Panel's WGII, are present and I should like them to tell you of our activities during the past year. Again, however, I should like to add a word concerning my personal gratification, and that of our National Committee, for the cooperation of a large number of scientific institutions, both public and private, without which such progress could not have been achieved. We are indeed grateful for the outstanding measures of cooperation which have made this possible.

In response to your request Dr Roger Revelle of the Scripps Institution of Oceanography has also arranged to be present today. You will recall that Dr. Revelle described last year our plans in oceanography. He will cover this area again for you, relating the oceanography program to studies in meteorology and glaciology These three fields are closely related in terms of the heat and water budget of the earth, a subject of fundamental importance to man's everyday living and even to the very possibility of his being able to inhabit the earth.

Two other major geographic areas in which we are active are the Equatorial Pacific and the Arctic. On these, Mr. Hugh Odishaw, the Committee's Executive Director, will report. He will also present several summaries of projects in every discipline.

UPPER ATMOSPHERE RESEARCH

I should now like to describe for you our programs in upper atmospheric research which, as many of you may know, is the area of geophysics which has long been closest to my interests. I shall also later cover the research which we are undertaking in terrestrial geophysics: Seismology, gravity, and latitudes and longitudes

In our upper atmosphere program we are concerned with the radiations and particles which cause the aurora and air-glow, which produce and control the reflecting regions of the ionosphere without which long distance radio communications is impossible, which are responsible for the rapid changes in the earth's magnetic field, and which include cosmic rays. Effects in all of these fields are directly interrelated and in all of these studies the the sun plays a dominant role.

From our earlier meetings with the Committee you will recall that we told you that the period of the IGY was selected to coincide with a predicted peak in solar activity measured by the 11-year cycle of sunspot activity. The sun has been increasingly active over the past year or two and current information indicates that the present cycle will be one of the highest on record. According to present information the sun has misbehaved a bit, and it appears that the highest point of the cycle is already upon us. However, this solar activity tapers off more gradually than it rises, and with the unusually high peak we feel sure that solar activity will continue at a sustained high rate during the IGY measurements period.

PRE-IGY RESEARCH

Some of our pre-IGY work has been fruitful in measuring effects of the present solar cycle. The opportunity to make some of these arrangements prior to the formal beginning of the IGY has been unusually fortuitous, for high atmospheric effects have been observed for the first time in history which are of fundamental significance to our planned program, both nationally and internationally For example, Dr. J. A. Simpson of the University of Chicago was able to measure cosmic rays resulting from a gigantic solar flare which occurred in February 1956. The results which he has obtained from these measurements have proved to be of fundamental importance to cosmic ray research. For the first time he was able to prove that cosmic rays are, at least occasionally, manufactured in the sun and ejected from it at energies of about 30 billion electron volts. Analysis of the measurements taken during this flare also indicates that interplanetary space is pervaded by strong magnetic fields and many kinds of charged particles. Scientists at the National Bureau of Standards were also able to identify ionospheric effects associated with the immense cosmic ray showers which resulted from this solar flare. This is the first time in history that this interrelationship between ionospheric physics and cosmic rays has been identified.

We have also taken advantage of the voyages of ships of Navy Task Force 43 to install a cosmic-ray recorder on vessels proceeding to the Antarctic. This has given us invaluable information concerning the incidence of cosmic rays in a region of the world which has heretofore been inaccessible. More important, however, by measuring the incidence of cosmic rays over the broad band of latitudes from here to Antarctica, unusual effects were noted which open to serious question the accepted concept of the earth's magnetic field as it has been measured from locations on the surface of the globe. Because of these questions, Dr. Simpson arranged with the Air Force last winter for a plane flight which circled the globe, making cosmic-ray measurements at high altitude in the region of the Equator These results have also proved uniquely significant in that they cause one to postulate that unusually strong magnetic fields exist far out in space which displace the cosmic-ray magnetic Equator, as is observed from the ground, by a substantial amount

Last fall pre-IGY test firings of rockets were made from a ship off the coast of southern California. Here again scientists were fortunate in firing an instrumented rocket at the time of a solar flare. The analysis of the data derived from this firing has shown for the first time the incidence of solar X-rays in the ionosphere.

These experiments are particularly interesting and significant because the effects which were recorded have been used in shaping the measurements which we will undertake during the IGY. Moreover, with the information derived from such experiments, we shall be more readily alert to capture similar events at our measuring stations all over the globe during the IGY.

The results of the high altitude airplane flight around the Equator, which was designed to measure cosmic radiation, has its effect in our planning for other IGY disciplines. In this respect I have alluded to the problem of locating the geomagnetic equator. There also appears to be reason to believe that the magnetic fields some thousands of miles in space may have an influence in the alinement of aurora which occur at heights of only 75 to 100 kilometers above the earth. One can speculate also that these magnetic fields, as determined by cosmic-ray measurements, have a direct bearing upon conventional ionospheric theory which may cause us to modify our present thinking.

IGY STATION NETWORKS

As you know, our programs in the fields of geomagnetism, aurora, and ionospheric physics have been designed to provide global coverage so that synoptic data during the interval of the IGY can be secured. Progress in the establishment of United States nets of stations in these fields has been excellent, and, with a few exceptions, we are confident that our measurements will be initiated on schedule. Equipment has been received and tested, sites have been selected and, in most instances, our scientists are now proceeding to field locations to set up their equipment and begin their checkout operations.

DATA EXPECTED

We feel that a host of answers to questions in geophysics will be secured from these operations. For example, for the first time we shall now be able to determine the coincidence of aurora in northern and southern latitudes, and thus verify the accuracy of our theories of the causes of these phenomena. Other advantages to be gained in the cosmic-ray program are knowledge of the reasons for large decreases of cosmic ray intensities during some magnetic storms, the worldwide variation of cosmic-ray intensity with the sunspot cycle, and extreme fluctuations of cosmic-ray intensity near sunspot maximum and with solar disturbances.

In geomagnetism, our program is designed to reveal facts about rapid magnetic field fluctuations which are usually accompanied by disturbances in radio wave propagation, often by auroral displays, and which also increase in number and intensity with sunspots.. Our ionospheric work will inevitably improve our development of "radio weather" global maps which should lead to improvements in our forecasts for long-distance radio communications; other experiments in ionospheric physics are similarly designed to elicit information about special effects such as sporadic-E and ionospheric forward scatter, both of which are vital to present communications problems.

THE IGY ROCKET PROGRAM

Geophysical phenomena concerned with the studies of the upper atmosphere have been seriously handicapped because direct observations and measurements were so difficult, or in most cases even impossible, although balloon techniques have been useful in studies of cosmic rays and in meteorology. However, the need for accurate information from the upper atmosphere calls for direct measurements, with which, in turn, we can calibrate our ground-based measurements. This is the reason that we have added rocket measurements and the earth satellite program to the United States IGY effort. Other individuals will discuss the satellite program but I should like to tell you briefly of the progress in the rocket program.

Our biggest effort will be made at Fort Churchill, Canada, in cooperation with the Canadian IGY Committee. Here, through the logistics assistance of our Department of Defense and Canada, we have established a rocket facility for the firing of Nike Cajun, and Aerobee rockets. Studies will be made of the structure of the atmosphere, including measurements of temperature, pressure, density, and wind. Special instruments will be used to measure the chemical and ion composition of the atmosphere in these high latitudes, which is also in the region of the maximum auroral zone. Particles and radiations from the sun will be observed and measured, as will measurements of currents affecting the earth's magnetism.

Last fall the Fort Churchill facility was completed and a series of test firings was undertaken. These firings were most valuable in proving out the facility, and, in fact, enabled us to identify minor deficiencies in the installation. These are now being corrected and we are assured of a successful program of firings at these high latitudes. Here again the rockets which were fired were instrumented, and we have been able to gather important preliminary IGY information which will help us in the rocket experiments launched during the IGY.

Our plans for firing other Aerobees at White Sands and Alamogordo, N. Mex., are likewise on schedule. In some instances these firings will be correlated with those of Fort Churchill to explore latitude effects of the phenomena in which we are interested. Arrangements are progressing satisfactorily for shipboard firing of Rockoons from one of the vessels of the Task Force 43 during next year's operations in Antarctic waters; this work is under the direction of Dr. James A. Van Allen of the State University of Iowa who has had long experience in geophysical research using rockets I have already referred to the pre-IGY test firings off the coast of Lower California, and our plans for a resumption of these firings during the IGY program are proceeding on schedule. We have also fired pre-IGY rockets for test purposes from shipboard in the waters of Davis Strait between Baffin Island and Greenland. Here again our techniques have been checked out and firings scheduled during the IGY are now assured of success

From the high atmosphere, I should now like to turn to the program concerned with the earth itself, its size and shape and structure.

THE EARTH'S CRUST AND INTERIOR

During the IGY three fields relating to the earth's crust will be studied: Seismology, gravity measurements, and latitudes and longitudes The United States program is designed principally to take advantage of the presence of other IGY operations in regions which are normally remote and inaccessible. Progress in these programs has been good and, in fact, some results have already been made as other IGY operations have commenced

ANTARCTIC PROGRAM

For our Antarctic program portable seismographs were procured and shipped during the past season's operations. These seismographs have already been put to use by traverse parties traveling from Little America to the Byrd Station.

Surveys of the ice thickness along the route of this traverse trail were made at regular intervals by the technique of exploding charges of dynamite and measuring the transit time of sound waves traveling through the ice to the ground and return. By this technique the ice thickness is measured and a profile of the continental terrain is secured as well. Preliminary reports of these measurements indicate a most interesting effect in the locale sourrounding the Byrd station Here preliminary seismic soundings suggest that the ice cover of the continent may possibly be 10,000 feet thick at some points. These preliminary readings are surprising, particularly since the measurement site is only about 5,000 feet above sea level This would suggest that there is land some 5,000 feet below sea level. Obviously, these preliminary readings must be checked carefully before any conclusions can be made. While most of this is probably due to peculiar topographic features, it appears that the weight of ice has undoubtedly depressed the continent in this region to some extent I might point out that this effect has occurred in Greenland where portions of the interior are also below sea level.

Ice thickness surveys and continental terrain mapping by this seismic technique will be continued in Antarctica during the coming seasons Mr. A. P. Crary, our scientific station chief at Little America and Deputy Chief Scientist for our Antarctic program, is now making his final plans for extensive traverse work during the forthcoming summer seasons Teams of geophysicists, traveling by tractor train, will move out from the Little America, Byrd, and Ellsworth Stations up to distances of several hundred miles to cover the regions between and around these stations. Seismic profiles will be taken regularly in addition to a full program of glaciology using other techniques so that this region of Antarctica will no longer remain the great unknown which it is today.

EARTHQUAKE STUDIES

At the South Pole, Byrd, Adare, and Wilkes Stations, station seismographs are also now being set up. The objective of this net is to measure earthquakes in Antarctic regions The Antarctic has long been suspected of being located in a center of earthquake activity, but only with the IGY has it been possible to investigate earthquakes in this region of the world.

Earthquake studies in other regions of the globe are also included in the United States program. In the Pacific, the Coast and Geodetic Survey will operate seismographs at three Western Pacific locations: Guam, Truk, and Palau Plans for this net are proceeding well, with routine measurements in progress at the first two locations, and construction now in progress at Palau. The Pacific Ocean area is another of the regions of the globe where knowledge of crustal shifts is greatly lacking, because of the obvious difficulties in covering this vast oceanic area and the attendant problems of maintaining seismographs at remote island locations To supplement this program the Scripps

Institution of Oceanography will also install a seismograph at Palmyra Island in the Central Pacific as an adjunct to its program of oceanography.

The Pacific island seismographs will supplement earthquake measurements made by long-established stations in this country and in South America. To further supplement this network the California Institute of Technology is completing construction of two strain seismometers which are designed to measure the accumulation of stresses in the earth's crust which results in active earthquakes. The overall system of instruments should do much to add to our knowledge of earthquake centers in this part of the world and assist us in predicting the likelihood of their occurrence and the extent of their effects. The importance of better information in this field was dramatically emphasized only a few weeks ago when the San Andreas Fault bordering the western coast of our country seriously shook San Francisco and caused considerable damage I think we can expect that the United States-IGY efforts in seismology, combined with worldwide studies by other nations, will enable scientists to make a much better map than we now have of the interior of the earth.

GRAVITY PROGRAM

Turning now to our gravity program, I can again report that our program generally appears ahead of schedule and, in fact, some measurements have already been made.

As in seismology, portable gravimeters have been shipped and were placed in use during the initial glaciological traverses in Antartica. Equipment has been supplied for each of the United States traverse teams and these instruments will be in regular use during the coming seasons of operations. During last winter's expedition to the Antarctic a team of scientists from the University of Wisconsin also visited McMurdo Sound. Basic gravity measurements, with an absolute pendulum device, were made to establish a reference figure by which to calibrate subsequent gravity measurements on these traverses and on planned airplane flights. During the course of travel for this purpose the University of Wisconsin team took advantage of their proximity to other important locales to make basic reference measurements in South America, Japan, New Zealand, and the Philippines These references can now be used during the IGY to calibrate future measurements in the same regions.

While local topography affects the pull of gravity at any precise location on the globe, a composite figure, secured from measurements all over the earth, is important for many geodetic purposes. Only in populated areas of the earth have reasonably complete gravity measurements been made. The vast oceanic areas of the world have long constituted an obstruction to the development of a good global gravity figure. The United States program includes projects which offer real promise of resolving the measurements of gravity at sea. Lamont Geological Observatory of Columbia University has contracted for two special gravimeters to be placed in submarines. The problem of measuring gravity at sea is extremely complicated by motions of the sea and the ships which travel upon it. However, by using submarines at rest below these surface disturbances, gravity measurements can be obtained in the vast ocean areas which cover about 75 percent of the globe. One of the instruments of the type Lamont will use has already been tested in the Mediterranean Sea, results have exceeded expectation and successful submarine operation seems assured Dr. Worzel of the Lamont Observatory is also working to develop a stable base for these gravimeters which would enable their use on surface vessels. While this task has never yet been accomplished successfully, Dr. Worzel's present efforts appear exceedingly promising. If this development matures, the prospects for more precise gravity mapping on a global basis will assuredly be within reach

LATITUDE AND LONGITUDE DETERMINATIONS

Except to the scientific specialists who are concerned about the shape of the earth and the composition of its crust—i. e., geodetic problems—people are generally prone to believe that the earth's latitudes and longitudes are precisely known. For many practical problems this is certainly true · Cartographers can make reasonably precise maps, and navigators can use these maps to pilot their ships or aircraft to their destinations with complete confidence. However, it is interesting to note that during the last war certain of the Pacific islands were found to be as much as a mile from their presumed locations; and even today we do not know exactly how far apart the continents are.

The IGY offers the possibility of improving the precision of global latitude and longitude measurements, and a small program in this field will be carried out at about 20 locations around the world.

The principal instrument used in this work is a new device known as the dual-rate moon-position camera, recently developed at the United States Naval Observatory. This instrument photographs the moon relative to the star background; one camera moves more rapidly than the other as it follows the transit of the moon with the result that, by a series of observations on a single night, the position of the observing station is accurately fixed in relation to star positions and the center of the earth. By using these cameras at strategic locations around the world during the IGY it is hoped that differential shifts between the continents can be determined with probable errors of only a few feet. These measurements are of epochal importance because comparison of the results obtained at this time can be made with those taken in the future to determine the direction of differential shifts, for example, over the next century.

ROLE OF CONGRESS IN IGY

Before turning your attention to other fields and areas of IGY activity, I should like to close with a comment or two on a subject on which I have very strong feelings, and one to which Dr. Berkner has already referred: Namely, the role of the Congress in this great endeavor.

I cannot emphasize too strongly how gratifying it has been to me and my colleagues to have appeared before you. Your committee has welcomed us warmly and heard us patiently time and again; but, more than that, your committee has repeatedly, over the years since this program began, demonstrated keen and detailed interest in the scientific problems confronting us and our efforts to understand our physical environment. Your committee has shown vision and insight in thinking about these problems and in encouraging us with our plans and hopes For these reasons I feel that you are partners with us in this program and that the successful launching of this unprecedented study is in large measure a tribute to the chairman and the members of the committee and the Congress.

Dr. KAPLAN. Thank you, Mr. Chairman.

At the last meeting of the committee, you will recall that I pointed out the character of the preparation for the program, the existence of technical panels, the large amount of cooperation that existed in the planning stage. I would like to report that this has been intensified, has continued, and has been one of the very gratifying aspects of the program—the really extensive cooperation.

Dr. Berkner has already pointed out the number of international meetings that have been held to coordinate regional problems. I might point out the significance there, that each nation is interested at these meetings to make sure the data other nations obtain will be of maximum usefulness to them.

What we or any other nation gets out of the IGY depends on the character, quality, and amount of the data.

With regard to the program this morning, I should like very quickly to expand just a little bit on who will report. Dr. Wexler, whom you already know, is the chief scientist of the IGY Antarctic program. He has just returned from the Antarctic. I might say he has traveled more since the IGY than the rest of his life put together. He is quite at home in Stockholm or in Tokyo, and knows all the hotel staffs there. He is going to tell you about the Antarctic program.

With regard to the earth-satellite program, Dr. Richard W. Porter, chairman of the panel for the earth-satellite program, and Dr. Van Allen, who is new to you, from the State University of Iowa, a very distinguished authority in the rocket field, will report; and then your good friend Dr. Roger Revelle, of the Scripps Institute of Oceanography, will talk about related programs, oceanography and glaciology. These have to do with air and water, and two other major geographical areas are the equatorial Pacific and the Arctic.

The recent general developments in our program are very interesting and we will call on our executive director, Mr. Odishaw, to present them, and also to present quickly some summaries of the projects in each one of the disciplines.

UPPER ATMOSPHERE RESEARCH

My own interest is in the physics of the upper atmosphere, and here I might generalize by pointing out that the pre-IGY results, the results we obtained simply in the process of preparing for this program, are already exciting.

This was brought home to me since, apparently not having enough to do in being chairman of the IGY, I am arranging a large international conference on the upper atmosphere. I was pleased at the number of United States people that I am forced to invite because of their performance, and the amount of the progress in upper atmospheric physics that will be reported at Toronto next fall, which is essentially pre-IGY in nature. There is really good promise.

PRE-IGY UPPER ATMOSPHERE MEASUREMENTS

I might recall to you that we selected the date of the IGY to coincide with large solar activity for many reasons which we described before. Dr. Berkner has already mentioned the cosmic ray event of February 1956, and one of the major items will be a description of that program. One of the exciting things that has already come out is that for the first time a real interrelationship between the ionosphere and cosmic rays has been identified as a result of this remarkable occurrence.

As to the Antarctic, very briefly because Dr. Wexler will enlarge on that, a lot of the operations of Task Force 43, which is the Navy assignment, essentially the Department of Defense assignment to the Navy to get us down to the Antarctic, et cetera, in all of those operations we attempted to carry out scientific work.

Here, again, the cosmic ray program has benefited particularly because of the fact that the long voyages of the ships have enabled us to make observations as to variations in cosmic rays with latitudes.

Another pre-IGY test was the firing of rockets from a ship off the coast of southern California. This was done by a group from the Naval Research Laboratory. They were lucky enough to fire an instrumented rocket at the time of a solar flare. This is not easy. Some elements of luck came into that. The analysis of that data has shown for the first time the incidence of solar X-rays on the ionosphere, which gives us not only information which we need but gives us a guide as to what to look for in the future.

Mr. THOMAS. Do you think all the work on the Pacific coast had anything to do with these tremendous floods we have been getting in Texas in the last 10 days?

Dr. KAPLAN. I have just appeared before the Oklahoma Chamber of Commerce and flew over Dallas.

Mr. YATES. It is just as well you flew over, Doctor.

Dr. KAPLAN. I did. It took me an hour and a half to get out of Dallas and Fort Worth. I was asked some questions, but I think Dr. Wexler is here, and he is the expert in meteorology and floods, and he will have to answer the questions on that. I have some rather strong feelings about it. I am already in trouble in California because of these things.

IGY ROCKET FACILITY AT FORT CHURCHILL

Coming to the other developments in the field of the upper atmosphere, in the IGY rocket program one of the outstanding developments is the setting up and the activation of the first rocket firing range, essentially in the Arctic, or more accurately, in the subarctic at Fort Churchill, on Hudson Bay.

The most difficult task, and frankly the one which at the beginning many of us were a little worried about, has been achieved; rockets have been fired. Experiments have actually been done in the process of testing the range—such experiments as direct measurements by means of mass spectrometers, the composition of the upper atmosphere, measurements which any ionospheric physicist will greatly appreciate of the distribution of the electron densities. Here we have a picture of the Nike-Cajun.

Mr. THOMAS. Will you be able to tell what is up there about 40 miles high?

Dr. KAPLAN. Pretty well, from these and future rocket experiments. The type of sampling which is going on is essentially a measurement in place at high altitudes, which is similar to the kind of measurements that the oil industry carries out in subterranean exploration when they want to get the composition of petroleum products.

CHARACTERISTICS OF HIGH ATMOSPHERE

Mr. THOMAS. What do you think we are going to find 40 miles high?

Dr. KAPLAN. Many things: The character of the nitrogen and oxygen up there; whether or not nitrogen oxide exists; the distribution of ozone; presence or nonpresence of atomic hydrogen, which may be of very great significance in fields other than geophysics.

Mr. THOMAS. It is limited in density, is it not?

Dr. KAPLAN. It is limited, but life on this earth would change profondly if we did not have an eighth of an inch of ozone, for example, to protect us from the ultraviolet light of the sun. This is a very thin atmosphere from 40 miles on up.

Mr. THOMAS. What is that layer?

Dr. KAPLAN. Essentially the upper atmosphere starts at 40 miles, although chemistry begins even lower, 12 or 13 miles, with the formation of ozone. As you go up and as the atmosphere thins out, all of this short-wave radiation is absorbed.

Mr. THOMAS. What is the highest altitude that man has gone so far? We hear many different things.

Dr. KAPLAN. The highest rocket sounding, I think, is 216 miles, so far as I know, for real measurements.

Mr. THOMAS. Man was not in that, though?
Dr. KAPLAN. No.
Mr. THOMAS. What is the highest altitude man has been so far?
Dr. KAPLAN. I think in the stratosphere, 75,000 feet, roughly. The Russians attempted to repeat that.
Mr. THOMAS. About 14 miles?
Dr. KAPLAN. About that. That is about 14 miles.
Dr. VAN ALLEN. A plane has been to about 120,000 feet.
Dr. KAPLAN. That may be.
Mr. THOMAS. The NACA plane out in California?
Dr. VAN ALLEN. This was an Air Force plane, flown from California.
Mr. THOMAS. From Muroc?
Dr. VAN ALLEN. Yes.
Mr. THOMAS. When?
Dr. VAN ALLEN. About 6 months ago. 120,000 feet.
Mr. THOMAS. That is around 24 miles.
Dr. VAN ALLEN. Something over 20 miles.
Mr. THOMAS. What shape was the pilot in when he came down?
Dr. VAN ALLEN. He said he felt no pain.
Mr. THOMAS. Excuse us, Doctor.

FORT CHURCHILL ROCKET SITE

Dr. KAPLAN. I visited the Fort Churchill facility, and a number of things were striking. One, of course, is the achievement itself. The other is the remarkable cooperation of the Canadians. Quite frankly, when I looked over their existing geophysical laboratory, with Dr. Davies, who heads the program for Canada, it was hard for me to find places in that laboratory that they had not turned over to the United States.

They were very, very generous; and, as in so many of our programs, the Department of Defense cooperation was excellent. Another striking point, I think that the Department of Defense, the Navy, Army, and Air Force, have played important parts, and they will continue to play significant roles.

Dr. Wexler can tell you more about Air Force roles in the drop at the South Pole. The Churchill operation was really a wonderful thing for the Army. General Gavin, their Chief of Research and Development, came up with me to dedicate the facility. He, as well as I, got a very good picture of the problems that we face in cold weather operations. I do not think I have to emphasize the need for more knowledge in the area, in geophysics in particular.

ROCKOON FIRINGS

Dr. Van Allen, I think, can tell you a lot more than I can about some of the other plans for firing of rockoons from shipboard. I think he has plans to fire rockoons, which are the balloon-launched rockets. You get them up on a balloon first and then launch them. It is much cheaper, since you get through the lower part of the atmosphere with the balloon. We hope to fire rockoons from the vessels of Task Force 43.

EARTH'S CRUST AND INTERIOR

The other part of the program I would like to point out very briefly is the part having to do with the earth's crust and interior: Seismology, gravity, and latitude and longitude measurements. These have been, I think, quite well described in our previous documents.

I might just remind you that in the study of seismology and gravity, one of the important aspects of the program is that for the first time worldwide measurements will be made of these extremely significant geophysical problems, earthquakes—their causes and the possibility of forecasting them—and a determination of gravity on a uniform basis because of the fact that we are going places in the Pacific, Antarctic and Arctic that are normally not available for conventional and continuing scientific work.

IGY DATA IS SYNOPTIC

As you recall, this was one of the criteria that we followed, although basically the IGY deals with observations that have to be made on a worldwide scale, on a synoptic basis. For example, we will put ionospheric physics on a synoptic basis and draw synoptic maps—as you draw weather maps, giving the temperature and other pressure, and so forth, for the weather in the lower 100,000 feet of the atmosphere.

We will be able to draw maps of electron distribution, know more about their variations, because of the tremendous amount of the coordinated work that is going on and make some real meaningful forecasts for communications purposes.

Dr. Waterman mentioned meteorology and communications as two of the practical aspects of the program. I think Dr. Revelle will justify readily the present and future significance of fields such as oceanography and glaciology.

I do not want to take too much time, Mr. Chairman. We have the details here. I would like to have the others now report on the different phases of the program.

Next I would like to call on Mr. Odishaw to talk about the Arctic and Equatorial Pacific.

Statement of Mr. Hugh Odishaw on Arctic and Equatorial Pacific

Mr. Thomas. We will insert your prepared statement at this point in the record, and you may proceed.

(The statement is as follows:)

Statement of Hugh Odishaw, Executive Director United States National Committee for the International Geophysical Year, National Academy of Sciences

GENERAL STATEMENT

I am pleased to have this opportunity to report to your committee on several aspects of the IGY program. Because the program, as you know, covers many disciplines in geophysics while field activity ranges from the north polar regions down to the Antarctic and in an east-west direction embraces oceanographic studies in the Atlantic and the Pacific, including station operations on islands in the far Pacific, even a summary is a matter of considerable length. For this reason I have brought with me several documents that attempt to present briefly the status of the total program.

The first of these, annex I, is a status report on the United States-IGY program. Prepared by the academy's IGY staff, in cooperation with our committees and panels and with project scientists, it attempts to present briefly the latest information in every discipline. It also includes a summary of the rocket program, which is a field of activity rather than a scientific discipline. It does not, however, summarize the area of the earth satellite because Drs. Porter and Van Allen have included the latest information in their testimony.

Annex I tells what progress has been made as of the present time, and it does this discipline by discipline, experiment by experiment. You may be interested in the fact that some 400 locations are involved in this effort on the part of the United States and that some 750 scientists, engineers, and technicians are directly involved in that portion of the program for which Congress has appropriated the IGY funds.

This, however, does not completely cover the magnitude of the effort in terms of personnel At least another 750 trained individuals are involved in those portions of the program where existing operations provided the base upon which the special program was built. Examples of such activity include many meteorological stations of the United States Weather Bureau, radio propagation stations of the National Bureau of Standards, and geomagnetic stations of the United States Coast and Geodetic Survey whose activities have been contributed to the effort. In large measure these activities are domestic ones, although some field stations outside the continental limits of the United States are involved, and for this reason our IGY program has placed emphasis on the establishment of stations where none existed before and which were needed in order to fill in an appropriate network of stations wherever United States interests were involved. In addition, there have also been many contributions from other public and many private institutions.

Annex II presents, by discipline and experiment, a list of the many laboratories and scientific institutions participating in the program. Finally, annex III presents an up-to-date list of our committee and panel memberships, which we thought might be of interest to you.

While the United States program may be described by disciplines, it may also be described by geographic regions For some purposes the first, for other purposes, the second, is convenient. One of these regions—the Antarctic—has already or will shortly be described. Perhaps two other regions merit special noting: the Arctic and the Equatorial Pacific, and I should like to say a few words about them.

THE ARCTIC

In May 1956 the United States National Committee for the IGY presented to the first regional CSAGI Arctic Conference at Stockholm, Sweden, the proposed United States IGY Arctic program At this Conference, delegates of Canada, Denmark, Finland, France, Germany, Iceland, Norway, Poland, Sweden, United Kingdom, United States, and the U. S S. R. discussed the overall Arctic IGY program to coordinate the remaining difficulties in the individual national programs before entering the operational stage. The United States program, which was presented to the Conference, discussed our plans for 2 drifting stations on the ice of the Arctic Ocean, about 50 stations in Alaska, on shipboard, and isolated stations at selected locations in the polar regions north of the continent. The program at these stations includes observations in the fields of aurora and airglow, cosmic radiation, geomagnetism, ionospheric physics, graciology, gravity, meteorology, rocketry, and seismology. The United States IGY stations designated to carry out these programs range in size from small Alaskan meteorological stations at such locations as Attu, Cold Bay, and Kodiak, and the geomagnetic stations at Healy and Big Delta, to the larger installations involving several disciplines at College, Point Barrow, Barter Island, Alaska; and Thule, Greenland; at which observations in most of the disciplines are to be undertaken.

Joint cooperative stations with Canada and Denmark will utilize existing facilities at meteorological stations like those at Alert and Resolute in the Northwest territories, and the newly constructed cosmic ray and rocketry installation at Fort Churchill, Canada, and the United States Air Force facilities at Thule, Greenland. Shipboard observations in oceanography and meteorology are planned for the North Atlantic area, while shipboard observations further north in the Davis Strait include geomagnetic, aurora, and cosmic-ray observations of the upper atmosphere, taken in conjunction with Rockoon launchings.

The USNC–IGY Arctic program is now well into its operational phase and the most challenging aspect of this program is the establishment of the two drifting stations in the Arctic Ocean and the glaciological station on the McCall Glacier in the Brooks Range of northern Alaska. To carry out these difficult tasks, the United States Air Force has agreed to supply logistic support, including the air delivery of cargo as well as the construction of the two drifting stations and the supplying of personnel necessary for their maintenance.

The USAF has now completed the air reconnaissance and initial landings for drifting stations A and B. Equipment and scientific instruments to be air delivered for the McCall Glacier project are being assembled and prepared in Fairbanks, Alaska.

While plans for the drifting stations and McCall Glacier were still in the paper stage, the United States Army completed construction of the rocket-launching station at Fort Churchill and to date six test rockets have been launched. The station site at Thule is being surveyed in preparation for the construction of the necessary IGY facilities, and the installation and testing of scientific equipment is proceeding at the other 39 United States stations and the 13 cooperative stations.

The establishment of the two United States drifting stations will complement geographically and scientifically the Soviet IGY drifting stations. Although United States scientific teams previously occupied an ice island and attempted to establish a drifting station on the pack ice, the IGY stations represent the most concerted attempt of this kind in United States Arctic exploration. Station A is being established on the pack ice in the vicinity of 81° N., 160° W., and according to current information, it is believed that a station established on the pack ice in this location will tend to drift in a north-northeasterly direction during 1957–58, with the direction becoming steadily more southeasterly through late 1958 and early 1959. The recently concluded initial air reconnaissance, conducted by the USAF, included the careful examination of the pack ice in the vicinity of the desired location: First by means of visual observations and thereafter by parties landing on the ice to test for the stability of the pack and to survey for a suitable location of a camp site and a landing strip.

After the initial construction crew of approximately 10 men has cleared a suitable runway, the air delivery of buildings, generators, fuel, food, and scientific equipment will begin. It is hoped that by May 15, the 10 scientific and 10 support personnel will be able to occupy the station for the summer period of operation. The station will be comprised of 20 Jamesway huts, which will serve as barracks, scientific laboratory space, comunications, storage, messhall, and kitchen. There will be additional installations including an antenna field, an inflation shelter for the upper air program and housing for geomagnetic and oceanographic instruments The station will be supplied with as many of the amenities of life as air cargo space will permit for the men who will remain at the station for a 3- to 6-month period before being relieved

Even before the initial reconnaissance for station A had been completed, other units of the USAF had located and made landings on station B, ice island T–3 (83° N., 97° W.), which has been previously occupied by United States scientific parties. A construction crew is already at work surveying the island for a suitable camp location and for a frozen lake which will serve as the initial landing strip. With the completion of this survey, the necessary equipment for the clearing of the landing strip was air-dropped and the air delivery of cargo began. The station will be made up of house trailers, which will serve as barracks, scientific laboratory space, communications building, messhall, and recreation building. Generators will be housed in larger type wooden buildings, which will also serve as heated areas for vehicle maintenance Seven scientific personnel and the necessary support personnel for the first period of operation will occupy the station by May 1. It is expected that this ice island will continue to drift in west-southwesterly direction during 1957–58

The USNC–IGY scientific program at stations A and B will include observations in aurora, oceanography, gravity, and surface and special meteorological observations. Station A will have additional programs in geomagnetism, thermal budget studies, and upper air observations. Station B will have an additional program in ionospheric physics. Aurora and airglow observations at both stations will be taken with an all-sky camera, which will photograph the sky at a solid angle of about 180° through the night on 16-millimeter film. In addition, station A will be equipped with a patrol spectrograph, by which studies of the latitudinal variation of the aurora will be made. Standard geomagnetic observations at station A will be made with an Askania variograph. The ionospheric vertical incidence soundings at station B will be made with a C-2 recorder. The meterological program at both stations will include standard surface observations, supplemented by special studies in radiation, carbon dioxide, precipitation chemistry, and snow crystals studies. Special studies in ozone concentration will be made at station B; the meteorological program at station A will also have a complete upper air program with two daily observations tracked by standard radar-type equipment. Standard gravimeter observations will be made to supplement the pendulum survey of the Arctic to be made during the period of the IGY. Oceanographic programs will be undertaken at both stations A and B. Standard glaciological observations will be made at station B, while thermal budget studies at station A will relate the heat exchange between the ice pack and its atmosphere and oceanic environments to seasonal variations in thickness and thermal regimen of the ice pack.

The McCall glacier program in the Brooks Range will include glaciological and micrometeorological observations. Although the station facilities will be utilized during the summer months by other scientific personnel, it is planned that four men will winter over during the year's operation of 1957-58. In order to conduct the desired glaciological observations, it will be necessary to establish 3 camps: 1 at the foot of the glacier, and 2 camps at different altitudes on the glacier. Preliminary supply and resupply airdrops will be made by the Air Force from Ladd Air Force Base, while personnel and delicate instruments will be delivered by small chartered aircraft flying from Point Barrow. The initial landings on the glacier have already been made, and it is expected that the airdrop of heavy equipment, food, and fuel will begin shortly and continue through May. By June 1, it is expected, scientific personnel will be delivered to the station, which will have been fully supplied for at least a period of summer operation.

The site of the IGY station at Thule at which will be made observations in aurora and airglow, cosmic rays, geomagnetism, ionospheric physics, gravity and seismology is currently under consideration. An ionosphere station is already in partial operation at the main USAF facilities and as soon as the IGY site is selected, this program will be moved to that station. The IGY station will consist of the present buildings in use by the ionospheric physics program, a house trailer in which will be installed the aurora camera and dome and additional wanigan-type buildings, which will serve as quarters for the 10 men needed to operate the program. Cosmic ray balloon flights and the gravity measurements will be made during the summer of 1957.

EQUATORIAL PACIFIC

Aside from oceanographic activity in the Pacific, studies in several disciplines will be conducted on islands in the central and far west Pacific waters. These islands are either possessions or trust territories of the United States and include the following groups: The Hawaiian Islands, several islands like Jarvis near the junction of the magnetic and geographic Equators, and several islands in the Palau, Mariana, Caroline chains.

For example, the United States Coast and Geodetic Survey is installing magnetometers in a two-station, close net at Guam, and Koror in the Palau Islands. This net of stations is particularly important as it sits astride the geomagnetic Equator. The opportunities to make magnetic measurements in the region of the geomagnetic Equator are scant enough because of the vast oceanic areas with which we must contend. However, this effort was considered very important to the IGY program for this very reason and with the assistance of the Trust Territories Administration installation is now being completed. Results will be of very significant interest when compared with similar results taken along the geomagnetic Equator at such locations as Huancayo, Peru, and central Africa.

To extend further the coverage of the geomagnetic equator in the Pacific Ocean area the Scripps Institution of Oceanography is installing three magnetographs at Palmyra, Jarvis, and Fanning Islands in the Central Pacific approximately 1,000 miles due south of Honolulu. Here again the location of these islands is very close to the geomagnetic equator; of particular importance, however, is the fact that Palmyra Island is located very close to the intersection of the geographic equator with that of the geomagnetic equator. All of the results obtained from the stations in the Pacific Ocean will be correlated with magnetic surveys made about 30 years ago by the Carnegie Institution of Washington. The Carnegie Institution employed a specially constructed vessel adaptable for magnetic work, which spent several years in traversing the waters of the Pacific. Since that time no substantial magnetic effort in the region of the geomagnetic equator has been possible.

I have already referred to the planned installation of magnetographs on Palmyra, Jarvis, and Fanning Islands. The Scripps Institution of Oceanography will have additional work, principally in oceanography, at two other of the line islands adjacent to Palmyra: Fanning Island and Jarvis Island. Here again the inaccessibility of these locations has heretofore precluded our scientists from making oceanographic measurements in these remote regions. However, plans have now been completed for the installation of tide stations on these three islands and work to establish the facilities is underway. I think it is interesting to note that these stations are planned to be semiautomatic. Scripps has contracted with a retired scientist in Honolulu to use his private vessel in making periodic visits to these islands to check the performance of equipment; gather the records and data which have been accumulated, and generally inspect the facilities. These cruises are planned for intervals of approximately a month apart. While this procedure is not as satisfactory as continued operation of equipment and surveillance by the scientists, this recourse has been adopted in order to secure the invaluable information which is desired from these locations.

I should like to say now a few words about the program in the Hawaiian Islands for, as you will appreciate, the Hawaiian Islands are strategically located midway between our western shores and the island groups which dot the far Pacific. Consequently, the Hawaiian Islands take on added importance as a bridge between observations in this country and those which will be made by Far Eastern nations such as Japan and the Philippines. Plans have been completed for an optical satellite tracking station in the Hawaiian Islands. Arrangements have also been mde for observations of the sun to be carried out by the University of Hawaii. This is particularly important as Hawaii can bridge the gaps in solar observations between those which will be made on our west coast and those of Japan.

Again because of its strategic location as the first island group after leaving the California shares, cosmic ray intensity measurements will be made from a station in Oahu; the existing magnetic station of the Coast and Geodetic Survey will be included in our program as will seismological measurements undertaken at the same observatory. In seismology, equipment will also be installed in conjunction with the magnetic work at Truk, Guam, Koror and Palmyra. Meteorological observations, of course, have been long carried out at Hawaii and these will be drawn into the program as will also the ionospheric vertical soundings now being made by the National Bureau of Standards. The Hawaiian Islands are one of the strategic locations at which the recently devised dual rate moon position camera will be installed in our program for latitudes and longitudes.

Finally, I think it would be interesting to call your attention to an addition to our rocketry program. Recently arrangements have been made for the firing of about 10 rockets from Guam, primary to study high atmosphere pressures and wind velocities. Again because of expeditionary problems and the remoteness of the locations, few rocket firings have been carried out in the broad regions of the Pacific The United States has made some firings off of our California coast and more are planned for the IGY. The Japanese also have a program in rocket firings However, the vast expanse between has not been covered and it appears essential to devote a small effort to bridge these enormous and unexplored regions of the globe The Signal Corps Engineering Laboratories have accepted responsibility for these firings. Visits have been made to the island and negotiations completed with the Department of the Navy for the necessary logistic support Firings will be limited in time and present plans contemplate completion of the program during the interval April to July 1958. Nike-Cajun combinations will be used to provide the basic upper atmospheric meteorological data which are desired.

UNITED STATES WORLD DATA CENTER

When we last appeared before you we were able to tell the committee of recent international developments whereby world centers had been agreed upon for the consolidation of geophysical source records and tabulations gathered by all nations participating in the International Geophysical Year program. At this meeting with you we presented for the first time plans for the United States to establish one such center, and all of us who were present were heartened by the reception which your committee gave to this proposal.

International plans have now been made firm: The United States plans to establish a world data center have been endorsed internationally and there will also be centers in the U. S. S. R. and in Western Europe. In general, it is the plan that all IGY nations will send copies of their measurements and source records to 1 of these centers which will duplicate this material and forward copies to the other 2 world centers. By this device the IGY data from all over the globe will be available in each center to scientists for research and study. In the past, inaccessibility of synoptic data taken all over the globe has been a great impediment to full utilization of geophysical data. We are pleased at the prospects which the future has to offer after these world data centers are established.

Because the greatest use of the data will be made if data from each discipline are deposited at an institution engaged in that particular field, when pre- and post-IGY data will also be available, we now plan to establish 12 archives whose functions will be coordinated by the National Academy of Sciences. Each of the selected institutions has a long history of interest and research in the field for which it is now responsible as a data center. Thus, scientists are available to guide and direct the data center activities, and many facilities such as space, equipment, and subordinate personnel are available at no cost to the program. For your information the following list presents our current plans:

1. Aurora I (instrumental): University of Alaska, College, Alaska.
2. Aurora II (visual): Cornell University, Ithaca, N. Y.
3. Airglow, ionosphere: Central Radio Propagation Laboratory, Boulder, Colo.
4. Cosmic rays: University of Minnesota, Minneapolis, Minn.
5. Earth satellite: Smithsonian Astrophysical Observatory, Cambridge, Mass.
6. Geomagnetism, gravity, and seismology. United States Coast and Geodetic Survey, Washington, D. C.
7. Glaciology: American Geographical Society, New York, N. Y.
8. Latitude and longitude: United States Naval Observatory, Washington, D. C.
9. Meteorology: National Weather Records Center, Asheville, N. C.
10. Oceanography: Texas A. and M., College Station, Tex.
11. Rocketry: State University of Iowa, Iowa City, Iowa.
12. Solar activity: University of Colorado, Boulder, Colo.

We have been in touch with all of these institutions and can report their acceptance of this plan We are now working out the details of procedures for handling data. In early April we met at Brussels with representatives of other nations where international coordination was effected. This meeting resolved the last major uncertainties to the successful establishment of the centers. With this time scale we believe that all of our centers will be ready to launch effectively into their assigned functions as the data begins to flow from the field. It is our hope that prompt implementation of these plans will result in the successful centralization of the vast majority of IGY data soon after the measurements period is over.

Mr. Odishaw. Mr. Chairman, if I may, I would like to refer to the maps.

Summary Progress Reports on the International Geophysical Year Program

There are several annexes which I think you have before you. As we understood it, you were very much interested in a status report of the total program; annex I is an up-to-date summary, experiment by experiment and discipline by discipline of the whole program, indicating the status of the various projects, the instrumentation that has been acquired and developed, the personnel, references to the project leaders and institutions, and where we are now.

This summary report was prepared by the Academy's IGY staff working closely with the committee and the panels and project leaders. We thought you would also be interested in a listing of the institutions that have major programs, and annex II provides this, experiment by experiment.

Finally, annex III provides an up-to-date list of the membership of the committee, the full committee itself, the regional committees and the panels.

(The documents referred to follow:)

ANNEX I A STATUS REPORT ON THE UNITED STATES PROGRAM FOR THE INTERNATIONAL GEOPHYSICAL YEAR

REPORT ON AURORA AND AIRGLOW PROGRAM

The problems of observing auroral phenomena of the upper atmosphere have been approached by the Technical Panel on Aurora and Airglow with 26 projects distributed in 6 universities and research institutions. The specific studies break down into eight sections and the description in detail is given below, often including projects and institutions simultaneously.

All-sky camera.—The aurora will be photographed by means of an all-sky camera which is capable of seeing the whole sky. Twenty-nine cameras were obtained under a project directed by Dr. C. T. Elvey of the Geophysical Institute of Alaska For the final design, the prototype was modified to conform with the instrument constructed by W. Stoffregen of Uppsala, Sweden, who employed a folded optical system, making a more compact instrument These instruments were constructed under a contract with Photo Mechanisms, Huntington Street, New York. All of the cameras have been constructed and most have been delivered to the field sites although not yet installed Cameras have been in test operation for some months at Cambridge, Yerkes, Williams Bay, Ithaca, Barrow, and College. The camera at Ithaca has been operated on every clear night showing aurora with good success.

The locations of the cameras, as now planned are: Arctic Drifting Stations A and B (Fletcher's Ice Island), Barrow, Bettles, College, Fort Yukon and Kotzebue, Alaska; Aklavik (tentative) and Knob Lake, Canada; Thule, Greenland; Bend, Oreg., Black Hills, S. Dak. (near Rapid City); Delaware, Ohio; Fargo, N. Dak., Fritz Peak, Colo.; Great Falls (Choteau), Mont.; Hanover, N. H.; Ithaca, N Y ; Pocatello, Idaho; Pullman, Wash.; Shingleton, Mich.; Williams Bay, Wis ; Vermillion, S. Dak.; Cambell Island and Invercargill, New Zealand; the six United States Antarctic stations; and Scott Base at McMurdo Sound (jointly with New Zealand) The cameras to be operated in the Antarctic and the Arctic Basin will be under the supervision of Project Director Dr. N. J Oliver of the United States Air Force geophysics research directorate; five cameras will be operated by Dr. C. T Elvey of the Geophysical Institute of the University of Alaska and the remaining United States cameras will be under the supervision of Prof. C. W. Gartlein of Cornell University.

Patrol spectograph.—The observing program of the patrol spectrograph is planned to give a profile of spectral features of the aurora along a meridional line showing the production of auroral luminosity of the earth's atmosphere by primary protons. The design and development of the prototype spectograph was completed by Dr. Joseph W. Chamberlain with Dr. A. B. Meinel as principal investigator. All 18 spectographs have been constructed under the supervision and direction of Dr. N. J Oliver of the Air Force Geophysics Research Directorate and Dr. Joseph W Chamberlain of the Yerkes Observatory. At the present time Dr. Joseph Chamberlain is testing one instrument. At Cambridge the prototype patrol spectograph is being used for training of personnel for the Arctic Basin and Thule programs and will be used for training the 1957–58 Antarctic personnel. In addition, calibration tests and other optical standard tests are being conducted.

The principal program that the Aurora-Airglow Panel had in mind for this spectrograph was the detection of hydrogen lines in the spectrum of the auroras and in particular the measurement of Doppler-shifts of these hydrogen lines. Tests that have been carried out with the prototype spectrograph indicate that the instrument will serve admirably for its intended purpose. A large auroral storm was observed at Yerkes on March 2, 1956. It showed very strong hydrogen lines over most of the sky. Hα and Hβ in particular show considerable broadening in the definite Doppler-shift toward the violet. A detailed analysis on the spectra and also on the spectra obtained simultaneously at Shingleton, Mich., is currently in progress.

Locations are now planned at and as follows: Arctic Drifting Station A. College, Alaska; Thule, Greenland; Black Hills, S. Dak.; Cambridge, Mass.; Fritz

Peak, Colo.; Ithaca, N. Y.; Sacramento Peak, N. Mex.; Shingleton, Mich.; Williams Bay, Wis.; the six Antarctic stations plus one spare; and Invercargill, New Zealand.

Scanning spectrometer.—The observing program of the scanning spectrometer is expected to provide information on the rapid changes of the auroral spectrum during periods of high geomagnetic activity. The four instruments of the general design by D. M. Hunten that have been planned for the IGY program have been procured and constructed under the supervision of Dr. N. J. Oliver and one has been tested at the Geophysics Research Directorate Cambridge Research Center and found satisfactory. Two instruments are being shipped now, one to College, Alaska, to be under the direction of Dr. C. T. Elvey of the University of Alaska and the other at Williams Bay under the direction of Dr. J. W. Chamberlain of the Yerkes Observatory, University of Chicago.

One scanning spectrometer has been tested and should soon be operating on schedule although aircraft difficulties may prevent an extended airborne program. At least a ground-based program will be carried out. This will be a specialized operation and will be conducted only during the presence of particular auroral features and severe auroral disturbances.

Final locations of scanning spectrometers will be College, Alaska; Saskatoon, Canada; Williams Bay, Wis.; Cambridge, Mass.; and Little America.

Auroral radar.—In this program the aurora will be observed by using radar. The design and construction of a prototype radar suitable for this project was under the direction of Dr. C. T. Elvey, Geophysical Research Institute, University of Alaska. It is, in most respects, a conventional radar except that it is operating on a much lower frequency (41 microseconds) with unusually long pulses (100-microsecond duration) and a very long range display (1,600 kilometers). The peak power output of the transmitter is 5 kilowatts. The minimum detectable signal power to the receiver is less than 10 to 14 watts. Specifications are now being processed and will be sent to several manufacturing firms with an invitation to bid on the 9 additional sets. In any contract let for the construction, it is expected that the manufacturer will supply a prototype within 90 days and the balance of equipment within 30 days after the prototype is accepted.

The Geophysical Institute prototype has operated satisfactorily almost continuously for the past 3 months. Aurora has been detected very regularly at all expected ranges, and the equipment performs well with a minimum of maintenance. The data thus obtained has so far only been examined to determine that the equipment is satisfactorily operating and will be analyzed further at a later date.

Current plans are for locations at Barrow, College, King Salmon, Kotzebue, Skwentna (or Farewell), and Unalaska, Alaska; Rapid City, S. Dak.; Ithaca, N. Y.; Pullman, Wash.; and Macquarie Island, Australia.

Radio wave absorption—Coordinated plans of the Geophysical Institute (Dr. C T. Elvey), Stanford University (Dr. A. M. Peterson), and Dartmouth College (Dr. William Rayton), called for the design, construction, installation, and operation of 13 ionospheric absorption equipments using the cosmic noise method at various sites in Alaska, Canada, United States, Greenland, and Sweden. These projects involve the following phases:

1. Design, construction, and testing of a prototype ionospheric opacity meter (riometer);
2. Preparation of riometer specifications and negotiation of a contract for the production of 13 commercially built riometers;
3. Production, testing, and approval of the first unit;
4. Production of 12 additional riometers;
5. Installation of 13 riometers,
6. Operation of the 13 commercially built riometers and the original Geophysical Institute prototype,
7. Analysis of data.

The schedule of above.

Phases 1 and 2 were completed by mid-February 1957;
Phase 3 will be completed by May 10, 1957;
Phase 4 will be completed by June 10, 1957; and
Phase 5, installation of six equipments, will be completed by June 30, 1957. Complete installation of all 14 equipments by July 31, 1957.

The prototype riometer, designed and built at the Geophysical Institute has been fully tested. Specifications for the commercially built models have been prepared in a contract negotiated with the Virginia Electronics Co., Washington, D. C. for the construction of 13 riometers. Tests have shown that the equipment is capable of continuous measurements of the relative ionospheric opacity to a high degree of accuracy (approximately 0 1 decibel) provided interference-free channels exist within the 100 kilocycle frequency sweep of the riometer. In practice, this has always been fulfilled at College, Alaska, during the past 6 weeks. During the testing period at the Ballaince Lake Field site of the Geophysical Instiute of the University of Alaska, several periods of strong ionospheric absorption have been observed, including one in which the zenithal absorption of the extraterrestrial signal reached 14 decibels—the highest value observed for 2 years. A simpler equipment is now being installed at Point Barrow, Alaska on a Signal Corps contract. This equipment should give information as to the relation between zenith observations made simultaneously at points inside and outside the auroral zone. In addition, the installation should provide valuable experience in the problems of setting up such equipment at remote field sites.

The operations of four instruments at Alaska will be under the direction of Dr. Elvey of the University of Alaska; those in Meanook, Canada. Pullman. Wash, and Standford, Calif., will be under the direction of Dr. A. M Peterson of Standford University; those in Knob Lake, Canada, Thule, Greeland, Hanover, N. H, will be under the direction of Dr. W. M. Rayton of Dartmouth College. The instrument at Ithaca. N Y., will be under the direction of Dr. Henry G. Booker. The final instrument will be operated at Kiruna, Sweden.

Meteor radar in the Antarctic—The design of the necessary equipment for this observation was done by Dr. Oswald G Villard, Radio Propagation Laboratory, Standford University, California. Observations at Little America during the winter of 1956 were carried out by Mr. Chester Twombly under the direction of Dr. N. J. Oliver, Antarctic project leader of the Geophysics Research Directorate and Dr. Villard. Eight rolls of 16 millimeter film have been returned from the Antarctic and have been sent to Stanford University for detailed analysis.

Airglow.—The main purpose of this project is to make observations with special telescopes of the OH band in the near infrared (7,500 Angstrom units) and of the H Beta (4,860 Angstrom units) In addition standard wavelengths to be observed are Oxygen Green (5,577 Angstrom units), Oxygen Red (6 300 Angstrom units) and Sodium (5,890 and 5,896 Angstrom units). The procurement and construction of the instrument for this observational program is under the direction of Dr Franklin E. Roach, the radio propagation physics division, Central Radio Propagation Laboratory, Boulder, Colo.

The six photometers to be built for this project plus the prototype have been completed so far as mechanical components are concerned A few minor electronic components remain to be built All the optical components except a birefringent filter have been completed These photometers are at present planned as follows:

Fritz Peak, Colo: The prototype instrument has been in full operation since October 1956 The initial scientific report on 3 months' use is now in progress:

Huancayo, Peru: All the components for this installation have been shipped Mr. Mateo Casaverde spent 6 months in Boulder to study the details of the photometer and the analysis of the data. Dr. Edward R Manring of GRD recently visited Huancayo to initiate the installation;

Camden, Australia: All of the components of one photometer have been shipped to Australia. Mr Megill of the CRPL staff will spend the month of March in Australia setting up the equipment;

Sacramento Peak, N Mex: The base and some of the electronic auxiliary equipment have been shipped. The remainder will be shipped by May 1, 1957;

College, Alaska: Special wire with insulation for low temperature will be used at this station. The base and control mechanism have been shipped;

Rapid City, S Dak: The photometer for this station is now mounted at the CRPL Boulder Laboratory where final tests are being made before the installation in South Dakota during June or July A visit to Rapid City, S Dak, has resulted in a recommendation of a location about 12 miles from the city. This location is under discussion with Dr A M Peterson of Stanford, who will cooperate in field operation.

The last photometer is now in reserve It was intended for installation at Minot, N. Dak. However, this project has not yet been activated.

Dr. Roach will supervise the observational operations of three of these instruments at Rapid City, S. Dak; Fritz Peak, Colo, and Minot, N. Dak., and Dr. E. R. Manring of the Air Force Geophysics Research Directorate will supervise the operational program at Sacramento Peak Observatory, N. Mex.; Tonanzintla, Mex., and San Juan, Argentina. Additional instruments will also be located at College, Alaska; Saskatoon, Canada; Thule, Greenland; Huancayo, Peru, and Camden, Australia.

Visual observation of the aurora.—The visual observations of the aurora will be made by a network of amateur and professional observers under the guidance of Dr. Carl W. Gartlein of Cornell University. This project is designed to carry out systematic synoptic visual observations of the aurora at some 180 locations. The observers will use alidades or a simple inclinometer and will make diagrams of the aurora over the meridian.

Reporting methods have been studied and the program is based on experience gained in an aurora data collection project sponsored by the United States Information Agency Broadcasting Service.

The program has been organized so that over 120 United States Weather Bureau stations are operating as a regular observing network for this program in the United States and Alaska. In addition, 56 volunteer stations have been organized across the northern tier of States. All of these stations are reporting directly to Dr. Gartlein and the observations will be sent to Ithaca in the form of mark sense diagrams.

A punchcard has been designed so that visual observations may be entered thereon. The data can all be entered by electronic punch, or where more desirable, part of it can be in mark sense. This design was done in cooperation with Dr. P. M. Millman of the Canadian Data Center. The wiring boards for the IBM machines have been ordered to expedite the processing and compilation of data.

REPORT ON COSMIC RAY PROGRAM

Our program for the study of the cosmic ray spectrum calls for exploration of the variation in mass and energy of the primary spectrum of the cosmic radiation as well as recording variations in cosmic radiation intensity at the surface and at altitude This program will be accomplished through 28 projects distributed to 18 universities and research institutions. The projects will follow three general methods: neutron and meson telescopes; balloon projects; and special problems.

Neutron and meson telescope stations.—Dr. Martin Pomerantz, Bartol Research Foundation, has put one neutron monitor unit into operation aboard a Swedish ship which has already made some crossings of the magnetic equator and has the second unit, planned for Thule, Greenland, under construction. A neutron monitor for College, Alaska, which was constructed under the direction of Dr. Serge A. Korff of New York University is now in operation.

Under the direction of Dr. Robert Brode of the University of California, Berkeley, one of the neutron monitor meson telescope units planned for installation at Berkeley is in test operation. The second and third, intended for Hawaii and the United States Ellsworth station in Antarctica are nearly completed. Shipment of the instrument to Hawaii is expected in early May for installation at the field site of the flare patrol project of the University of Hawaii. The instrument for the Ellsworth station will be shipped in October 1957.

Under the direction of Dr. S. F. Singer, University of Maryland, the meson telescope for the Antarctic, now planned for the Wilkes Station was shipped last winter and is now almost completely installed. The telescope for Thule is under construction now and will be shipped some time in May 1957.

Under the direction of Dr. J. A. Simpson, University of Chicago, a neutron intensity monitor was installed on one of the United States Navy icebreakers which accompanied the Antarctic expeditions of 1955–56 and 1956–57.

The special arrays for the study of atmospheric-geomagnetic and solar influences on mu-meson components and nucleonic components of cosmic radiation under the direction of Dr. Robert L. Chasson, at the University of Nebraska, are well under way and it has been reported that the equipment was in initial operation on the last March 1957.

Balloon programs.—Some balloon flights have already been made by several groups at Guam on an expedition sponsored by the Office of Naval Research during January 1957. Some of the universities and institutions that participated at Guam were the State University of Iowa under Dr. Kinsey A. Anderson, Southern Illinois University under Dr. Otis B. Young, the University of Chicago under Dr. J. A. Simpson and Dr Marcel Schein, New York University under Dr. Serge A. Korff, the University of Minnesota, and University of Missouri.

Other investigators report that considerable progress is being made in the development of miniaturized flight sets. Dr. H. V. Neher of California Institute of Technology reports that 20 ionization chambers for his flights are now being assembled. This quantity will be sufficient for the 1957 operations. Other universities and institutions that are progressing with plans and preparations for balloon flights are Bartol Research Foundation under Dr. Martin Pomerantz; University of Chicago under Dr. John A Simpson, The Institute of Nuclear Studies, University of Minnesota under the direction of Dr. E. P. Ney; New York University under Dr. Serge A. Korff; University of Chicago under Dr. Marcel Schein; State University of Iowa under Dr. K. A. Anderson; Southern Illinois University under Dr. Otis B. Young and the University of Rochester under M. F. Kaplon.

Special problems—Reports from investigators show that progress is being made on construction of various types of counter arrays. Most of the field stations are expected to be in operation by May or June 1957

Dr. Paul H Barrett of the University of California, Santa Barbara, reports that 4 of the 6 Cerenkov counter substations located on the campus at Goleta, Calif., for his large-shower detector, will be in operation in March 1957. Dr. Nelson M. Duller of the University of Missouri, Columbia, Mo., is preparing for the observation of zenith angle variations of the intensity of high energy mu-mesons. Dr. S. F. Singer of the University of Maryland is preparing to set up mountain stations at Climax, Colo., and possibly in the Canadian Rockies, to study highspeed cosmic ray fluctuations. Dr. Victor H. Regener, University of New Mexico will study the nature of semidiurnal planetary variation of atmospheric pressure by means of recordings of the cosmic radiations at the joint Bolivia-Brazilian high altitude research laboratory at Chacaltaya, Bolivia. Dr. Leticia del Rosario of the University of Puerto Rico will measure the sudden increase and slow decrease in cosmic ray intensity at the time of solar flares and and attempt to correlate the results with similar measurements taken with neutron counters Equipment for these special projects is under construction or test now; installation will be complete by July 1957.

REPORT ON GEOMAGNETISM PROGRAM

The establishment of the majority of new standard observatories and variation stations in Alaska, the Pacific, continental United States, and the Antarctic, is under the direction of Capt. Elliot B. Roberts, head of the Geophysics Section, United States Coast and Geodetic Survey Captain Roberts is assisted by Mr J H. Nelson, of the Coast Survey, who had had many years of experience as a geomagnetician, and who has developed a special instrument, the differential magnetograph, which will be used during the IGY

North-South network, Alaska.—All of the equipment has now been received in Alaska. installation will be started as soon as weather conditions permit. All housing shelters are ready: locations will be Anchorage, Kotzebue, Northway, Fort Yukon, and Barter Island, Alaska.

Healy-Big Delta, Alaska, observatories—All instruments have been received and tested. Construction work was completed in Alaska in December 1956, and installation of instruments was completed in March 1957.

College, Alaska, differential magnetograph.—Seventy thousand feet of cable interconnecting the three station network have been installed and tested. A 1 2 mile powerline was installed at one of the sites and a diesel generator at the other All instruments have been delivered to College and installation is now complete; housing for the instruments was completed in 1956. The magnetograph is now in satisfactory operation

Arctic ice-floe variograph.—The variograph is now available and being tested A modified base for the instrument has been received; this was necessary because of a shifting of the base expected at the site. Installation is expected by late May 1957

East-West network, United States.—Delivery of major components of instruments is now completed. Testing and calibration will be done after the Pacific and Alaska equipment is shipped. Locations will be at or near Espanola, N. Mex.; Casper, Wyo; Price, Utah; Climax, Colo.; Burlington, Colo.; Beloit, Kans.; and Carrollton Mo

Guam.—The equipment has now been delivered to Guam. The station will have use of the National Bureau of Standards facilities which were transferred to the Coast Survey in the summer of 1956. Negotiations have been completed with the Air Force for a permit to use the land area; the Weather Bureau has been assisting with construction of special buildings and logistic problems. Installation of equipment is expected to be completed soon and measurements should begin in May 1957.

Koror.—Construction of facilities at Koror have been completed. Space will be shared with the Weather Bureau, the trust territory government has given considerable assistance in the establishment of the facilities. Installation of equipment is complete, and measurement will begin in May 1957.

Jarvis-Palmyra-Fanning.—The three variographs have been received, tested, and calibrated at Fredericksburg, Va., by Dr. Ronald Mason of Scripps Institution of Oceanography. Dr. Martin J. Vitousek has recently joined the staff of Scripps Institution for supervising operations in the Line Islands. The instruments are now en route to the Pacific for installation.

Antarctic.—All equipment for the Antarctic stations is now being installed at the various stations. Operation will begin in May–June 1957

Rapid Run magnetographs.—All magnetographs have been received, tested, and shipped to field locations at College, Barrow, Sitka, Healy, and Big Delta, Alaska; Tuscon, Ariz.; Fredericksburg, Va; Honolulu, Hawaii; Guam and Koror. Instruments were shipped to the Little America station, Byrd station, and Wilkes station, Antarctica, in 1956.

Visible recording variographs.—Twelve variographs are now being adapted to drive visible recorders for prompt observation of magnetic variations, in addition to the one which was supplied for the Little America station. Equipment will be shipped as soon as the ionosphere stations are ready to receive and install the instruments.

South America five-station network.—A special experiment to study the equatorial electrojet currents is being undertaken under the direction of Dr. Merle A. Tuve, director, and Mr Scott E. Forbush, both of the Department of Terrestrial Magnetism of Carnegie Institution of Washington. Two of the instruments are now being tested and calibrated at Fredericksburg, Va. The other two are not expected until September 1957. The fifth instrument is in operation at Huancayo Geophysical Observatory, Huancayo, Peru. Mr. Scott Forbush is presently in South America making final arrangements for the locations of the four stations north and south of Huancayo.

Low frequency electromagnetic radiation.—Mr Elwood Maple of the Geophysics Research Directorate, Air Force Cambridge Research Directorate, reports that the tape-transport mechanism for the recorders is ordered and expected for delivery in June. Dr A R. Jordan of the Denver Research Institute is undertaking the construction of the preamplifiers, amplifiers, and other electronics. Denver Research Institute is also preparing the pickup which will be about 5 feet long and 1 inch in diameter, with special iron cores and about 5,000 turns of wire. The coils will be equivalent in sensitivity to air-core coils 3 feet in diameter with about the same number of turns. The Ampex Corp. is supplying special 3-channel heads for standard one-quarter-inch magnetic tape; this will allow recording of 3 components simultaneously.

An initial test was concluded at College, Alaska, and the tapes are now being analyzed Most of the disturbances were atmospheric signals originating in distant lightning discharges, but Mr. Maple found several cases of fluctuation levels which were recorded a few hours in advance of disturbances recorded by the magnetic observatory

Three stations—College, Alaska; Cambridge, Mass, and Denver, Colo.—are expected to be in full operation by July 15, 1957. The remaining two stations—Thule, Greenland, and either San Juan, P R., or a station in Florida—are expected to be in operation by the end of August 1957

REPORT ON GLACIOLOGY PROGRAM

Antarctic program.—All equipment and supplies for the first year's operation have been delivered to the Antarctic. Mr. Albert P. Crary of Geophysics Research Directorate, Air Force Cambridge Research Center, scientific station leader at the Little America station and Deputy Chief Scientist for the United States-IGY Antarctic program, reports that a glaciology traverse team has successfully completed the first traverse from Little America to Byrd Station. The scientists on this party made meteorological observations, seismic, and gravimetric observations of the thickness of the ice and the nature of the underlying terrain, and examined the surface layers of the ice for structural information. Mr. Crary reports that the crevasse detector which explores the ice ahead of a specially fitted Weasel by means of sound waves, has proven to be an invaluable instrument. The crevasse detector was instrumental in the successful and safe establishment of a trail from Little America to Byrd Station. Based on the information gathered by the first traverse and reconnaissance flights, Mr. Crary is planning the remaining series of traverses for the coming season.

At Byrd Station glaciologists have successfully completed the first exploration of the ice sheet in the vicinity of the station using seismic techniques. Mr. Crary has confirmed that the ice was found to be about 10,000 feet thick. The actual elevation of the station above the sea level is only about 5,000 feet so 5,000 feet of ice must be under sea level. The indications are that the ice rests on land or rock. An unusually interesting geological formation is indicated by these preliminary results.

Mr. Carl Eklund, scientific station leader at Wilkes Station, reports that the icecap station for glaciological and meteorological studies had been established 50 miles from the Wilkes Station at an elevation of 4,000 feet. A 100-foot deep pit will be dug there in May 1957, for studies of structure and history of accumulation of the snow over the past several hundred years. A study of relative motion has been initiated with the use of 12 stakes set in the ice. Tunnels have also been excavated in preparation for the digging of the deep pit. At Wilkes Station itself, studies have begun at a large moraine at the edge of the ice sheet; glacial geological investigations are being conducted on the Windmill Island group; preliminary work has begun on ice crystallography and photographic study of ice conditions; recordings of ice temperature are continuing at a special station to study snow as a structural material.

Northern program

Blue Glacier, Olympic National Park, Wash.—Mr. Edward R. LaChapelle, who has been instrumental in the success of the avalanche-control program of the United States Forest Service, Alta, Utah, has taken over responsibility for this program. Mr. LaChapelle plans to establish his field stations on the Blue Glacier in June 1957, and to maintain a scientific party throughout the winter until the end of summer 1958. This will allow detailed studies of the glacier over a complete accumulation-ablation cycle. Dr. Robert P. Sharp, of the California Institute of Technology, will make a detailed study of the dynamics of the movement of the Blue Glacier during the summers of 1957 and 1958. The Blue Glacier will be one of the most carefully studied and documented glaciers in the history of glaciology.

McCall glacier project (Brooks Range, Alaska).—Walter A. Wood, Director of the Arctic Institute of North America, is undertaking logistics planning of this program. Dr. Richard C. Hubley, chief scientist of the US–IGY northern glaciology program, wil be the project chief scientist. Mr. Wood was in Alaska during April 1957, to arrange for the staging operations from Ladd Field, Alaska, and it is expected that the field party will fly to the site during early May 1957, and remain there until September 1958.

Glacier surveys in Alaska and continental United States.—The program of surveying and photogrammetric mapping of selected glaciers in Alaska will be carried out by the American Geographical Society, under the direction of Dr. Charles B. Hitchcock, director of the society, and Mr. William O. Field, department of exploration and field research of the society. Dr. Terris Moore, former president of the University of Alaska, will join the expedition for aerial photography of the Wrangell Mountains.

Mr. Mark F. Meier of the United States Geological Survey is undertaking a study to determine how best to organize a program of glacier census and survey in the continental United States. The Geological Survey, the National Park Service, and the committee on glaciers of the American Geophysical Union, and various private organizations are cooperating in such work.

These surveys will be part of a coordinated effort to provide a complete description of glacier coverage by all nations in the Western Hemisphere.

Arctic Basin program.—A program for the study of the sea-ice physics and sea-ice-atmosphere heat exchange at Drifting Station A in the Arctic Basin is being directed by Dr. Phil E. Church, executive office of the department of meteorology and climatology, University of Washington. Dr. Norbert Untersteiner of the Austrian Meteorological Service has obtained leave to serve as project chief scientist for the field program. Reconnaissance is now underway for the selection of a suitable site, and it is expected that the scientific party will fly in to the station in May or early June 1957. Personnel will be rotated about every 6 weeks.

Operations in Greenland.—The Snow, Ice, and Permafrost Research Establishment (SIPRE), Corps of Engineers, United States Army, has undertaken some special programs for the IGY in addition to their own work, much of which is related to IGY objectives and will be available as IGY data. SIPRE completed the drilling of a hole in the Greenland ice cap 1,700 feet deep, in a test of techniques and equipment. Dr. Henri Bader of SIPRE reported that a temperature gradient of only 0.5° F, from 24.5° to 25.0°, per 1,000 feet was measured. A second hole will be drilled this summer, the temperature profile will be obtained, and the rate of closing of the hole will be measured. Similar equipment is now in the Antarctic to drill a deep hole in the vicinity of Byrd Station. An important contribution of SIPRE was the training of our Antarctic glaciological personnel during the summer of 1956. SIPRE arranged for these men to make short traverses in Greenland for training in traverse techniques and in the use of glaciological instruments

REPORT ON GRAVITY PROGRAM

Antarctic program.—Portable gravimeters are now in use on the Antarctic glaciology traverses. Dr. George P. Woollard, professor of geology, University of Wisconsin, sent a team of two men to the Antarctic this past winter to make gravimeter and pendulum measurements at some of the Antarctic stations in order to provide reference points for the traverse teams. These measurements, part of a world-gravity survey, will also establish ties to measurements made in lands in the Southern Hemisphere In traveling to the Antarctic stops were made to take measurements at sites in South America, Japan, Philippines, Australia, New Zealand, as well as the McMurdo Sound in Antarctica. Gravity ties between other Antarctic stations will be established by the use of plane flights under the direction of Mr Albert P. Crary, scientific station leader at Little America.

Pendulum and gravimeter networks.—As mentioned above, at some sites pendulum and gravimeter measurements have already been taken. It is planned to complete several long north-south lines of gravity determinations during the IGY to increase further the coverage of reliable gravity determinations and to provide a large number of first-order pendulum stations for control points in local gravity surveys About 12 pendulum and 40 gravimeter stations have been occupied during the recent year.

Submarine gravity program.—Three sets of specially designed pendulums and timing and recording equipment are being constructed under the direction of Dr. J. Lamar Worzell, associate director of the Lamont Geological Observatory, Columbia University. The first set of individual pendulums has been completed and is being aged. The other two sets are substantially completed along with the cases, support mechanisms, timing equipment, and recording cameras.

Two specially designed gravimeters are being built for Lamont by Prof. Anton Graf, of Munich, Germany. Dr. Worzel tested one of the prototype instruments in October 1956, in the Mediterranean. He reports that the instrument performed better than expected and is readily adaptable for submarine use. Dr. Worzel believes that with suitable stabilized platforms now being developed the Graf gravimeter should be adaptable for use on surface vessels; this development would revolutionize the study of gravity at sea and would be a major contribution to the study of the shape of the earth and gravity mapping.

Earth tidal studies—Dr. Louis B. Slichter, director of the Institute of Geophysics, University of California, is now using a highly sensitive recording gravimeter for the measurement of the tidal movement of the earth at various locations. The instrument, developed by the La Coste-Romberg Co., Austin, Tex., in cooperation with Dr. Slichter and others at the Institute of Geophysics, is sensitive to about one-billionth of the value of gravity at the earth's surface; this corresponds to a change in distance from the center of the earth of about one-eightieth of an inch.

During the month of November 1956, Dr. Slichter obtained records at the physics department of the University of Hawaii, Honolulu; the maximum amplitude of the tidal motion was about 4 inches. Dr. Slichter is planning to purchase a second instrument in order to measure the tidal variation in gravity on both sides of great crustal structures, for example, continents and mountian chains. At the same time an instrument will be in continuous operation in Austin, Tex., to provide a record of tidal variations at one place during the time that the other instruments will be occupying field stations around the world.

REPORT ON IONOSPHERIC PHYSICS PROGRAM

Vertical incidence soundings.—Dr. Ralph J. Slutz and Mr. Harry Sellery, Central Radio Propagation Laboratory of the National Bureau of Standards, Boulder, Colo., report that all of the C–4 sounders (14 in all) have been tested and accepted, but not all have been delivered to final sites. Four have been sent to the Antarctic in addition to two C–3 sounders and are now being installed; the instrument at the Pole Station has been in operation since March 1957. Two sounders have been shipped to South America, and four others are being held pending the solution of customs problems. Two were supplied to the Signal Corps Radio Propagation Agency (SCRPA) for operation in the IGY program; one of these is destined for Thule and the other for Grand Bahama Island. The C–3 presently at Thule will be shipped to drifting station B (Fletcher's Ice Island). Two C–4's will be held at Boulder, one for training and one possibly for Maui, where an older instrument is now operating. One C–3 instrument, in excellent operating condition, was sent to Pepperrell Air Force Base, Newfoundland, instead of the C–4 originally planned; this station commenced operation in late January. Other vertical incidence stations will be at: Drifting station B; Adak, Anchorage, College, and Barrow, Alaska; Washington, D. C. (Fort Belvoir), Fort Monmouth, N. J.; Stanford, Calif.; White Sands, N. Mex.; Fort Randolph, C. Z.; and Ramey Air Force Base, P. R.; Wilkes, Little America, South Pole, and Ellsworth stations; Antarctica; Kihei, Maui Island, T. H.; Okinawa, Ryuku Islands; and in cooperation with the various national committees Godhavn, Narsarssuak, and Thule, Greenland; St. John's, Newfoundland, Canada; Reykjavik, Iceland; Bogotá, Colombia; Huancayo, Chiclayo, Chimbote, and Talara, Peru; La Paz, Bolivia; Concepcion, Chile; Cape Adare, Antarctica; Baguio, Philippines; and Grand Bahama Island, Federation of the West Indies.

Mr. Alan H. Shapley, Central Radio Propagation Laboratory, has organized traveling teams of two men, one expert on sounding equipment, the other a specialist in record interpretation and data. These teams will visit all United States-IGY vertical incidence stations during the IGY, with the first visit occurring before the IGY perod begins. Under Mr. Shapley's direction, his group also developed the CSAGI draft IGY vertical incidence sounding manual. New station personnel are trained at the Boulder Laboratories; training has also been given to scientists from Colombia and Mexico.

Fixed-frequency backscatter.—Dr. Alan M. Peterson, of Stanford University, Stanford, Calif., is in charge of this program; he reports that all equipment has been received at Stanford and that shipment to field stations is now underway. One instrument is in operation at Stanford University, and two others have just commenced operation at Fort Monmouth and College. The remaining stations are expected to be completed by June 1957. Some changes in sites have been made and the locations are planned now at College, Alaska; Boulder, Colo.; Fort Monmouth, N. J.; Pullman, Wash.; Stanford, Calif.; Fort Randolph, C Z ; Thule, Greenland; Knob Lake and Meanook, Canada. Camden, Australia; Okinawa, Ryukyu Islands; and Grand Bahama Island, Federation of the West Indies

Radio noise—Mr. William Q Crichlow and Mr. Robert Disney, of the Central Radio Propagation Laboraory, Boulder, Colo, inform us that the delivery of most of the equipment will be completed by June 1957, but that delivery of the last units will be delayed until July 1957. All stations are expected to be in operation by about August 1957. Stations at Bill, Wyo., and Boulder, Colo., are in operation. Two units have been delivered to Signal Corps Radio Propagation Agency for use at Thule, Greenland, and Chiva Chiva, C Z The installation at Thule will await final siting selection in May or June 1957. Locations will be: Bill, Wyo.; Boulder, Colo.; Front Royal, Va.; Chiva Chiva, C. Z.; Maui, T. H.; Byrd Station, Antarctica; Accra, Ghana; Cook, Australia; Johannesburg, Union of South Africa; Rabat, Morocco; Rio de Janeiro, Brazil, Singapore, Malaya; Stockholm, Sweden; Thule, Greenland; Tokyo, Japan.

Whistler program.—Dr. Robert Helliwell, Stanford University, reports that for his network of stations, Anchorage, Unalaska, and College, Alaska; Boulder, Colo.; Stanford, Calif.; and Seattle, Wash., are in operation with prototype or temporary equipment. Dunedin and Wellington, New Zealand, and Macquarie

Island, Australia, are also operating, reporting their observations to Dartmouth and Stanford. Dr. Helliwell also has a test station in operation at Cape Horn, Chile; and reports reception of whistlers as well as reception of echos from pulses specially transmitted by radio station NSS. The NSS echos arrive at predicted delay times and are apparently propagated via the whistler mode; reception of the echos from NSS is about 50 percent even during periods when whistler activity is absent.

Dr. Millett G. Morgan and Dr. H W. Curtis, of Dartmouth College, Hanover, N. H., report that for their network of stations, Knob Lake, Canada; Hanover, N. H.; Washington, D. C.; Gainsville, Fla.; Burmuda; and Port Lockroy, Antarctica, are now in operation. Other stations are planned at Nome (or Kotzebue), Alaska; Battle Creek, Mich.; Ellsworth Station, Antarctica; Godhavn, Greenland; Father Point, Quebec; Frobisher Bay, Baffin Island, Canada, and Huancayo, Peru.

Transequatorial forward scatter.—Dr. Kenneth L. Bowles and Dr. Robert Cohen, Central Radio Propagation Laboratory, Boulder, Colo., are now performing tests with transmitting trailers located near Havana, Ill., and receiving equipment at Boulder, Colo. Besides being a test the experiment may also provide some information on the height of the scattering layer and the angular dependence of back-scattered signals. It is planned to ship trailers to South America during early May and be ready for operation July 1, 1957. One circuit will be Antofogasta, Chile, to Guayaquil, Ecuador; the other from Arequipa, Peru, and Trujillo, Peru. The transmitter at Antofogasta will also transmit signals eastward to Clorinda, Argentina, and Sao Paulo, Brazil

Oblique incidence sporadic E.—Dr. Ernest K. Smith, Central Radio Propagation Laboratory, Boulder, Colo., has completed arrangements for his stations, but informs us that some delay may be encountered because of difficulties in construction and delivery of equipment from the manufacturer. The program will establish two circuits similar in latitude span but widely separated in longitude. One will be from Panama (transmitting) to Guantanamo Bay, Cuba (receiving), the second circuit will be from the Philippines (transmitting) to Okinawa (receiving). The Okinawa transmitting location will also beam signals northward to two receiving locations in Japan operated by Japanese scientists. A test circuit will be operated from Havana, Ill., to Boulder, Colo.

True height determinations—In conjunction with the program of vertical incidence soundings, Dr. Arthur H. Waynick, State University of Pennsylvania, plans to compute the true height of the ionospheric reflecting layers using modern computer techniques. For each month hourly calculations will be made for 5 selected days of magnetic interest, 3 world days, and some rocket-ascent days. Values will be computed for stations at Washington, D. C.; Panama; Talara and Huancayo, Peru.

Radio amateur program.—Dr. Wolfgang Pfister, Geophysics Research Directorate, Air Force Cambridge Research Center, is scientific supervisor of a program being carried out by the Amateur Radio Relay League, Hartford, Conn. Dr. Pfister informs us that 815 radio amateurs are now participating. Of these, 703 are in the United States, the remainder in several foreign countries. Regular reporting, twice a month, of radio contacts made in the VHF amateur bands was begun January 1, 1957, and a monthly newsletter published by ARRL was begun in December 1956. ARRL will screen the data, convert it to tables and punchcards, from which the propagation midpoints will be calculated.

Radio star scintillations and ionospheric winds.—Dr. E. C. Stevenson, University of Virginia, Charlottesville, Va., will operate three stations to monitor radio signals from cosmic sources. Two of these stations are under construction now; Dr. Stevenson expects to have all stations in operation by July 1, 1957.

Sweep frequency back scatter.—Dr. Millet G. Morgan, Dartmouth College, Hanover, N. H., will set up stations at Knob Lake, Canada; and Hanover, N. H.; Dr. Morgan does not expect to begin operation until the fall of 1957.

REPORT OF LONGITUDES AND LATITUDES PROGRAM

Astronomical observations.—Dr. William Markowitz, of the United States Naval Observatory, Washington, D. C., expects to receive special astronomical astrolabes from France by June 1957. These astrolabes along with crystal clocks will be used for longitude and latitude observations at the United States Naval Observatories at Washington, D. C., and San Diego, Calif., and at the United States Coast and Geodetic Survey Astronomical Observatory at Honolulu, T. H., under the direction of Mr Donald Rice, Chief, Gravity and Astronomy Section.

Moon-position program.—The special dual-rate camera designed by Dr. Markowitz, United States Naval Observatory, will be installed in about 20 astronomical observations around the world. They are being shipped now and will begin operations in June and July 1957. The measuring engines for analyzing the plates obtained by the cameras are still under construction, but Dr. Markowitz expects them to be completed by about June or July 1957, in time for analysis of the first plates from the observing program.

REPORT OF METEOROLOGY PROGRAM

Antarctic meteorological observations.—The six IGY Antarctic stations have been established according to plan. Basic instruments, expendable and auxiliary items have been received at the stations to make complete surface and upper air observations and for the special meteorological studies. Approximately 2,100 packages of meteorological materials, weighing in excess of one-quarter million pounds, were shipped to Anarctica during Deep Freeze I and II. All of these, with the possible exception of 2 or 3 noncritical items, seem to have been received by the stations.

Damage due to shipping has been slight and has not affected the meteorological program as planned except at the Byrd Station. There, so many radiosondes in the emergency air drop were damaged that upper air observations will be reduced from twice to one daily except during world days. Meteorological station leaders will be asked to periodically report their needs; and, in this way, a list of a small number of items will be developed for procurement and shipment during Deep Freeze III.

All stations are in operation and, except for the reduction of the number of soundings at the Byrd Station, the observational programs are considered to be complete.

Communication conditions permitting, meteorological reports from all stations will soon be transmitted regularly for use by the Antarctic Weather Central and by all Southern Hemisphere countries. Meteorological data are being tabulated and punched according to standard procedures. Much of the collected information will require time summary and analysis; however, because so little is known of conditions in the interior of Anarctica, simple day-to-day observations of elements, such as temperatures and snowfall, are of considerable interest Monthly climatic summaries are being requested from each United States station

A program for recruiting meteorological personnel for the 1957–58 operation has begun Six meteorologists, 8 rawin observers, and 3 rawin technicians will be required. Personnel will be trained as required at the Weather Bureau rawinsonde school and at Weather Bureau stations All of the Antarctic personnel are expected to attend a 2- or 3-week training school to be held at the Weather Bureau in Washington, D. C., prior to their departure. Information will be requested from the Antarctic stations to assist with the training and it is hoped that a short period of on-station training in the Antarctic will be possible in order for experience to be passed on first hand.

South American cooperative upper-air stations—GMD–1A equipment for the 3 Chilean stations has been purchased and shipped to South America, and action has been taken to repair and rehabilitate 2 sets of SCR–658 equipment for the stations at Lima, Peru, and Guayaquil, Ecuador. All this equipment will be in excellent condition and there should be little difficulty in carrying out successful operations with it Spare parts and other supplies necessary for the program with these instruments have already been obtained and shipped. Orders have been placed for the necessary 800-gram high-altitude balloons which will be used at all 5 stations.

Aside from the instrumental equipment, which is all being supplied from the United States Weather Bureau, and the auxiliary supplies required for operation of this equipment, little other material or equipment is necessary Under the agreements with the countries concerned, they will furnish quarters, inflation facilities, office furniture, and the observers for the program However, United States technicians will be assigned to each station.

The countries concerned are going ahead to construct the necessary inflation facilities, to arrange for proper office quarters, and carry out other types of preliminary work necessary to the establishment of the stations. No actual establishment of a station has yet been accomplished, but it is expected that preliminary soundings can be begun on June 1, 1957, with the regular program going into full operation on July 1, 1957. Action has been taken by the Weather Bureau, through the State Department, to obtain agreements with the countries concerned covering this program. To date, that for Chile has been completely accomplished and those for Peru and Ecuador should be finished within the next 2 weeks Mr. Marcus W. Brooks, of the Weather Bureau, has made complete site surveys at all five locations. Final decision on all technical details of the program have been made. Plans for training of the South American observers (there will be 6 for each station supplied by the countries concerned) provide for the training of all 18 of the Chilean observers at Quintero; for training the Peruvian observers at Lima; and for training the Ecuadoran observers at Guayaquil. The countries concerned all are apprised of the training plans and have indicated their approval of them. To assist in the large training program in Chile, the Weather Bureau will detail Mr Monroe A. Lanham from our Columbia, Mo., Training Center to Quintero for approximately 2 months. After this duty, Mr. Lanham will then visit Lima and Guayaquil on his way north to ascertain whether training at those points, which will be conducted by Mr. George L. Gadea at Lima and Mr N L. Koski at Guayaquil, has been successfully accomplished. The Weather Bureau is also prepared to furnish any further technical assistance and additional training aids if these should be required It is expected that training will begin at Quintero and Guayaquil on or about April 15, 1957, and at Lima a week or so later.

United State high-altitude rawinsonde balloon program.—Plans for this program are well advanced. Under present thinking, all rawinsonde stations of the Weather Bureau will be included in the network (including the joint arctic rawinsonde stations operated in cooperation with Canada, the 8 national hurricane research project stations in the Caribbean, and all stations in Alaska and in the Pacific), a total of 105 stations. Action has been taken to place orders for the balloons and appropriate instructions will be furnished to all United States stations in ample time for the program to begin on July 1, 1957. It is expected that the use of these balloons will permit flights to 80,000 feet or higher, at least 80 percent of the time during the IGY program. All stations in the program will use the high-altitude balloons for two observations a day at the standard times of 0000 and 1200 Greenwich mean time If a station takes four observations a day, the 0600 and 1800 Greenwich mean time observation will be accomplished with 500-gram balloons.

IGY Antarctic Weather Central—On February 5, 1957, when Mr M. J. Rubin, IGY Antarctic Weather Central project leader, left Little America, the weather central had been established in its permanent quarters. All furniture and other installations had been set up, except for the library and research area which was still occupied by the amateur radio equipment.

On the basis of preliminary synoptic weather map analysis over a period of a month, heights of the Pole Station (2,805 millimeters) and the Byrd Station (1,500 millimeters) were tentatively established. Also, some ideas as to summertime-weather patterns in the Ross Sea were developed.

The weather central personnel had begun working on two 12-hour shifts beginning January 31, 1957 Not much data were available at that time, but some improvement in this condition was noted shortly thereafter. In a radio contact, on March 9, with Mr. W B. Moreland, meteorologist in charge of the weather central, Mr Rubin was informed that some improvement in data reception was evident. On April 8 it was reported that 70 percent reliability had been achieved in reception of Australian and New Zealand data, although no South American or South African data were received. United States stations in Antarctica were transmitting collections of their weather reports once daily, but negligible data were received from other stations in Antarctica. It is expected that the situation will improve when communications facilities are improved. Currently, sea-level charts are being prepared 4 times daily and 700, 500, and 300 millibar maps are prepared once daily for regions where data are to be had. Time sections and adiabatic charts are prepared for the available stations.

It is estimated that a full-scale weather collection will be possible by May 15, and the first broadcasts of analyses will be on June 1, 1957.

Arctic ice floe meteorological project—Equipment and supplies necessary for surface synoptic, pibal and specialized programs for two IGY Arctic ice floe stations, one on Fletcher's Ice Island and the second on the ice pack approximately 500 miles north of Barrow, Alaska, have either been procured and are ready for shipping; are en route to the Weather Bureau from the manufacture or from several Air Force depots; or are nearing construction or repair completion in the Weather Bureau Instrumental Engineering Division. Equipment (on a loan basis), expendables, and supplies for a rawinsonde observations program will be provided by the Army Signal Corps and will be ready for shipment the latter part of March 1957.

Station establishment will begin the first part of May 1957. The Air Force plans on an equipment and supply airlift to both stations during April 1957 and to airlift personnel during the first week of May 1957.

Preliminary tests have been made with the surface ozone recorder at the University of New Mexico under the direction of Dr. Victor Regener. Research necessary prior to the construction of an improved infrared hygrometer is now nearing completion. Models similar to all other meteorological equipment planned for use at the two Arctic ice floe stations have been previously operated and observation procedures for their use have been prepared.

Two electronic technicians will alternate 3-month tours of duty on Ice Island T-3. These technicians have been selected and one of them is now in a training status in Washington, D C. Two electronic technicians will similarly alternate 3-month tours of duty at the icepack station. Two technicians have been selected but, since neither will be available before June 1957, a third must still be recruited to establish the station In addition, Mr. T. H. McDonald, meteorologist-radiation specialist, United States Weather Bureau, will travel to the icepack station with the first scientific group and assist with the installation and initial operation of the radiation equipment. Three trained meteorological aids are now being recruited for the rawinsonde program.

Geochemical measurements of carbon dioxide and surface ozone.—The infrared carbon-dioxide recorder and the surface ozone recorder are safely at the Little America IGY station, as are 108 evacuated glass flasks of 5-liter capacity for air sampling Twenty-four flasks of this type are at the Wilkes Station and the Amundsen-Scott Station.

The surface ozone recorder at Little America is in operation and the carbon-dioxide recorder was expected to be in operation by April 15, 1957. Regarding the status of the other parts of the program, the feasibility of taking air samples by weather reconnaissance aircraft has been demonstrated Also, 40 stations in North and South America have been selected where samples in flasks may be collected. Because of a cooperative arrangement between Scripps and the Weather Bureau, laboratory facilities for the analysis of samples are expected to be available by the time they are required

Preliminary tests were made with the carbon-dioxide equipment at Scripps and with the ozone equipment at the University of New Mexico prior to shipment to Antarctica Studies of the adverse effects of water vapor on the CO_2 observations were made and these have largely been eliminated by the use of a low-temperature unit on the incoming lines

REPORT ON OCEANOGRAPHY PROGRAM

Island observatories.—In the Atlantic Ocean the establishment of stations for recording the sea level and long period waves is under the direction of the Lamont Geological Observatory, Maurice Ewing, director. Dr. William Donn and Mr. Walter C. Beckman are the principal project scientists who are arranging for the construction and purchase of equipment and the establishment of the stations Besides the recording of tide and wave data, an important part of the program is the collection of temperature profiles and water samples to depths of about 900 feet in the vicinity of the installations. This is necessary for the computation of the density to determine how much of the apparent change in mean sea level between seasons is due to the change in volume rather than in mass.

Equipment has already been installed and is operating at the Lamont Field Station in Bermuda, and equipment has been shipped to the Barbados Isalnds for installation. Oceanographic ships operating in the Atlantic plan to take hydrographic stations in the vicinities of the various island observatories to supplement the data collected by small boats near the islands.

Installation in the Atlantic will be at Long Island, Cape Hatteras, and a "Texas tower" near New York and in cooperation with other IGY national committees at Iceland, Bermuda, Azores, Barbados, Ascension, south Georgia, and Reunion.

A long-period wave recorder will be installed at Adak, Alaska, and arrangements for collection of temperature data and water samples at Adak, Attu, and Kodiak in the Aleutian Islands are being made by Dr. Richard H. Fleming, executive officer, Department of Oceanography of the University of Washington. Tide gages are now operating at these locations.

A long-period wave recorder will be installed at a tide-gage station in the Hawaiian Islands and water samples and temperature data collected under the direction of Mr. Albert Tester, Pacific Oceanic Fisheries Institute, Department of the Interior.

The Scripps Institution of Oceanography of the University of California, La Jolla, Calif., Dr. Roger R Revelle, director, is responsible for the establishment of about 20 stations in the Pacific, some in cooperation with oceanographers of other IGY countries. Mr. J. D. Frautschy, Miss June Pattullo, Dr. William Van Dorn, and Dr. Gordon W. Groves, of Scripps Institution, are all active in various phases of this program. Dr. Groves is currently in the Phoenix Islands for the installation of equipment at Canton and Hull Islands and expects to travel from there to the Gilbert Islands for installations possibly at Ocean Island and Nauru. Negotiations are undreway with Captain Nay, chief of the French IGY activities in French Oceania for the establishment of stations in the Tubuai Islands and Tuamotu Archipelago. A representative of Scripps, probably Miss June Pattullo, will work in this area during the IGY.

Lt. Comdr. Roberto Perald Bell, an officer of the Chilean Navy, is now at Scripps to study oceanographic theory and technique and to discuss arrangements for cooperative work at Easter Island. Negotiations are also underway with the National Committee of Ecuador to arrange cooperative stations in the Galapagos Islands, and with the National Committee of Mexico for stations at Guadalupe and other islands.

In some locations small boats will be chartered and local personnel employed for the servicing of instruments and the collection of temperature data and water samples. At other locations Scripps personnel will stay in residence during the IGY, and at still other locations personnel of the United States Weather Bureau and the United States Coast and Geodetic Survey are assisting in the program.

In the Pacific, besides the stations in the Aleutians previously mentioned, tide-gage stations will be operated at Eniwetok and Kwajelein in the Marshall Islands; Hilo, Honolulu, Kahului, and Nawiliwili in the Hawaiian Islands; Fanning Island; and Midway Island. In addition to tide gages, long-period recorders will be operated and temperature and water samples taken at Canton Island; Guam; Koror; Johnston Island; Jarvis and Palmyra Islands, Moen Island; and Truk Island Stations in cooperation with other IGY countries will be at several locations in the Phoenix Islands; Gilbert Islands, Tubuai and Tuomotu Islands; Galapagos Island; Easter Island; and possibly Pitcairn Island and some islands off the coast of Mexico.

Ship operations, Atlantic.—The research vessel *Vema* of Lamont Geological Observatory is now operating in the southwest Atlantic Ocean off the coast of Argentina, in cooperation with Argentine vessels. Several Argentine oceanographers are aboard the *Vema* studying techniques. The research vessel *Atlantis* of Woods Hole Oceangraphic Institute, under the direction of Dr. Columbus Iselin, director, will join the *Vema* in late 1957 and 1958 for a systematic series of stations so located in the deep waters to duplicate stations occupied many years earlier by other expeditions. The *Jakkula*, operated by the Agricultural and Mechanical College of Texas, under the direction of Dr. Dale F. Leipper, head of the department of meteorology and oceanography, will also take part in the Atlantic work. These deep stations will allow the mapping of the deep-ocean currents and the comparison of the present findings with those obtained earlier by such famous expeditions as those carried out by the ships *Meteor* and *Discovery*. The *Vema, Atlantis*, and *Jakkula* will be joined by ships of Argentina, Brazil, the United Kingdom, Germany, Canada, and the Union of South Africa. The *Vema* has already occupied 20 hydrographic stations, taken 25 sediment cores of the ocean floor, traveled about 10,000 miles taking magnetic records, deep soundings, and water samples for tritium and carbon 14 analysis.

The research vessel *Crawford* of the Woods Hole Oceanographic Institute, is presently engaged in a 4-month cruise in the South Atlantic, taking advantage of the more moderate climatic conditions there in the early part of the year The *Crawford* has already taken 3 deep oceanographic stations out of a planned 7, and is also collecting large water samples for analysis for radioactive elements

The *Crawford* will make a similar trip in 1958 to complete the stations planned by Woods Hole, although the details of the planning will await the analysis of the data from the present cruise.

The *Atlantis* has just completed a joint expedition to the gulf stream with the *Discovery* which is operated by the National Institute of Oceanography, England. The two ships were testing various methods of measuring deep currents directly by the use of neutrally buoyant submerged floats. The floats are tracked from the ships and the movement, and hence the currents causing the movement can be calculated.

Ship operations, Pacific.—Research vessels *Spencer F. Baird* and *Horizon*, of Scripps Institution of Oceanography will be operating during the spring, establishing some of the island observatory stations. Dr. Martin Vitousek, formerly of Stanford University and the University of Hawaii, has joined the staff of Scripps Institution for the establishment and operation of the oceanographic and magnetic observatories at Jarvis, Palmyra, and Fanning in the Line Islands Dr. Vitousek owns and operates an auxiliary yacht which he will use to service the Line Island stations

The major cruises in the Pacific will commence in the summer of 1957 when the *Brown Bear*, University of Washington, will operate in the North Pacific, joining ships of Canada, Japan, and possibly the U. S. S. R in a synoptic survey of part of the North Pacific current In coordination with vessels of Scripps Institution, and Canada, the *Brown Bear* in 1958 will be engaged in a longitudinal profile survey, carrying observations as far north as the Bering Strait

The *Horizon* and *Baird* plan to make an expedition to the area bounded by the Society Islands, South America, and 45° south latitude, during the period November 1957 to March 1958 During the spring and summer of 1958 the Scripps vessels will join ships of other countries, in two surveys One operation will study the variations of the equatorial countercurrent between the Equator and about 10° north; the second operation will study the nature and extent of the equatorial undercurrent in the region bounded by 5° south and the Equator, and 90° and 150° west.

Geographical program.—During the operations of the various research vessels at sea, samples of surface and deep waters will be taken for later analysis in the laboratories of the various oceanographic institutions. Of major importance will be the analysis of tritium and carbon 14, which will supply information on the age of the water samples From the distribution of the ages of various samples, added information on the currents in deep water and the overturn of deep waters will be available.

At Lamont Geological Observatory, Dr. Bruno Giletti is analyzing samples for tritium and Dr. Wallace Broeker is working on carbon 14 samples which have been collected earlier in the Arctic and North Atlantic Ocean. At Scripps Instiution, Dr. Hans Suess and Dr. Norris Rakestraw are working on establishment of analyzing facilities; Dr. Vaughn T Bowen and Dr. B. H. Ketchum are similarly working at Woods Hole Oceanographic Institute; and Dr. Donald W. Hood and Dr. Richard G. Bader at the Agricultural and Mechanical College of Texas have been working on preparation for analysis of samples. Dr. Richard H. Fleming, executive officer of the Department of Oceanography, and Dr. Robert G. Paquette, will be in charge of the program of the University of Washington.

The carbon-dioxide concentration in the atmosphere and surface waters will also be studied in considerable detail. Dr C D. Keeling, Scripps Institution of Oceanography, has been testing an instrument which measures the concentration of carbon dioxide in an air sample by the absorption of infrared radiation in the sample. The instrument is capable of a sensitivity of 1 part of carbon dioxide in 10 million parts of air. The Weather Bureau has a similar instrument in operation at the IGY Little America station. Antarctica Three instruments will be operated aboard various oceanographic vessels in the Atlantic and Pacific Oceans to sample the air in the middle of the oceans, far distant from contamination from industrial sources Both Scripps Institution and Agricultural and Mechanical College of Texas are working to develop auxiliary equipment for use on shipboard to measure the concentration of carbon dioxide in sea water. As part of the carbon-dioxide program, air samples will be collected in stainless steel or glass flasks and analyzed at the Scripps Instiution. The flask samples will be taken at selected meteorological stations and by aircraft meteorological reconaissance flights

Antarctic oceanography.—The ships of Task Force 43 have made oceanographic observations in Antarctic waters as frequently and extensively as possible. They have made deep casts, collected bottom samples and cores, bathythermograph observations, and have taken many miles of depth soundings. The ships of the task force will continue their scientific contribution to the oceanographic program in subsequent years.

Arctic oceanography.—The Arctic Basin affords a unique opportunity to engage in deepwater oceanography without a ship. Observations will be made on both drifting stations, "A" and Fletcher's Ice Island. Norman Goldstein, Geophysics Research Directorate of the Air Force Cambridge Research Center, Maurice J. Davidson, of the Lamont Geological Observatory, Dr. Phil E. Church, University of Washington, and L. V. Worthington, and G. W. Metcalf of Woods Hole Oceanographic Instiute are coordinating efforts and planning in preparation for work at the two stations. Standard oceanographic work such as deep casts, bathymetry, coring, and current measurements, will be made; other specialized studies will include seismic exploration of the ocean bottom, and a detailed examination of the energy balance between and surface water, the ice, and the lower part of the atmosphere. The latter work embraces the fields of micrometeorology, ice-physics, glaciology, and oceanography and experts in these fields are coordinating their skills and interests.

REPORT ON ROCKET PROGRAM

During the summer and fall of 1956 pre-IGY rocket firings were conducted by agencies participating in the United States rocket program for IGY. These firings to test out rockets, their experiments, launching facilities, and general operations at the sites selected for use during IGY, took place at the White Sands Proving Ground, in the Pacific Ocean off San Diego, Calif., in the North Atlantic Ocean, and at Fort Churchill, Manitoba, Canada. Agencies participating included the Air Force Cambridge Research Center, the Ballistic Research Laboratories of the Aberdeen Proving Ground, the University of Michigan, the Naval Research Laboratory, and the Signal Engineering Laboratories.

The bulk of this report will deal with rocket firings at Fort Churchill, Canada, since this part of the program represented the major effort and since it was in connection with the Fort Churchill preparations that the bulk of the USNC funds were expended. However, the other pre-IGY firings were vitally important to the United States rocket program and are reported on briefly in the following three paragraphs.

Seventeen rocket firings took place at locations other than Churchill that were official pre-IGY firings in that the rockets were assigned IGY numbers and appear in the documents setting forth the United States IGY rocket program. Ten Rockoon firings were made from a United States Navy ship which was stationed off the coast of San Diego, Calif. The firings were conducted by the Naval Research Laboratory during the period July 17–27 1956. Each Deacon rocket carried solar ultraviolet and X-ray detectors. The actual firing of the rockets from the balloons took place upon ground command. It was hoped that the commands could be given so that the rockets would be aloft during the time of solar flares. Actually, however, the balloon drift rates encountered during the firings were high enough to force the firing of several of the rockets when no solar flares were observed. The final data from the trip are still under consideration but it can be said that one rocket was outstanding in that the desired measurements were made during a solar flare.

Two Nike-Cajun rockets were fired at the White Sands Proving Ground during August 1956. One rocket was instrumented for the study of pressure, temperature, and density by the University of Michigan for the Air Force Cambridge Research Center. The second was instrumented by the Ballistic Research Laboratories for the study of charge density in the upper atmosphere. Both rockets were also tests of the new Nike-Cajun two-stage rocket research vehicle. Each of the firings was a success, the rockets reaching predicted altitudes in the range of 90 to 100 miles, and the desired information being obtained on the performance of the prototype instrumentations.

Five Nike-Cajun rockets were fired from shipboard between the east coast of the United States and Greenland in the fall of 1956 These rockets contained the falling sphere experiment for the measurement of atmospheric density. This experiment was prepared for the Air Force Cambridge Research Center by the University of Michigan. The experiment is an exact prototype of the one to be flown during the IGY at Fort Churchill. Preliminary information indicates that all five flights were considered successful.

The remainder of the rocket firings took place at Fort Churchill, Canada, with the close cooperation of the Canadian Government. Operations at Fort Churchill were under the direction of the United States Army Ordnance Corps, who furnished the project officer and Lt. Col. L. G. Smith. Assisting Lieutenant Colonel Smith were Cmdr. O. E Hearn for the Navy, Lt. Col. P. E. Watras for the Army Signal Corps, and Maj. Edward Duff for the Air Force.

Six rockets, five Aerobees and a Nike-Cajun were fired at Fort Churchill during the months of October and November 1956. The firings took place after 6 months of intensive planning and construction had completed the launching complex on schedule. During the peak of this effort 178 people were directly connected with the program at Fort Churchill. Although operations during the fall period were conducted under many difficulties, the program finished on schedule. As a matter of record 4 rockets were fired during the last 8 days of the program, and the last rocket was fired only 60 hours after arrival by rail at Fort Churchill. Operational difficulties were encountered in three major areas. the first of these was the completion and integration of the facility. Ironing the difficulties out of any large rocket launching facility is a major undertaking and it is a tribute to the personnel involved that the work originally contemplated was completed by the end of the fall period. The second area of troubles was due to natural causes. Bad weather was experienced during the period of operations. It was not only cold (down to −25° F.), but firings were hampered by almost continuous, low cloud cover. Trouble in the area was also caused by radio interference to the DOVAP (Doppler-velocity and position) system. This interference was due to long range propagation of taxicab radio signals and of DOVAP signals originating from other missile ranges. The radio interference problem forced the Fort Churchill project to launch its rockets either at night or during weekends. The final area of operational difficulties was man-made and included the loss of one rocket due to an explosion, the loss of another (which was subsequently replaced) during preparations, and finally damage to the Aerobee tower caused by the rocket firings.

A Nike-Cajun rocket was fired on October 20, 1956, at 1601 hours central standard time as the first rocket in the Churchill pre-IGY operations. The rocket was instrumented to measure pressure, temperature, and density by the University of Michigan for the Air Force Cambridge Research Center. The rocket reached a peak altitude of approximately 70 miles as predicted and the instrumentation appears to have operated properly.

Aerobee rocket (model AJ10–34) was launched at 0240 hours central standard time on October 23, 1956. Again the instrumentation for the measurement of pressure, temperature, and density was prepared for the Air Force by the University of Michigan. The rocket's altitude was 90 miles which represents good performance. The experiment is considered to have been a success.

Aerobee-Hi Rocket (model RV–N–13b) instrumented by the Naval Research Laboratory for auroral and magnetic field investigations, exploded in the launching tower early in the morning of November 5, 1956, while being held from firing pending the presence of an auroral display at zenith. The Naval Research Laboratory has subsequently determined the cause of the failure and has initiated corrective action. The tower itself was damaged somewhat by the explosion but repairs were effected at once with the cooperation of the Canadian machine shops at Fort Churchill.

Aerobee rocket (model AJ10–25) was fired at 0546 hours central standard time on November 12, 1956. This rocket was instrumented by the University of Michigan for the Signal Engineering Laboratories The experiment was SEL's exploding grenade method of measuring temperature and winds in the upper atmosphere. Rocket performance was on the low side of average, the peak altitude being about 42 miles. The experiment was considered successful.

Aerobee-Hi rocket (model RV–N–13b) was launched on November 15, 1956, at 1332 hours central standard time. This rocket instrumented by NRL for the measurement of charge density in the ionosphere reached a peak altitude of 80 miles. This represented poor rocket performance but the experiment seems to have worked well and data are being analyzed.

Aerobee-Hi rocket (model RV–N–13b) was fired on November 17 at 1048 hours central standard time. This rocket reached a peak altitude of 130 miles, as predicted, carrying a pressure, temperature, and density experiment prepared by NRL. Early evidence is that the experiment should be considered a success.

Aerobee-Hi rocket (model RV–13c) was fired at 2321 hours on November 20, 1956, as the final rocket in the pre-IGY program. The experiment, prepared by NRL, was a gas and ion composition measurement in the upper air above

90 kilometers. The rocket performance was excellent, peak altitude being in the vicinity of 158 miles. The experiment worked very well and the data are being reduced.

The firing of these rockets required the installation of complete range and launching facilities at Fort Churchill. The launching complex itself consisted of an Aerobee tower, movable 10° in any direction to compensate for winds, a building to house the Nike-Cajun (or DAN) launcher, preparation buildings, telemetering trailers, a blockhouse, a generator building, a helium building, and connecting tunnels.

Installed at various sites throughout the military reservation at Fort Churchill were numerous instrumentation sites. Included were a five-station DOVAP system and ballistic cameras, installed and operated under the direction of BRL, two telemetering trailers and an ionosphere station installed and operated under the direction of NRL with the assistance of personnel of the New Mexico College of Agriculture and Mechanic Arts, and a network of sound-ranging geophones installed and operated by SEL. Also included and installed and operated under the supervision of the White Sands Signal Corps Agency were two radars, range safety plotting boards and a command transmitter, a frequency monitoring station, a timing system, meteorological and wind ballistic balloon launching facilities and sites, and a complete range communications system.

Experience gained during the program will insure that the rocket agencies will be able to meet their commitments during IGY on schedule and that the experiments conducted will be the best possible within our present technology. This entire program was made possible only with the help and cooperation of the United States Department of Defense and additionally, in the case of Fort Churchill, by the help and cooperation of the Canadian Government.

REPORT ON SEISMOLOGY PROGRAM

Antarctic.—The work in the Antarctic comprises the establishment of station seismographs for recording the seismic disturbances from local and distant earthquakes, and the use of portable seismic equipment on the glaciological traverses for exploration of the ice thickness and the nature of the underlying terrain. The station seismographs were procured by the United States Coast and Geodetic Survey; seismographs of a more specialized nature were supplied by the Lamont Geological Observatory, and the California Institute of Technology. The portable equipments for the traverses were supplied by Lamont Geological Observatory (Dr. Maurice Ewing); Weston Observatory, Boston College (Daniel Linehan, S. J.); University of Wisconsin, Department of Geology (Dr. George P. Woollard); and the California Institute of Technology (Dr. Frank Press).

All equipment has been delivered to the Antarctic and is now being installed at the IGY stations. The first traverse, from the IGY Little America Station to the IGY Byrd Station has been completed; subsequent traverses will make further use of the portable equipment.

Long-period and Lg-phase seismographs.—These instruments are being constructed under the supervision of Dr. Jack Oliver and Mr. George H. Sutton at the Lamont Geological Observatory. One long-period instrument is now being installed at the Coast and Geodetic Survey Seismological Observatory, in Honolulu, T. H.; instruments will be shipped in April to stations in the Belgian Congo and Trinidad. Instruments operated by resident personnel are planned for installation at Lwiro, Belgian Congo; Poona, India; Hong Kong, China; Tokyo, Japan; Honolulu, T. H ; Suva, Fiji; Santiago, Chile; Trinidad, Federation of the West Indies; Rio de Janeiro, Brazil; Uppsala, Sweden; and Resolute Bay, Canada. Alternate sites are available should local conditions impair operation of the instruments.

Construction of the lg-phase instruments is continuing under the supervision of the same group as for the long-period seismographs. Lamont reports that the first instrument is nearing completion and the first shipment is being readied. Instruments operated by resident personnel will be installed at Huancayo Geophysical Observatory, Peru; and Trinidad, Federation of the West Indies.

Crustal seismograph.—Two strain seismographs are being constructed and installed under the supervision of Dr. Hugo Benioff, seismological laboratory, California Institute of Technology. The first installation at Santiago, Chile, has been completed and the seismograph is now being tested. Construction of the second installation at the Huancayo Geophysical Observatory, Peru, began early March and is expected to be completed in June or July 1957.

Sea exploration—In the Atlantic, seismic exploration of the ocean floor will be undertaken by the Lamont Geological Observatory under the supervision of Dr Maurice Ewing, Director of the Observatory, and Mr. Walter C. Beckmann. Two ships are required for the operation; the *Vema*, of Lamont, will be assisted in part by the *Atlantis* of Woods Hole Oceanographic Institute, and by ships of other countries. The *Vema* is now at sea working with Argentine ships in the West Atlantic.

In the Pacific, the seismic exploration will be done by the Scripps Institution of Oceanography, under the supervision of Dr. Russell W. Raitt and Dr. George Shor, using the Scripps vessels *Horizon* and *Baird*. This work will be done as part of the cruise planned to study the deep currents, November 1957 to March 1958.

A related series of seismic studies will be carried out under the direction of Dr. George P. Woollard, University of Wisconsin. Dr. Woollard plans to extend lines of seismic soundings from land out to sea, crossing the Continental Shelf, a study of the transition from land to oceanic structure.

Standard seismograph stations.—Several new standard seismographic observatories will be established to increase coverage of existing networks. These new stations are being established under the supervision of Dr. Dean S Carder, Chief, Seismology Branch, United States Coast and Geodetic Survey. The stations at Guam and Truk have been in operation since May 1956; installation at Koror, Palau Island, is underway and is expected to be completed in May 1957. During May the stations at Guam and Truk will be overhauled and some additional equipment installed In cooperation with Scripps Institution of Oceanography a seismograph will be installed at Palmyra Island, in May or June 1957.

REPORT ON SOLAR ACTIVITY PROGRAMS

The United States solar activity program will be carried on by existing solar observatories with extensive basic patrols, and supplemented by an intensive specialized study of flares and other unusual phenomena. The solar activity program has 21 special observational projects that are distributed among 9 universities and research institutions

Line profile of flares—Under the direction of Dr. Walter Orr Roberts of the high-altitude observatory of the University of Colorado, a flare-locating instrument with a simplified coronographic optical system patterned after the prominence camera in operation at Sacramento Peak has been functioning as of September 20, 1956. However, the narrow band filter is not available yet and only a few flares have been photographed Attention is being given now to the problem of establishing the location of the spectograph slit, after locating the position of the flare on the disc with the fire-detecting device.

White light coronal photometer.—After some preliminary tests and modifications at Boulder, a photometer was installed at Climax, Colo., under Dr. W. O. Roberts of the University of Colorado, where the range of observations extended, under favorable conditions, to the height of about three-fourths of the solar radius. Further modification to increase the range is now underway.

Indirect flare detection—A prototype instrument employing a receiver of 27 kilocycles for the detection of SEA (Sudden Atmospheric Enhancement) and a second receiver at 18 megacycles, for the detection of SCNA (Sudden Cosmic Noise Absorption) has been in operation at a field site near Boulder since the fal lof 1956. It was found that large flares were reliably detected by small subflares only occasionally Construction has started on the 3 final instruments · 1 for Boulder, under the direction of Dr. W. O. Roberts: 1 for Sacramento Peak, under the direction of Dr. John W. Evans of Geophysics Research Directorate; and a third at McMath-Hulbert Observatory, University of Michigan, under the direction of Dr. Robert R. McMath.

Solar flare patrol—Work is continuing at high-altitude observatory, University of Colorado, under Dr Walter O. Roberts in construction of components for the optical flare patrol program. One difficulty has been locating suitable calcite for the narrow band filters. Some calcite of marginal quality has been obtained, and calcite of very high quality has been located but at a price which may prove to be too high. Provisional designs have been completed and are now under study. It is expected that the Acme 35mm reflex cameras will be received shortly. The three Hallé H-alpha filters have been received in Boulder.

Under the direction of Dr. John W Evans, the Air Force Geophysics Research Directorate at Sacramento Peak Observatory. Sunspot, N. Mex., most of the equipment for the flare patrol spectrographic work and recording of the radio spectrum from 100–600 megacycles (the latter at Fort Davis, Tex.) is in operation Orders have been placed for additional cameras, filters, blanks, and film. Motion pictures have been obtained for the first time of the green line corona over very active regions of the solar limb.

The lenses for the optical system, a heliostat, and photoelectric guider have been received at the University of Hawaii Lens mounts have been constructed, the optical system was set up, and the final design of the optical system is nearing completion; the first test photographs were obtained on March 31, 1957.

Mount Wilson Observatory, California, will provide its observations and reductions from its existing equipment Seth B. Nicholson of the National Academy of Sciences has an observing fellowship and will provide the data for the IGY.

Radiofrequency spectra.—Under the direction of Dr. Leo Goldberg, University of Michigan, Ann Arbor, Mich., equipment is being constructed to observe the radiofrequency spectrum of solar bursts. A 28 foot antenna for the radio telescope to be used at the University of Michigan for detection of solar radiation has been installed and is operating. The receiver covering part of the proposed frequency range from 500 to 200 megacycles has been partly completed. It is expected that the completed instrument will be in operation over a large part of the frequency range by the end of May 1957 Other institutions which will report on solar radio noise patrol are: Central Radio Propagation Laboratory, under Dr. R. J. Slutz; (168 and 465 megacycles); Cornell University, under Dr. C. W. Gartlein (200 megacycles); and Naval Research Laboratory under Dr. R. J. Coates (10 centimeters and 3 centimeters)

High resolution profiles and H-alpha in solar flares.—Under the direction of Dr Robert R McMath, University of Michigan, the Stone spectro-heliograph has been set up to obtain high resolution profiles of the H-alpha line on motion-picture film in rapid succession during the course of solar flares. Approximately 24 H-alpha flares spectra had been obtained up to February 1957. A few of these spectra have been analyzed in a preliminary manner. The first analyses have shown that it will be necessary to obtain photographs of the H-alpha line in a solar flare simultaneously with the vacuum spectrograph and Stone spectroheliograph. The simultaneous photographs are required for evaluation of corrections needed to eliminate the distortion of the line profile as a result of the low resolving power of the Stone instrument.

REPORT ON WORLD DAYS AND COMMUNICATIONS PROGRAM

Additional teletype and telephone facilities have been installed at the IGY World Warning Agency, on the grounds of Fort Belvoir, Va. The World Warning Agency, Roger C. Moore, Head, is operated by the North Atlantic Radio Warning Service of the Central Radio Propagation Laboratories, National Bureau of Standards. Four tests weeks during the months of January, February, March and April were held during which the World Warning Agency issued test alert and special world interval messages The messages were sent to all countries and warning agencies around the world via meteorological radio and teletype networks, radio, and commercial cable. The messages were distributed to United States stations by the United States Weather Bureau teletype network. Arrival times of the messages have been analyzed and the results have indicated that, in general, the system is performing excellently There are occasional delays in message delivery to some remote stations but every attempt is being made to smooth out communications difficulties.

The World Warning Agency has also been preparing standard messages which contain abbreviated information on solar and geomagnetic activity, unusual cosmic ray events, etc., and are sent to certain United States scientists whose experiments and observations depend on rapid information of this type. Such messages also will inform such scientists of imminent rocket firings and cosmic ray balloon launchings.

The final trial week will be in May, during the 10th to the 16th, and a full month of trial for observations and communications will occur in June 1957. The experience with the preceding trials indicate that the transition to actual IGY operations will be a smooth one.

Annex II. Program Participation by Institution in the United States Program for the International Geophysical Year

AURORA AND AIRGLOW

All-sky camera: University of Alaska, Cornell University, National Bureau of Standards, Air Force Cambridge Research Center—Geophysics Research Directorate, Arctic Institute of North America.

Airglow observations. National Bureau of Standards, Air Force Cambridge Research Center—Geophysics Research Directorate, University of Alaska.

Visual observations: Cornell University, University of Alaska.

Auroral radar University of Alaska, Cornell University, Stanford University.

Patrol spectrograph: University of Chicago, Air Force Cambridge Research Center—Geophysics Research Directorate, National Bureau of Standards, Arctic Institute of North America.

Radio-wave absorption: Air Force Cambridge Research Center—Geophysics Research Directorate, Stanford University.

Meteor radar in Antarctic: Stanford University.

COSMIC RAYS

Balloon programs: Franklin Institute, California Institute of Technology, University of Minnesota, New York University, University of Washington, Southern Illinois University, University of Missouri, University of Rochester.

Neutron and meson detectors: Franklin Institute, University of California at Berkeley, University of Chicago, University of Maryland, University of Nebraska, New York University, University of Puerto Rico

Special investigations: University of California at Santa Barbara, University of Maryland, University of New Mexico, University of Missouri.

GEOMAGNETISM

Antarctic observations: United States Coast and Geodetic Survey.

North American operations: United States Coast and Geodetic Survey.

Equatorial measurements: United States Coast and Geodetic Survey, Carnegie Institution of Washington, Scripps Institution of Oceanography.

Special investigations: United States Coast and Geodetic Survey, Air Force Cambridge Research Center—Geophysics Research Directorate.

GLACIOLOGY

Antarctic glaciology: Arctic Institute of North America, Snow Ice and Permafrost Research Establishment.

Northern Hemisphere—Glacier observations and glacial mapping: American Geographical Society.

Alaska—McCall Glacier: Arctic Institute of North America.

Arctic sea ice physics: Arctic Institute of North America.

Western United States—Blue Glacier: California Institute of Technology, University of Washington.

GRAVITY

Antarctic gravimeters and traverses: Lamont Geological Observatory, University of Wisconsin, Woods Hole Oceanographic Institution.

Submarine gravity: Lamont Geological Observatory.

Earth tides: University of California at Los Angeles.

Gravity networks: University of Wisconsin, Woods Hole Oceanographic Institution.

IONOSPHERIC PHYSICS

Vertical incidence soundings: National Bureau of Standards, Pennsylvania State University, Signal Corps Radio Propagation Agency.

Fixed frequency backscatter: Stanford University.

Whistler program: Stanford University, Dartmouth College, Naval Research Laboratory.

Forward scatter: National Bureau of Standards.

Oblique incidence sporadic-E: National Bureau of Standards.

Radio noise: National Bureau of Standards.

Radio star scintillation: University of Virginia.
Sweep frequency backscatter: Dartmouth College.
True height calculations: Pennsylvania State University.
Radio wave absorption: University of Alaska, Dartmouth College.
Amateur participation: Air Force Cambridge Research Center—Geophysics Research Directorate.

LONGITUDES AND LATITUDES

Astronomic determination of longitude and latitude: United States Naval Observatory, United States Coast and Geodetic Survey.

METEOROLOGY

Antarctic meteorology (including weather central): United States Weather Bureau.
70–80° west longitude line: United States Weather Bureau.
High altitude rawinsonde: United States Weather Bureau.
Arctic meteorology: United States Weather Bureau.
Atmospheric ozone: United States Weather Bureau.
Earth albedo: Smithsonian Insitution.

OCEANOGRAPHY

Ship operation: Lamont Geological Observatory, Agricultural and Mechanical College of Texas, Scripps Institution of Oceanography, Bureau of Ships—Department of the Navy, University of Washington, Woods Hole Oceanographic Institution.
Island observatories: Lamont Geological Observatory, Pacific Oceanic Fisheries Investigation—Department of the Interior, Scripps Institution of Oceanography, University of Washington.
Geochemical program: Lamont Geological Observatory, Agricultural and Mechanical College of Texas, Scripps Institution of Oceanography, University of Washington, Woods Hole Oceanographic Institution.
Arctic Ocean studies: Lamont Geological Observatory, Woods Hole Oceanographic Institution.

ROCKETRY

Fort Churchill experiments: Air Force Cambridge Research Center—Geophysics Research Directorate, Naval Research Laboratory, Signal Corps Engineering Laboratories, Ballistics Research Laboratories, State University of Iowa.
Southern California experiments: Naval Research Laboratory.
Rocket measurements on Guam: Signal Corps Engineering Laboratories, State University of Iowa.
Arctic and Antarctic shipboard experiments: State University of Iowa, Air Force Cambridge Research Center—Geophysics Research Directorate.
White Sands–Holloman: Air Force Cambridge Research Center—Geophysics Research Directorate, Ballistics Research Laboratories, Naval Research Laboratory.

SEISMOLOGY

Antarctic seismology: Arctic Institute of North America, Boston College, Lamont Geological Observatory, United States Coast and Geodetic Survey, University of Wisconsin.
Long period seismographs: Lamont Geological Observatory, California Institute of Technology.
Crustal strain: California Institute of Technology.
Crustal studies—land and sea: Lamont Geological Observatory, Scripps Institution of Oceanography, University of Wisconsin, Carnegie Institution of Washington.
Standard seismograph stations: United States Coast and Geodetic Survey.
Long phase studies: Lamont Geological Observatory.

SOLAR ACTIVITY

Solar flare patrol: University of Hawaii, Air Force Cambridge Research Center-Geophysics Research Directorate, University of Colorado, Naval Research Laboratory.

Indirect flare detection: University of Colorado, Rensselaer Polytechnic Institute, Air Force Cambridge Research Center-Geophysics Research Directorate.
Line profile of flares: University of Colorado.
White light coronal photometer: University of Colorado.
Radio frequency spectra: University of Hawaii, Cornell University, Naval Research Laboratory.
Profiles of H-alpha: University of Michigan.

WORLD DAYS AND COMMUNICATIONS

Operation of United States and world warning center: National Bureau of Standards.

EARTH SATELLITE

Launching vehicles: Naval Research Laboratory.
Scientific experiments: State University of Iowa, University of Maryland, Air Force Cambridge Research Center-Geophysics Research Directorate, Signal Corps Engineering Laboratories, Ballistics Research Laboratories, Naval Research Laboratory, California Institute of Technology, University of Wisconsin, Franklin Institute, Research Institute for Advanced Studies.
Optical tracking: Smithsonian Institution.
Radio tracking: Naval Research Laboratory.
Telemetering of scientific data: Naval Research Laboratory.
Scientific coordination: National Academy of Sciences.

IGY DATA CENTER

Aurora: University of Alaska, Cornell University.
Airglow, ionosphere: Central Radio Propagation Laboratory of National Bureau of Standards.
Cosmic rays: University of Minnesota.
Geomagnetism, gravity and seismology: United States Coast and Geodetic Survey.
Glaciology: American Geographical Society.
Longitudes and Latitudes: United States Naval Observatory.
Meteorology: National Weather Records Office of United States Weather Bureau.
Oceanography: Agricultural and Mechanical College of Texas.
Rocketry: State University of Iowa.
Solar activity: University of Colorado.
Earth satellite: Smithsonian Astrophysical Observatory.

ANNEX III. MEMBERSHIP OF COMMITTEES AND PANELS OF THE UNITED STATES NATIONAL COMMITTEE FOR THE INTERNATIONAL GEOPHYSICAL YEAR

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H. G. Booker
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L. M. Gould
E. R. Piore
F. W. Reichelderfer
E. B. Roberts
J. A. Simpson
P. A. Siple
A. F. Spilhaus
M. A. Tuve
A. L. Washburn
Harry Wexler
Ex officio and liaison:
W. W. Atwood, Jr.
L. V. Berkner
J. W. Joyce
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A. H. Shapley, Vice Chairman
N. C. Gerson, Secretary
W. W. Atwood, Jr
L. V. Berkner (ex officio)
L. M. Gould
J. W. Joyce (liaison)
Hugh Odishaw
F. W. Reichelderfer
A. F. Spilhaus
M. A. Tuve

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Harry Wexler, Vice Chairman; Chief Scientist, United States-IGY Antarctic Program
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Leo Goldberg	J. A. DePue, recording secretary

WORLD DAYS AND COMMUNICATIONS

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J. W. Evans	H. H. Beverage, consultant
A. B. Meinel	R. A Mattmueller, consultant
M G. Morgan	Roger Moore, consultant
H. E. Newell, Jr.	M. E Nason, consultant
Ira Boyle, consultant	Stanley Ruttenberg, recording secretary

Mr. ODISHAW. Dr. Kaplan has asked me to say a few words about two of the regions where our effort will be considerable. You can divide this program several ways. You can take the disciplines and discuss them field by field, and annex I, in effect, does this. There are some 12 or 13 disciplines involved, as you know.

You can also divide it regionally. In the United States program, there is emphasis on the United States and Alaska, and some cooperative work will be done in South America. Then there is a major activity in the Antarctic, a major effort in the Arctic regions, and also in the equatorial Pacific.

One perhaps might add that there is a major effort in a fifth region, the high atmosphere dealing with rockets and satellites. Dr. Kaplan has alluded to the rocket area and Dr. Porter and Dr. Van Allen will discuss the satellite region.

ARCTIC PROGRAM

In the high northern latitudes we will have observations and measurements at about 58 sites. About 19 of these are going to be conducted in cooperation with our colleagues and friends in Canada. This map (indicating) sets forth a few major sites; Fort Churchill, as Dr. Kaplan mentioned, is a major rocket-launching installation of great importance because the aurora can be studied there, as well as other upper atmosphere disciplines, with rockets.

There are a number of key stations in Alaska. There is an aggregate of stations around the Institute of Geophysics at College, Alaska, and there will be various studies there, ionospheric studies at stations of the National Bureau of Standards, magnetic studies under the Coast and Geodetic Survey, and various other studies that will be discussed.

ICE FLOE STATIONS

Perhaps the greatest significance of this program has to do with the ice floes—as you will recall, a rather recent addition to our program. We discussed it with you when we last appeared before you.

The Arctic Basin, unlike the Antarctic Continent, is in fact an oceanic area, generally covered with ice of varying thickness—some 7 to 13 or 15 feet. It varies considerably. It is difficult to study that region because the ice pack breaks up and moves.

The Russians have long had drifting ice stations and apparently have done some very good work in North Polar geophysical studies. At the present time, the Russians have a program of two drifting ice stations on the ice pack, one over here (indicating) and one around the North Pole. Our own program includes two stations, one here called station A, one here called station B. The later is on Fletcher's Ice Island.

We were fortunate in getting the services of Col. Joseph Fletcher of the Air Force on temporary duty. He has served as the Arctic Basin projects leader. He has been instrumental in seeing to it that these two stations have been programed, coordinated, and begun.

Both of these stations within the last few weeks have been occupied.

Mr. THOMAS. What is the depth of the ice there?

Mr. ODISHAW. At drifting station A, the ice is some 7 to 13 feet thick. A whole series of flights were necessary out of Barrow and Fairbanks to find a suitable piece of ice, and finally to land on it.

Several pieces were found at various times, but weather conditions and navigational difficulties made it almost impossible to find them again. Colonel Fletcher himself flew on some of these missions. Several planes were involved in these search operations. Finally the Air Force found a piece and managed to get a couple of people on it, with a reflector and some radio gear. They have placed equipment now on the floating ice and several additional support people are there.

Mr. YATES. When you say "are there," you mean living there?

Mr. ODISHAW. Yes, personnel are living there right now. They have gotten in within the last 2 weeks.

Mr. THOMAS. Where is that ice that is 10,000 feet deep?

Mr. ODISHAW. That is in the Antarctic. Our own instruments for the Arctic Basin program are on their way to Ladd Air Force Field. Our personnel are also getting ready to go up there. They will be at Ladd Air Force Base around May 15, and within a few days thereafter they will be placed at the station and measurements will begin.

Mr. YATES. How large is Fletcher's Ice Island?

Mr. ODISHAW. It is a dozen to 15 miles long, and 3 or 4 miles wide. It is suitable for an airstrip. As a matter of fact, even on this smaller piece of ice, the ice is suitable for landing planes.

Mr. VURSELL. Do those ice floes meander around much?

Mr. ODISHAW. Yes, sir. They move, not too rapidly. As I understand it, they are moving in a clockwise direction. Moreover, there is danger in case of drifting station A that the ice will break up. The personnel must be alert at all times. They may have to move in a hurry.

ANTARCTIC ICE THICKNESS

Mr. THOMAS. Why is the ice so thin there, when at the South Pole it is so thick?

Mr. ODISHAW. That is due to the difference between having a continent beneath the ice and having water. The Arctic is an ocean area, with access to the North Atlantic and Pacific. There is surface freezing. The water itself, however, acts as an ameliorating force and prevents ice buildup.

Mr. THOMAS. They are the two extremes of the earth. You do not have ice at one extreme that is presumably more than 40 or 50 feet thick. At the other end it is 10,000 to 13,000 or 14,000 feet.

Dr. KAPLAN. Mr. Chairman, with great accuracy you have put your finger on one of the principal reasons for our wanting to go to these places.

Mr. THOMAS. What is the theory behind it? Repeat your answer again.

Mr. ODISHAW. In the Antarctic you have a land continent beneath. Thermally, the ice can build up; over the centuries, thousands of years, the ice just builds up, whereas where you have an ocean beneath you, you have another thermal condition. The water itself contains enough heat to prevent an undue buildup.

Mr. THOMAS. What is the land beneath you at the other end of the pole?

Mr. ODISHAW. In the South Pole region?

Mr. THOMAS. Yes.

Mr. ODISHAW. You have a continent of between 5½ million and 6 million square miles, a land mass.

Mr. THOMAS. All covered with ice?

Mr. ODISHAW. Yes, sir.

Mr. THOMAS. As big as this hemisphere and Europe combined?

Mr. ODISHAW. It is bigger than the United States and Europe.

Dr. WATERMAN. You get the same condition in Greenland. That is covered with ice because that is a continent.

Mr. THOMAS. What water mass do you have at the opposite pole?

Mr. ODISHAW. Here in the north you have the Arctic Ocean itself.

Mr. THOMAS. And no land at all?

Mr. ODISHAW. Not in this region.

Mr. THOMAS. What is the nearest land?

Mr. ODISHAW. On the one side, Siberia, some Scandinavian countries, Greenland, and Canada.

Mr. THOMAS. How far away is Greenland?

Mr. ODISHAW. The distance of the northern tip would be about, I would estimate, some 300 or 400 miles from the Pole. Station B is 450 miles from Thule.

Mr. THOMAS. How far is station B from Goose Bay?

Mr. ODISHAW. I would estimate that is about 1,500 miles or more.

Mr. THOMAS. It is cold enough in Goose Bay without going any further north.

Mr. ODISHAW. The distance from Fletcher's Ice Island to Thule is close to 500 miles.

Mr. JONAS. If station A breaks up, how do you plan to get your personnel off?

Mr. ODISHAW. Move them to another floe.

Mr. JONAS. How would you move them?

Mr. ODISHAW. It depends on the nature of the breakup. They have some equipment—tractors, sleds—that will help them move quickly if they have to.

Mr. JONAS. If it breaks up your airfield how will you ever get them out of there?

Mr. ODISHAW. Light planes equipped with skis afford the best possibility in emergencies. There has been experience of this kind; the Russians have had this very thing happen.

Mr. BOLAND. Have they lost any personnel?

Mr. ODISHAW. No, sir. No personnel were lost by the Soviets.

Mr. THOMAS. May I interrupt you and read from page 12 of the report? It says:

At Byrd Station glaciologists have successfully completed the first exploration of the ice sheet in the vicinity of the station using seismic techniques. Mr Crary has confirmed that the ice was found to be about 10,000 feet thick. The actual elevation of the station above the sea level is only about 5,000 feet, so 5,000 feet of ice must be under sea level. The indications are that the ice rests on land or rock. An unusually interesting geological formation is indicated by these preliminary results.

Dr. BERKNER. The chairman has put his finger on one of the most interesting discoveries in the Antarctic.

Mr. YATES. I remember when Dr. Gould first testified before this committee that scientists did not know at that time whether there was an ocean or a land mass in the Antarctic.

Dr. WEXLER. It would look now as though there may be an inland sea, a body of water of some kind, that is frozen all the way down. We do not know.

Mr. YATES. Mr. Odishaw seems to refute what Dr. Gould said.

Dr. WEXLER. This is one small part of the Antarctic where the measurements have been made.

Mr. THOMAS. Dr. Wexler, you would have to say you are not sure yet whether that ice, where you may have a layer of ice underneath this one, could be as far as you know now several thousand feet thick?

Dr. WEXLER. Yes.

Mr. ODISHAW. In the Antarctic; yes.

Dr. WEXLER. 10,000 feet of ice.

Mr. YATES. Do you know whether that is the limit of the ice? Do you know that it does not extend beyond 10,000 feet?

Dr. WEXLER. Yes. At this particular area we know it does not go beyond 10,000 feet.

Dr. YATES. Could it extend beyond 10,000 feet in other areas?

Dr. WEXLER. Yes. Over here the height is 14,000 feet. For all we know there may be 14,000 feet of ice, or even more.

THERMAL EFFECT OF OCEANS ON ARCTIC ICE

Mr. THOMAS. Getting back to the Arctic, where you have 10 to 14 feet, are you sure that that is about all it is going to be, when you get through testing it?

Mr. ODISHAW. The ice island itself, as Dr. Wexler points out, is thicker. There will be variations, but there will be nothing like the thickness of ice in the Antarctic.

Mr. THOMAS. You have to figure out the difference between the land mass and the water mass and what effect it has?

Mr. ODISHAW. The warming effect of the water is most important.

Dr. WEXLER. I think the chairman put his finger on a very interesting point and that is this: Why is not this ocean frozen over all the way down? Apparently there is enough warm water coming into the Norwegian current from the gulf stream to feed enough energy into the Arctic Ocean to overcome the tendency toward freezing. If this turns out to be a sea in what we call West Antarctica, if we have an ocean here, our conclusion can be one of two alternatives: Namely, it is a cutoff inland sea, a true cutoff from the ocean, or else there are very narrow passages which do not permit enough heat to be transported by the ocean currents.

Dr. REVELLE. When you get a great thickness of ice on a land mass, the land mass actually sinks because of the weight of the ice, so that, for example, in northern Europe during the Ice Age, Finland and a good deal of northwestern Russia were actually under sea level because of the overburden of the ice. The land has been rising ever since the ice melted, for the last 10,000 years. Say, for example, in Finland, the Russians used to gain a new duchy in Finland every century as the land rose out of the sea.

EFFECTS OF ICE MELTING

Mr. YATES. Will you develop one point that Dr. Gould also commented on, which I found exceedingly interesting, and that was relating to the degree of melting of the subpolar icecap? As I recall the testimony, he said if the same rate of melt continues, it is conceivable within 20 or 25 years a peninsula such as Florida might become inundated.

Dr. WEXLER. Yes. I think it will be a much longer period.

Mr. BOLAND. As I remember, he said this would be so if this is a solid ice mass.

Dr. WEXLER. If a catastrophe should occur, that might be so. Nature operates much slower.

Mr. THOMAS. You go ahead. Forgive us for interrupting here.

Mr. ODISHAW. This condition, Mr. Chairman, that you referred to in the Antarctic in terms of these operations around Byrd is similar to the situation in Greenland. There, too, you have a rather thick ice sheet and evidence is that there are parts of the interior of the continent that are considerably below sea level. I think the estimates are some 500 or 1,000 feet.

EQUATORIAL PACIFIC PROGRAM

If I may turn for a moment to the equatorial Pacific, there we have some 18 stations. The principal activities are centered in the Hawaiian Islands, in this little group of islands [indicating] around the geographic Equator, and over here in the Marianas and the Carolines. These areas have major stations whose activities cover almost every discipline in the IGY.

May I now turn to a topic relating to the world data centers?

Mr. YATES. Are there stations of other nations in that area, too?

Mr. ODISHAW. Yes. There are stations of other nations. The French, the Australians, the Japanese, and the New Zealanders are active in various regions of the Western Pacific.

Mr. YATES. Do you have a chart which shows all the combined endeavors of the participants?

Mr. THOMAS. Dr. Berkner will put that in the record, with a brief description of the activities of each one of our foreign government colleagues.

Proceed, sir.

IGY DATA CENTERS

Mr. ODISHAW. The problem of the IGY data centers was discussed with you when we last met. These plans, as Dr. Berkner, I believe, indicated, have progressed. There will be three major IGY data centers; IGY center A will be in the United States. There will be one in the U. S. S. R. (center B) and one in Western Europe (center C), which will have a branch or two in Japan.

The data center in the United States will be decentralized into a series of about 12 subcenters which are listed in the document before you. Plans have progressed. We are considering the detailed budgets, and it looks as though we will be able to achieve this very important mission within the IGY. Data from all over the world will be collected by these centers. There will be, in effect, three complete sets of depositories for all of the raw and semiprocessed data.

If I may, I should like to refer for a moment to one other area that has been of some interest.

INTERCHANGE OF PERSONNEL

Mr. JONAS. Will there be any exchange of personnel? For example, will we have any people in the Soviet zone, and will they be here?

Mr. ODISHAW. In general, programs are staffed by each nation itself, in terms of its own program. There are bilateral arrangements where cooperation between two nations is desired, and there is some interchange.

As a matter of fact, right now there is an interchange between the U. S. S. R. and the United States. There is a Soviet meteorologist at Little America, at the Antarctic Weather Central, an international activity for which we have responsibility. There are also representatives of several countries there, including an Argentinian and a New Zealander, at Little America. We have a man, going back to the exchange with the Soviets, at the U. S. S. R. station at Mirny, in the Antarctic. There will be a few instances of interchange and cooperation of this kind.

SCIENCE EDUCATION

One of the questions that has been of some interest to this committee and the Senate committee has been the area of the results of the IGY and the value of the IGY ultimately. Some of these have been discussed. I do not intend to go into that.

I should like to refer to a byproduct, namely, the educational value of the IGY. Members of the House and Senate have expressed interest in this area, and the National Science Foundation, as you know, has a great deal of interest in it.

We have already been able to do a few things in this connection, working with educational institutions and universities, aside from the area of committee activity of a more public type—addresses, et cetera, which may have had a beneficial effect.

We have worked in some detail with a number of institutions, and I should like to leave with you examples of what has been done toward reaching schoolchildren and the youth of the Nation, working with various educational institutions.

EXECUTIVE DIRECTOR COMMENDED

Dr. KAPLAN. Mr. Chairman, before calling on Dr. Porter, I would like to interrupt the formal presentation and take the opportunity of making a few brief remarks about Mr. Odishaw's services as Executive Director for the United States National Committee.

From our previous appearances in which Mr. Odishaw has played a significant part, I am sure that you have suspected the role which he has undertaken in the planning, development, and execution of the United States program. I should like to be more specific.

From the earliest days of program planning and budget preparation, Mr. Odishaw has borne major responsibility for participating in the determination of policy objectives and has accepted primary responsibility for the translation of these policy directives into the development of the program and its assignment to the large number of participating institutions. He has daily been compelled to deal with innumerable complex problems and his remarkable ability to cope with these situations has, I believe, been a dominant factor in achieving the success of which we are now assured.

For example, he has directed his staff in working closely with our technical panels as they developed the program, assigned it to the institutions, and granted the funds with which the projects are now being undertaken. In innumerable instances he has negotiated with other agencies both within the Federal Government and without, on many matters crucial to the IGY effort.

He and the staff, for example, have had heavy logistics and operational tasks, working with the Department of Defense in the installation of our Antarctic stations and, similarly, in connection with the Arctic Basin floating stations. To cite another example, he has represented the committee and our Earth Satellite Panel most successfully in very complex and intricate negotiations with respect to the earth satellite program and has played a key role in its conception and development.

During his 3 years of service for the United States program, he has given of himself untiringly, even though this has continuously required working almost without a break throughout the whole period.

Hence, I cannot overemphasize the contributions which Mr. Odishaw has made to the United States program. I can only state my belief that the Academy and the National Committee, as well as the Nation, are deeply indebted to him.

Mr. THOMAS. A fine statement. The committee joins you in your fine statement concerning the efforts of Mr. Odishaw.

Mr. ODISHAW. Thank you, Mr. Chairman.

I should like to thank Dr. Kaplan for his most kind and gracious compliment. However, if I may, Mr. Chairman, I should like to demur because the planning, the development, and the growing realization of this unprecedented enterprise have been the achievement of innumerable people. I should say that this achievement starts with many in this room—with the members of this committee itself, with the distinguished members of the Academy's committee, and the representatives of the National Science Foundation, and reaches out to scientists, engineers, and technicians in literally every State of the Union. These people have devoted and contributed hundreds and thousands of hours of their own time to this program, and the great results which this effort already promises will be a tribute to what all of them have done, are doing, and will do.

Statement of Dr. Richard W. Porter on Earth Satellite Program

Dr. Kaplan. I would like to call now on Dr. Porter.

Mr. Thomas. Dr. Porter, let us print your statement in the record at this point, then you proceed to amplify on this earth satellite program. It is one of the most interesting programs of the IGY.

(The statement is as follows:)

Statement of Dr. Richard W. Porter, Chairman, USNC-IGY Technical Panel on the Earth Satellite Program, National Academy of Sciences

EARTH SATELLITE PROGRAM

I appreciate the opportunity of meeting with you gentlemen again to report on the progress of the IGY earth satellite program. I had the pleasure of initially discussing this with you a little over a year ago. At this time I should like to summarize the progress on each aspect of the program. The IGY earth satellite program is, as I indicated in my previous testimony, pioneering in the fullest and purest sense of the word.

ORGANIZATION

Following the endorsement by the United States Government and the assurance of the requisite support for an earth satellite program in the International Geophysical Year, the broad array of effort necessary for the accomplishment of the scientific, engineering, and operational aspects of the task was organized. In behalf of the United States National Committee for the IGY, the Technical Panel on the earth satellite program has carried out the technical direction of the program.

The Department of Defense has the task of providing the necessary operational support, including development, construction, and launching of the rockets which will accelerate the satellites into orbit, and the instrumentation necessary to measure their performance. Principal responsibility of this three-service rocket effort has been placed with the Office of Naval Research and the Naval Research Laboratory, where a project has been established under the name Vanguard. The United States Army and the United States Air Force are contributing existing facilities and skills in a number of areas.

The Naval Research Laboratory has contracted with the Glenn L. Martin Co. to design and assemble the complete launching vehicles. Martin, in turn, has subcontracted the rocket engines for the first stage to the General Electric Co. and for the second stage to the Aerojet-General Co. Two competing subcontracts have been let for the small, solid-propellant third-stage rocket, 1 to the Grand Central Rocket Co., of Redlands, Calif., and 1 to the Allegheny Ballistics Laboratory of the Hercules Powder Co. Other important subcontractors to Martin include the Minneapolis Honeywell Co., which will contribute the gyroscopes; and Vickers Electric, which will contribute the magnetic amplifiers used in controlling the flight path.

At the recommendation of the National Academy of Sciences, the National Science Foundation has granted funds to the Smithsonian Astrophysical Observatory at Cambridge, Mass., to establish and suitably equip 12 special photo-telescopic observation stations located throughout the world, to organize amateur astronomers into supporting teams of volunteer visual observers, and to establish the necessary data processing and computing facilities for optical and photographic data.

The National Academy also recommended transfers of funds to the Naval Research Laboratory to develop, supply, and operate the necessary equipment for radio tracking and radio telemetry, to set up associated data processing and computing equipment, to provide some of the instruments to be carried within the satellite, and to provide assistance in design and environmental testing to other scientific agencies.

Among the other agencies which already have grants for internal instrumentation, or with whom arrangements are currently being made for supporting work, are the State University of Iowa, the University of Maryland, the University of Wisconsin, California Institute of Technology, Bartol Research Foundation, Research Institute for Advanced Studies, the National Advisory Committee for Aeronautics, the Ballistics Research Laboratories of Army Ordnance, the Signal Corps Electronics Laboratory, and the Geophysical Research Directorate of the Air Force Cambridge Research Center

GENERAL CHARACTERISTICS OF A SATELLITE

In order to create an artificial earth satellite it is necessary to raise an object to an altitude where the air density is very small, and to make it go fast enough in a direction parallel to the earth's surface so that its centrifugal force, or the force tending to make it fly off into space will be just equal to the gravitational force which tends to make it fall toward the center of the earth. The minimum altitude turns out to be about 200 miles and the velocity between 18,000 and 19,000 miles per hour. The very small amount of air which remains at this altitude will slow the satellite gradually, but it is believed that in such an orbit the satellite would persist for at least several weeks. At 300 miles it is believed that the satellite would possibly last for as long as a year and perhaps even longer.

IGY SATELLITES

As was stated last year, the satellite is a spherical body weighing approximately 21.5 pounds and having a diameter of about 20 inches It contains a radio transmitter which will operate for several weeks at approximately 108 megacycles with a power level somewhere between 10 and 100 milliwatts and will serve to permit radio tracking. During short periods the power can be increased to permit transmission of data to the ground. The power for this transmitter will be obtained from chemical batteries

When the spherical body has reached an altitude of about 300 miles it will be pushed into orbit by a small solid propellant rocket weighing about 500 pounds fully loaded. This rocket, when burned out, will be separated from the sphere and will also continue to float in the orbit as an inert object. The remainder of the rocket assembly will consist of two liquid propellant rockets, so arranged as to be fired in sequence, the smaller second stage using acid and one of the hydrazines as propellants, and the larger first stage using liquid oxygen and gasoline.

The complete assembly will weigh about 20,000 pounds and will take off with a sea-level thrust of about 27,000 pounds. Its structure will somewhat resemble the United States research rocket Viking. Like the Viking, the rocket motor in both stages will be mounted on gimbals to provide lateral control. Both the first and second stages will be gyrostabilized in roll, pitch, and yaw and the third stage will be spin-stabilized.

The first stage will burn out after about 2 minutes of flight at a distance of about 40 miles from the launching site, at a velocity of between 3,000 to 4,000 miles per hour. The second stage will begin burning immediately and will attain a velocity of approximately 11,000 miles per hour at an altitude of 130 miles and will then coast up to approximately 300 miles. At this point, where the trajectory is parallel to the surface of the earth, the last stage will be fired, bringing the velocity up to the orbital speed of about 18,000 miles per hour

LAUNCHING AND SATELLITE ORBIT

The satellite will be launched from an Air Force facility at Cape Canaveral, Fla., in an orbit inclined approximately 35° with the equatorial plane. Sufficiently precise guidance will be provided to hold the elliptical orbit to within the limits 200 miles perigee and about 1.200 miles apogee.

The ellipticity of the orbit will depend, of course, on the accuracy of the guidance and on the relationship of the actual velocity at the end of firing of the third stage to the velocity required for a circular orbit at that altitude. In order to increase reliability, a relatively simple system will be used for guidance and control, and a comfortable velocity margin will be provided over the minimum required value. Both of these considerations, although obviously desirable, will tend to increase the probable ellipticity of the orbit.

At this point I think it would be well to comment on the engineering difficulties which may be encountered. The experience gained in the past 10 years with high-altitude research rockets will, of course, be helpful, but the requirements of this program go far beyond anything that has been done before. For example, there are 6 magic numbers, which describe the specified performance of the booster vehicles; that is, 3 weight ratios and 3 rocket-exhaust gas velocities. At the time the basic-design decisions were made none of these had been successfully accomplished in flight tests, although there was ample evidence that they could be achieved. Since we must coincidentally accomplish all these objectives to put our satellite into orbit, it seems entirely possible that some of our early attempts will fail. In any case, successful flights definitely cannot yet be guaranteed by any specific date.

A test program has been established which includes at least six preliminary test vehicles. None of the tests are intended to establish a satellite in orbit, but only to test various critical components and combinations of components under realistic flight conditions and to train people responsible for carrying out the various technical functions in order to improve the probability of success. Once the test program has been concluded, "earnest tries" will be attempted, in each of which an attempt will be made to place a fully instrumented satellite in orbit. The present effort calls for attempting to place six instrumented satellites in orbit.

The first test vehicle, known as TV–0, was fired virtually on schedule early in December. This test vehicle was a modified Viking rocket, with the addition of only a few of the new elements for the satellite. Its predominant purpose was to provide an opportunity to "shake down" the new crews and new instrumentation. It was completely successful.

As indicated above, at least 5 or 6 more test vehicles will be launched, each to assess a certain subsystem or group of components or subsystems before the first earnest try. I regret that I cannot now give you even the approximate date of that first try; there are still many uncertainties in the program, and the responsible agencies prefer to wait a little longer before publishing a schedule. The official statements to date have promised only that the United States would attempt to put a satellite in orbit during the International Geophysical Year, i. e., before the end of 1958; naturally the schedule will call for a first try earlier than that date so as to allow time for a reasonable number of successful attempts

Tooling for the structure of the large first stage is complete, and several complete structures have been built Several rocket engines for this stage have passed qualification tests; some have failed to pass, and an intensive program is now underway to overcome the apparent difficulties. All of the parts of the guidance and control system are undergoing laboratory testing, individually and as an assembled system, at the Martin Co. Solutions have been found for the critical problems affecting the successful design of the pressurized second-stage rocket, and delivery of this equipment is expected on schedule. It now appears that both contractors for the solid-propellant third stage will come through on time with satisfactory designs. Both are currently conducting static firing tests.

The second-test vehicle, called TV–1, is scheduled for launching at about the present time TV–1 will include the first-stage rocket, a transition section which will permit the addition of the third-stage rocket assembly with its protective nose cone This test will permit evaluation of the separation of the third-stage rocket.

RADIO TRACKING AND COMPUTATION

The Department of Defense, as a part of its mission to place the satellite in orbit and to prove orbit attainment, directed the Naval Research Laboratory to include a liimted radio tracking operation in their program. Quite independently, the USNC for the IGY assigned to the Naval Research Laboratory the responsibility for a precision radio tracking system as a part of the scientific program. Thus the composite responsibility of NRL in this regard includes the development and design of equipment, the establishment and operation of radio tracking stations, and the attendant reduction and computation of radio orbital data

The radio tracking program at NRL has been directed toward the requirements of (1) the immediate observation of satellite position and the rapid computation of an approximate orbit (this provides the initial proof of attainment of orbit and enables telescopic cameras to be made ready for subsequent more precise observations of the satellite) ; and (2) the continued radio observation of a satellite in orbit, both night and day, under all conditions of visibility. This will insure enough data for fairly precise computations of orbit, which would be particularly important in the case of a short-lived satellite.

The radio tracking system, known as Minitrack, uses a phase comparison method in which a radio signal is transmitted from the satellite to the ground station, which acts essentially as a radio-frequency interferometer. Satellites will transmit Minitrack signals at about 108 mc Each ground station will include a precision multiple antenna array and an involved electronics installation. The expected precision of operation is about 3 minutes of arc under normal conditions with improvement to 20 seconds of arc for nighttime observation at small zenith angles. The interception pattern of the antennae from each station is several hundred miles long at satellite altitudes. A picket fence of eight prime Minitrack Mark I stations is being set up approximately along the 75th meridian, between 35° N. and 35° S. latitudes. Thus there will be virtual certainty of intercepting the satellite once on each passage Stations will be located at or near Washington, D. C ; Savannah, Ga , Havana, Cuba; Antigua, British West Indies; Quito, Ecuador; Lima, Peru; Antofagasta, Chile; and Santiago, Chile. Installation and operation of these stations is being carried out by the Department of Defense through the Army Corps of Engineers, with the assistance of the Inter-American Geodetic Survey. Operation of the stations will also include support from the Army Signal Corps. The cooperation of many nations has clearly been required and has been generously granted.

The initial Minitrack Mark I station near Washington, D. C, has already been in operation for several months for test, calibration, and training operations by the Naval Research Laboratory. Calibration has been by means of radio astronomy and by aircraft flying over the station. A contract established by NRL with the Bendix Corp. (Towson, Md, division) calls for the manufacture of nine Minitrack equipments, with biweekly deliveries scheduled to start May 15, 1957.

Other radio tracking stations are being established at San Diego, Calif., with operation by the staff of the Naval Electronics Laboratory; and at Woomera, Australia, with operation by Australian scientists through arrangement with the Australian National Committee for the IGY.

Each Minitrack Mark I station will include, in addition to the radio tracking sysem, a complete receiving and recording system for the telemetered reports from the experiments carried in the satellite. As soon as Mark I stations provide observations of position and time of satellite passage, calculations of the orbit must be made. This must be done at very high speed so that orbit data and position predictions for chosen observation sites can be calculated during a single revolution In order to do this, the prime Minitrack stations are being linked by radio and telegraph with a central office at the Naval Research Laboratory in Washington, D. C. This central office will communicate directly with a computation center for the radio data and also with a corresponding central office for the precision optical stations. The Naval Research Laboratory has contracted with the International Business Machines Corp. for the establishment of a radio tracking computation center in Washington, D. C. A high-speed computer (704) will be used.

As a part of its scientific program, NRL has also developed a much less elaborate radio tracking system known as Minitrack Mark II. This installation is within the technical and perhaps the economic capability of a university laboratory group or an advanced radio club. Data from a Mark II station, when combined with information of the position of the satellite obtained from primary tracking networks, can yield accurate and valuable positional information. Scientists, both here and in other countries, have indicated interest in Mark II and there is good likelihood that a number of Mark II stations will be put into operation.

OPTICAL TRACKING AND COMPUTATION

Ultimate precision of tracking will be provided by the optical system, consisting of a primary net of 12 stations The USNC–IGY has assigned the Astrophysical Observatory of the Smithsonian Institution the responsibility for the optical tracking program, including the equipping, establishing, and the operating of the stations, as well as the computing of orbital data.

Observation stations will use improved Schmidt cameras and crystal clocks. The clocks will have estimated rates of a few milliseconds a day and will be readable to one millisecond; this time accuracy promises a positional determination of the satellite's position to less than 10 seconds of arc along its path. The cameras use an F/1 Schmidt-type system of 20-inch aperture with mirror aperture of 30 inches. With the predicted angular speed and brightness of the satellite, this equipment is expected to provide an accuracy of about 2 seconds of arc in a direction transverse to path.

The optical tracking equipment has an estimated capability of tracking a 15-inch diameter sphere at a distance of 1,000 miles. This corresponds to a stellar magnitude of 10 to 11, and is more than adequate for tracking the satellite, which should vary approximately from stellar magnitude 6 to 9 in passing from perigee to apogee.

The satellite tracking cameras and the timing equipment are now under construction The basic contractors are Perkin-Elmer Corp., Norwalk, Conn., which is producing the optical components, and Boller & Chivens, Inc., South Pasadena, Calif, which is making the mechanical components. The crystal clocks and their accessories are being built by the Norrman Laboratories, Williams Bay, Wis. The correcting-plate glass is being produced by the Schott optical glass works in West Germany, while the mirror blanks come from the Corning Glass Works, Corning, N. Y. Several mirror blanks have already been delivered and the first glass from Germany arrived in January. Completion of the first optical system, its camera body and mount, is expected by early July.

The first camera is scheduled for delivery and installation by August 15, 1957, at the prototype satellite tracking station at White Sands, N. Mex., where it will be subjected to intensive shakedown trials. The remaining cameras, to be delivered at the rate of two per month, will be shipped by air to tracking stations throughout the world. It is expected that all 12 stations will be operative by April 1958.

It appears that the minimum acceptable coverage of the satellite orbit requires 12 optical observation stations, and sites for these have been selected to provide the most effective set of scientific observations. The stations will be located in White Sands, N. Mex., United States of America; Cocoa Beach, Fla., United States of America; Curacao, Netherlands Antilles; Woomera, Australia; Tokyo, Japan; Cadiz, Spain; Arequipa, Peru; Naini Tal, India; Villa Dolores, Argentina; Iran (Teheran or Shiraz); South Africa (probably Olifantsfontein); and Hawaii (probably Maui). The stations in other countries will receive operating assistance and collaboration from local scientists. Again we are indebted to colleagues abroad and to various nations for their cooperation and assistance in this effort.

It is estimated that, on the average, each station will be able to photograph the satellite at least once a week. Not only must the station be located near the satellite's path in order to make observation, but the satellite must be in the twilight zone at the time. Several hours before an expected transit, the latest data on the orbit will be radioed to the station, giving the settings of the yoke, the gimbal ring, and the camera, the brightness of the satellite, its angular velocity, and the moment when tracking must begin. Appropriate settings will be made on the telescope and, at the appointed instant, the tracking mechanism will be engaged. Subsequent operation of the camera will be automatic.

Between 10 and 100 separate photographs of the satellite may be made during each transit, depending on the particular circumstances. These photographs will be developed immediately and a rough position for the satellite will be measured, for transmission to the Computing Center in Cambridge, Mass., where it will be used in improving the predictions of the satellite's flight The film itself will be shipped to the Computing Center for high-precision measurement. After observations of all the IGY satellites have been completed, these precision measurements from all stations will be combined in the solution of complex orbit equations to yield geophysical and geodetic data.

SATELLITE EXPERIMENTS

A year ago I indicated that a wide variety of experiments would be possible in the satellite program and mentioned specifically the following: the measurement of air drag and air density in the upper atmosphere; the geodetic determinations of the shape of the earth and the relative position of land masses; composition of the earth's crust; temperature and pressure conditions in the upper atmosphere; meteoric particles; and ultraviolet and cosmic radiation Preparations have been made for carrying out these experiments as well as some others.

It should be noted that much of this scientific program will derive solely from position measurements of the satellite in orbit, entirely aside from any instrumentation which it may carry. For example, once the orbit is established; the location of any point on the earth's surface can be measured with an accuracy almost equivalent to a chain and transit survey by timed observations of the satellite made from that point.

It is well known that the earth is not a perfectly symmetrical sphere, but rather an oblate spheroid, shorter from pole to pole than along an equatorial diameter. Thus, its mass must be represented, not as a point, but rather as a disc. For this reason, any satellite orbit other than a polar or equatorial orbit will precess. This so-called precession of the nodes will have a period of about 2 months for the 35 degree orbit. Another perturbation having a much longer period is the rotation of theline through the apogee and perigee in the plane of the orbit, which is referred to as the motion of the line of apsides. If these perturbations can be observed over a long enough time they will provide a more accurate measure of the oblateness of the earth than any method currently available.

Still other perturbations, notably the gradual change in the height at perigee and apogee, will provide a measure of air density, principally in the region of the perigee. Since no other means is currently available for making accurate measurements of air density at these altitudes, the satellite should improve the accuracy of existing information very considerably. There is also a plan under consideration to release a larger, very lightweight inflatable sphere made of aluminized plastic at some point in the satellite orbit. Because of its higher drag-to-weight ratio, such a sphere would make it possible to obtain more accurate data in much shorter periods of observation.

The radio direction measurements at 108 megacycles will be subject to angular errors which will be a function of the integrated ion density along the path of the radio transmission and the zenith angle of that path. If the orbit is well known and radio measurements are taken over a wide arc, including some relatively large and some relatively low zenith angles, it should be possible to compute a value of integrated ion density at each satellite passing over a radio direction-finding station. These data, togther with information about the structure of the ionosphere which will be obtained by other means, should be extremely valuable in ionosphere research.

At the invitation of the USNC-IGY, a meeting of many of the scientists in the United States having experience and interest in upper atmosphere research through instrumented rockets was held in Ann Arbor, Mich., in 1956. More than 30 papers were presented at this meeting, proposing various experiments which might be accomplished by means of a small satellite. A working group on internal instrumentation, headed by Dr. James A. Van Allen, was established by the technical panel on the earth satellite program to provide a focal point for evaluating these and other possibilities which might be suggested at a later date. Out of the work of this group has come a selection of four "hard core" experiments which currently have top priority for the flight investigation IGY satellite program. These four experiments, selected on the basis of relative simplicity, state of development of the proposed instrumentation, importance of the expected results in illuminating some broad field of science, ease of interpreting the results, and competence or experience of the proposing agency, will consist of the following: Measurement of the ultraviolet radiation from the sun (at approximately 1,216 angstroms); measurements of the earth's magnetic field; measurement of cosmic ray intensity; and measurement of the total radiation to and from the earth In addition to the four "hard core" experiments, a number of secondary, environmental tests are being planned for inclusion along with one or more of the primary experiments. These secondary tests include measurements of temperature, skin erosion by meteoric dust, puncture of the satellite shell by meteorites, and frequency of impact of meteorites too small to puncture the skin.

The internal instrumentation program will be discussed in detail by Dr. Van Allen.

SATELLITE ORBIT

Dr. PORTER. Last year, at the time of our appearance, I recall somebody asked me what keeps the darned thing up there, anyway.

Mr. THOMAS. Did you bring that blackboard and that formula with you and that chart?

Dr. PORTER. I had to resort to some mathematics, as you recall.

Mr. THOMAS. We helped you work out that formula.

Dr. PORTER. I was interested to note that columnist Othman afterward, upon looking at the record, made the comment that the silence which must have greeted my testimony was bipartisan. I will try to do a little better this time, if I may.

Mr. YATES. He did not know. We were not really silent.

Mr. THOMAS. I think you did very well.

Dr. PORTER. As a matter of fact, there is a very simple explanation for the way in which the satellite stays in space. You have already heard of the sphere as being in free fall, a gravitationless situation. This is precisely true. It continues to fall and yet never reaches the surface of the earth.

I think I can illustrate this with this little ball that we will say is the satellite, and the earth. If I drop it straight down it falls to the surface. If, however, I give it some velocity, parallel to the surface of the earth, it tends to fall in a path which is actually one end of a very long, narrow ellipse and eventually it strikes the surface of the earth.

As I give it more and more velocity, it reaches out on a longer and longer ellipse, going farther and farther around until finally it continues, if I give it just the right velocity, to fall in a curved path, which goes right around the earth and comes back to the starting point.

In this very simple way, we illustrate the fact that it is indeed freely falling all the time. If I give it the right velocity to begin with, parallel to the surface of the earth, it continues to go around and around the earth without ever falling to the surface.

Mr. YATES. There is so much meaning in this phrase "right velocity"; is there not?

Dr. PORTER. So much meaning in the phrase. That "right velocity" is somewhere between 18,000 and 19,000 miles per hour.

I want to remind the committee that the Department of Defense has accepted the responsibility to build and launch, using their own funds, the vehicles necessary to propel the satellites up to this right velocity, and at the right altitude.

It is the responsibility of the National Academy of Sciences to provide scientific supervision for the utilization of the satellites, and to advise and make recommendations to the National Science Foundation with respect to expenditures for this purpose.

PHYSICAL DESCRIPTION OF SATELLITE

The weight of the satellite remains at 21½ pounds, as we reported last year, and its diameter is still 20 inches, except for 1 experiment where the diameter will be reduced to about 13 inches; in this case, in order to provide something which is highly visible, it is currently planned to expel a very lighweight plastic and foil balloon, which will be blown up at altitude and then evacuated but will remain in a very lightweight, but stable condition. This will be 30 inches in diameter and will constitute a second satellite weighing less than a pound which continues to revolve in orbit. You will hear more about this later, I think perhaps from Dr. Van Allen.

THREE STAGE ROCKET VEHICLE

You also recall that I mentioned at the time of my last pleasant visit with your committee that the final push to the satellite, the final increment of velocity which is given in this position parallel to the surface of the earth, is given by a small solid propellent rocket weighing about 500 pounds.

The first one of these small solid propellent rockets has passed its qualification tests, has been delivered, and I just heard on the radio this morning, coming to the committee meeting, that it has been fired at Patrick, Fla., within the last 24 hours in combination with the first stage, this combination being referred to as TV–1.

The second liquid-propellent stage rocket which is being produced by Aero-Jet General Corp. has also been accepted and shipped to the Martin Co.

Two of the big first-stage rocket engines initially passed all their tests several months ago. However, some of the later engines on the third and fourth—the third and fourth engines under test—showed some heat transfer problems which have now been overcome, and a new engine incorporating these modifications has now been completely qualified and is awaiting installation at Martin. These same changes are being made in the first engines in order to give them added reliability.

The first stage burns about 2 minutes and brings the velocity of the combined vehicle up to 3,000 or 4,000 miles an hour at a point about 36 miles from the launching site. The second stage brings the velocity up to about 11,000 miles per hour, at an altitude of about 130 miles. Then the combined vehicle, with this velocity, coasts on up to about 300 miles, at which time it is traveling parallel to the surface of the earth.

At that time, the third stage rocket fires, bringing the velocity up to a little over the 18,000 miles per hour that is required to keep it going indefinitely at that altitude.

SHAPE OF THE ORBIT

Now, if the velocity produced by that third stage, or by the combination for that matter, is a little too high, then we have a elliptic orbit. I can demonstrate in this way: If it is going to fast it comes out farther from the earth on the opposite side, and again returns to its starting point; if we give it too small a velocity, then it comes in closer to the earth on the opposite side, and back out again to its initial starting point.

Mr. YATES. This assumes it will not penetrate any layer that surrounds the earth.

Dr. PORTER. If it comes in too close to the earth, the drag will pull it down. Assuming it is a little too small a velocity, if the deficiency in velocity is very small, then the vehicle will start at 300 miles and maybe pull down to 200 miles at which point the drag is still not sufficient to cause any rapid deterioration, then back out to 300 miles again.

If the direction is wrong, then we have another kind of effect as follows: If the direction is pointed too high, instead of being parallel to the surface of the earth it is pointed up a little bit, then the vehicle will go out farther on the part of the earth that is 90 degrees from the starting point, and back in closer at the point 270 degrees, and then back to its starting point again.

Mr. THOMAS. Dr. Porter, put your finger on the globe there. Where are you going to fire this?

Dr. PORTER. From Patrick Field at Cape Caneveral, Fla.

Mr. THOMAS. Graphically show, when you get up to 300 miles, where is it going to be? That is the height you ultimately hope to achieve.

Dr. PORTER. Coming out from Patrick, go out to about 300 miles.

Mr. THOMAS. About where would that put you?

Dr. PORTER. Not far from Puerto Rico, at 300 miles.

Mr. THOMAS. You are not going straight up, are you?

Dr. PORTER. Not straight up; no. It takes off straight up, but it very rapidly bends over. By the time it is 300 miles up, it will be going nearly paralled to the surface of the earth.

Mr. THOMAS. Where would it be now at 300 miles altitude?

Dr. PORTER. At 300 miles altitude it will be not far from Puerto Rico, and off to the left, taking off in this direction [indicating].

Mr. THOMAS. You are not at the top of the globe yet, though, are you?

Dr. PORTER. No. This satellite never goes to the top of the globe. It will take off at an angle like this.

Mr. THOMAS. At what altitude would it have to go to go to the top now?

Dr. PORTER. It is not a question of altitude. It is a question of the direction of firing. We will intentionally fire it in such a direction that it will rotate in a plane which is inclined 35 degrees with the Equatorial plane.

Mr. THOMAS. You are going 300 miles above the surface of the earth, are you?

Dr. PORTER. Yes; 300 miles above the surface of the earth at a point in the Atlantic Ocean.

Mr. THOMAS. If you were going at the point, say, at the top, at the Arctic, what would be the altitude above the earth's surface?

Dr. PORTER. It could be at any altitude that we desire, but in this particular case, the orbit never passes over either the Arctic or the Antarctic.

SELECTION OF SATELLITE'S ORBIT

Mr. YATES. Was there a reason for your selecting this particular 35-degree orbit rather than sending it over the poles?

Dr. PORTER. Yes; there are several reasons. We have to fire from Patrick for reasons of time. There was not time to set up a firing base anywhere else. Also, it would be very expensive to set up a firing base anywhere else. Patrick exists now; it is available and we would prefer to make use of existing facilities for this initial program.

Firing from Patrick, there is a definite limitation on the directions in which one can fire without firing initially over heavily inhabitated sections of land. We do not want to fire, for example, up over New York City. We do not want to fire directly over these inhabited islands, so what is being done, then, is selecting a firing direction which just skirts the Bahamas. It is inclined as far as we can without going over areas of land that might object to having the initial paths affect them.

Mr. THOMAS. It will be 300 miles high. When it circles, you will go around the Bahamas and what is your other spot?

Dr. PORTER. We come over, passing the Equator somewhere in here, passing over on the opposite side, passing over South Africa, and then coming back, around the earth, we pass near Santiago and then head south again.

Mr. THOMAS. All that time you will be up 300 miles high?

Dr. PORTER. All the time we will be either at 300 miles, if we hit exactly the right velocity and exactly the right direction, or we will be varying in altitude from 200 miles, perhaps out as far as 1,500 miles.

Dr. KAPLAN. You should remember, Mr. Chairman, that the earth rotates under the orbit.

Mr. JONAS. How long will it take?

Dr. PORTER. Approximately 90 minutes to make 1 complete revolution. During that time the earth will have rotated approximately 22 degrees, so that the next time it comes around it will pass over a portion of the country that is 22 degrees west. Each passage will be 22 degrees west with respect to the surface of the earth.

Mr. VURSELL. Since I came in late, your base from which you fire is in or near Puerto Rico?

Dr. PORTER. The base from which we fire is the Air Force proving ground which is sometimes called the Patrick Air Force Base, near Titusville, Fla.

Mr. VURSELL. Patrick Air Force Base, Fla.?

Dr. PORTER. Yes, sir. We will be firing a little bit south of east from Florida.

SATELLITE TRACKING

Mr. JONAS. Will you have any stations around the world that will know exactly when this is over them?

Dr. PORTER. Yes, I will give you the exact locations of all the stations if you like.

Mr. BOLAND. Will it always travel over the same areas and the same operating stations?

Dr. PORTER. No, sir. Because of the rotation of the earth we have a pattern like this [indicating] on the surface of the earth as the earth rotates. Each successive tracking station will be located 22 degrees west and some time or other the satellite will pass over every point in that band.

I think another thing which we should talk about is the tracking arrangements. Very early in the life of our panel we established a working group on tracking which is headed by a very distinguished engineer and scientist, Dr. Pickering, who is the head of the Jet Propulsion Laboratory at the California Institute of Technology.

Other members also working in this group are Dr. Whipple of the Smithsonian Observatory.

Mr. THOMAS. What was that name again?

Dr. PORTER. Dr. Fred Whipple of the Smithsonian Observatory.

Mr. THOMAS. Is that located in California?

Dr. PORTER. No, sir; he is located at Cambridge. He was trained in California, but he is currently located at the observatory at Cambridge, Mass.

Then we have Dr. Clemence of the Naval Observatory, Dr. Mengel of the Naval Research Laboratory, Dr. O'Keefe of the United States Army Map Service, Dr. Heiskanen of the University of Ohio, and Dr. Kuiper with Yerkes Observatory, University of Chicago.

RADIO TRACKING SYSTEM

The radio tracking portion of this job is being carried out by the Naval Research Laboratory, using equipment known as Minitrack. They are doing this partly with their own funds under the mission to prove whether or not the satellite actually is in orbit and partly on JGY funds to obtain scientific data.

The method used in this radio tracking equipment is known as a phase comparison method. This can be explained very simply: If I select two spots on the surface of the earth and if we send a signal from this point [indicating], the signal will arrive at the nearer point sooner than it will arrive at the farther point. By measuring the difference in the phase of the received signal, which is tantamount to, say, measuring the difference in time of arrival, one can detect the angular displacement of the source; and, by using 2 groups of stations or 2 bands of stations, one can detect angular displacement at 2 different locations by the direction vector from the spot on the earth to the source of transmission. This is what is meant by the term "phase comparability." The antennas are fixed on the surface of the ground; they do not have the drag problem and they can be located with great precision. The precise nature of the tracking is largely attributable to the phase comparison method which is used here.

ION DENSITY MEASUREMENTS

The basic accuracy of the system is about one-third of a minute, or about 20 seconds of arc, which will be achieved actually only at night, and at low zenith angles; that is, when the source is almost directly overhead. Under other conditions there will be errors due to bending of radio waves when they pass through the ionosphere which will bring the accuracy down to something like 5 or 10 times that amount, or something like 3 minutes or more. However, with many readings—the successive passes—tied together by the known equations of motion of the satellite it is actually possible to use these errors to measure the density of ions in the ionosphere and to turn these errors to a useful purpose.

This is particularly useful when we add to it the data we will have from the optical tracking of the satellite from which we will know the position of the satellite very well.

If we find the radio measurements are giving us an answer which is something different from the known position of the satellite, then we will use those discrepancies to tell us what the integrated ion density from the point on the earth to the satellite must have been.

A prototype Minitrack station is now in operation at Blossom Point, Md., and I am sure that if any members of the committee would like to see such a thing in operation, the United States Naval Research Laboratory people would be delighted to have you visit it.

Mr. THOMAS. Thank you, sir.

OPTICAL AND RADIO STATION SITES

Dr. PORTER. There is a contract with Bendix in existence which calls for the manufacture of 9 more of these stations to be delivered at a rate of 2 per month, starting in May of this year, or starting this month. My understanding is that these delivery dates are expected to be met. I think if we can hold up the map I can point out better where they will be located.

Those [indicating] are the optical tracking stations. The triangles on that chart indicate the locations that I will read off: There is one in San Diego, Calif., Woomera, Australia, and then continuing on down a sort of picket fence from Blossom Point, Md., we go to Savannah, Ga.; the one at Cuba; then we have Antigua, British West Indies; Quito, Equador; Lima, Peru; Antofagasta, Chile; and Santiago, Chile.

Mr. JONAS. They are removed from the line of fire?

Dr. PORTER. The stations that I referred to as a kind of picket fence represent a line of stations which will be passed over by the satellite once every time it comes around the earth, running from here [indicating] down along the west coast of South America. As the satellite comes around, it will vary from 35 degrees north latitude to 35 degrees south latitude.

Mr. JONAS. Will the picket stations be manned at all times?

Dr. PORTER. The picket sations will be manned at all times; yes, sir.

Mr. JONAS. Then, it will pass Chile about 3 or 4 times; will it not?

Dr. PORTER. It is making some 14 to 15 transits per day so that in about a day it is going to be down south, then it comes back up north again and it continues to cross over the fence at different latitudes at different transits, but it will always be receivable from one of these picket fence stations.

Mr. THOMAS. Why do you have those four stations there in South America?

Dr. PORTER. The four stations in South America represent the southern end of this picket fence. If we did not have something south of the Equator we would only see the satellite half of the time.

Mr. YATES. Are those stations to be manned by personnel or will they be just pickup stations?

Dr. PORTER. These will be manned by a fairly sizable group of people and at each of those stations there is also a receiver station for the radio telemetry signals which will be the only method for getting the scientific experiment data back.

PRECESSION OF SATELLITE

Mr. JONAS. Does the satellite come back over the launching area each time?

Dr. PORTER. No, it will pass 22.5° west of the launching point. Actually, I should say that the launching point will have moved 22.5° east of the point from where the satellite was launched. The satellite comes back over the same point in space, but the earth, because of its rotation, will have moved the launching site 22.5°.

Mr. Jonas. You will have difficulty, then, keeping up with it.

Dr. Porter. This is the reason why there is a complete chain of stations; it will pass near one of these stations every time it comes around.

Mr. Jonas. When do you plan to get it back and lock it up?

Dr. Porter. We do not ever plan to get the IGY satellites back. As they gradually lose energy, they will fall down into the denser and denser atmosphere and eventually become so hot they will break up.

Mr. Jonas. You never expect to get one back intact?

Dr. Porter. That is correct, sir.

MARK II MINITRACK

I should like to add that there is a design which has been worked out by the Naval Research Laboratory people.

Mr. Thomas. What group was that?

Dr. Porter. There is a design which has been made by the Naval Research Laboratory people for a simplified version of this direction-finding equipment which they refer to as Mark II Minitrack.

We do not propose to build and supply any of these equipments with Government funds. The only thing we propose to do is to supply information to professional and amateur groups who desire to build their own. We believe that it is beyond the capacity of such groups, generally speaking, to build a complete Minitrack such as will be installed at the stations referred to.

LIFETIME OF SATELLITE

Mr. Thomas. As a practical proposition, how many times is that going to traverse the earth before it disintegrates? You were speaking of people who wanted to build these things to watch the satellite. Will 2 weeks cover it, or 3 weeks, 10 days, 48 hours, or what?

Dr. Porter. The answer to this question, honestly, is "I do not know," and neither does anyone else.

Mr. Thomas. That is what I felt. A couple of days would give you a whole lot of information, or 24 hours, or 2 hours.

Dr. Porter. We can put some limitation on it. It will certainly not be less than a few weeks, nor more than a few years. We sincerely hope that more than one of these would be launched successfully.

SATELLITE LAUNCHING DATES

Mr. Vursell. When do you anticipate the first launching?

Dr. Porter. The first launching would, of course, have to be determined by the Department of Defense; that is, the date for the first launching. They have not yet given us a final schedule on this subject, but we have been assured that there will be launchings, and that there is a probability of at least one successful launching during the IGY, and that would be before the end of 1958. I confidently hope that all of them will be launched during the IGY and that the launchings will begin a good deal earlier than that, but I have no authoritative information as to the date of the first launching.

Mr. YATES. Did you say the date for the beginning of the launchings was September?

Dr. PORTER. No; I have not given any date for the beginning because I do not have any data on that.

Mr. THOMAS. The original plan was for September of this year.

Dr. PORTER. That was the target date—September—or the period that we had hoped for.

Mr. YATES. How far are we off our hopes now?

Dr. PORTER. I would expect that there is some delay beyond that, but I do not know. We have asked for this information but at the present time we do not have the information from the Department of Defense.

Dr. WATERMAN. Probably, the best information is that the components testing and so on have come up to specifications so far as the technical problems are concerned, and it seems to be pretty well on schedule.

Mr. THOMAS. Some information leaked out about 30 days ago and it was carried in the Stars and Stripes, or some military publication—I have forgotten which—that the chances were it was going to be anywhere from 3 to 6 months late. Of course, that article was purely speculative.

Dr. KAPLAN. I think one might say, Mr. Chairman, that this is similar to other areas of experimentation in new areas and new things.

Mr. THOMAS. You are plowing in virgin soil, and you cannot predict the answers.

Dr. PORTER. I would expect, knowing how programs of this sort go, that it would not be unreasonable to expect that there would be some delay.

Mr. BOLAND. How many satellites do you expect to launch?

Dr. PORTER. The present program calls for 6 test vehicles to be made, which will not result in satellites and then 6 earnest trys, by which I mean 6 fully instrumented satellites in which there will be an announced intention to put the satellites in orbit.

Mr. YATES. Can you tell us what is holding up the launching of the satellite on the target date?

Dr. PORTER. Well, there are certain aspects of this program which have not yet been solved. I do not personally know of any aspects which have not been solved, but some of them have taken, perhaps, longer in solving than they were scheduled to take.

Mr. THOMAS. Your biggest headache, to be perfectly accurate about it, is your powerplant; is it not?

Dr. WATERMAN. At the moment, Mr. Chairman, the component phases have to be tested individually and then they have to be tested in combination. The only start that has been made in the combination testing is the one that Dr. Porter referred to.

Mr. THOMAS. You mean the one which was fired this morning?

Dr. WATERMAN. Yes, sir.

Mr. THOMAS. The chances are you are going to be on schedule?

Dr. PORTER. Well, one certainly hopes so. As far as my panel is concerned, we expect to have all of our internal instrumentation ready for any scheduling, including the beginning and later scheduling.

Mr. THOMAS. That is encouraging.

Dr. PORTER. Our radio tracking stations would be in place on time of original scheduling, but our optical stations will not be ready quite so soon.

Mr. JONAS. When will you know whether this test this morning was successful or not?

Dr. PORTER. As soon as I get through with the meeting here, I hope to get on the phone and find out.

Mr. JONAS. I thought, maybe, a call would have been in by now to tell you whether or not it was all right.

Dr. PORTER. They would not have the records ready for some hours, and I think it would be more fruitful if I wait to check on it later on in the day.

HEIGHT OF ROCKET FIRINGS

Mr. JONAS. What is the greatest height to which rockets have been launched?

Dr. PORTER. I am not familiar with the details of the military rocket firings, and I could not give you those even if it would be appropriate. The highest firings that I know of for a single-stage rocket was the Aerobee which was fired either yesterday or the day before, and which reached an altitude of 193 miles. However, that is not the type which is to be used in this program.

Mr. JONAS. What about the greatest height that a rocket has reached in combination?

Dr. PORTER. A good many years ago the Bumper program, which consisted of a WAC Corporal in the nose of a V-2, for which my group was responsible, at that time reached an altitude of 250 miles.

Mr. JONAS. Have you ever reached an altitude of 300 miles?

Dr. PORTER. 300 miles has not been reached by any nonmilitary vehicle that I know about.

RELATIONSHIP OF SATELLITE PROGRAM TO IGY

Mr. YATES. Doctor, I do not want to minimize your efforts, but is not the satellite program which has been so dramatized only a minor part of the entire IGY program involved in this experiment?

Dr. PORTER. It is certainly only a part of it. To me, it is not a minor part, but perhaps in the overall——

Mr. YATES. I mean in the overall.

Dr. PORTER. Yes. It needs to be put in its proper context with regard to the whole IGY program. It is not the whole IGY program, by any means. It is only a part which has to be fed in very carefully with the rest of the program, and this is part of the work of the National Academy of Sciences and of the group under Dr. Kaplan, of which I am a part; we do our very best to see to it that the satellite part of the program is made a useful contribution, or contributing asset, to the whole program.

Mr. YATES. But I think it is well that we do have this explained as a part of the program, I think in the public mind the only thing happening in the IGY is the fact that a satellite is being launched.

Dr. PORTER. I agree with you entirely. I am very pleased to note that an article will appear in one of the popular magazines which will put the satellite program in what I regard as the more proper context.

Mr. YATES. This is only one experiment which ties in with a tremendous number of other experiments; is it not?

Dr. PORTER. Exactly.

Mr. THOMAS. Go ahead, Doctor, with your presentation.

OPTICAL TRACKING PROGRAM

Dr. PORTER. To wind it up rather quickly, let us talk for a few minutes about the optical and telescope observations. The Smithsonian Astrophysical Observatory at Cambridge, of which Dr. Whipple is director, is in charge of this part of the program. It consists of two parts; one part will involve telescopic stations located at a number of points throughout the earth, and another will involve a network of visual observation locations manned by volunteers using simple monoculars. Telescopic cameras of a type known as Schmidt telescopes will be used. They have a 20-inch aperture, and the same focal length, giving a ratio of F/1. They should be able to photograph a 20-inch sphere out to 1,500 to 2,000 miles if there is proper illumination. This illumination has to be produced by sunlight coming from near the horizon at dusk and thereby providing a dark sky to look against.

The optical measurements are useful only during a period of about an hour before sunrise and about an hour after sunset. Under these conditions the satellite will look something like a very faint shooting star. The camera has a special drive that periodically stops motion and produces a more intense image. The drive tends to keep up with the motion and, as I said, this produces a more itense image, since the photography is done against a background of stars.

By having a number of locations we are able to get very high degrees of accuracy out of this system—about 2 seconds of arc perpendicular to the direction of travel and about 10 seconds of arc parallel to the path.

The reason for this difference is that the accuracy parallel to the direction of the path is determined to some extent by the accuracy with which time can be measured. Time will be measured by the most accurate crystal clocks known. Our time records will be photographed on the same film as the telescope uses. These clocks have a degree of accuracy on the order of one to two milliseconds per day.

Mr. THOMAS. That is reasonably accurate, I would say.

Dr. PORTER. They can be corrected by radio data over a long period of time. Actually, the most difficult technical part of manning the photographic telescope stations is operating these crystal clocks. The telescopes themselves are made by Perkin-Elmer, of Norwalk, Conn., and Nunn, Boller, and Chivens.

The first camera is to be delivered to White Sands, N. Mex., in August, which is one of the primary and permanent stations, and 11 more will be delivered and installed at various times, extending from August to March of 1958.

By March of 1958 they will all be on location and operating.

Mr. THOMAS. Well, you will not be ready, then, in September, will you?

Dr. PORTER. No, there will be 1 or 2 stations available in September, and more available each successive month from that point on. However, the full complement of telescope stations will not be available until early in 1958. This is a situation that we are not entirely happy about and a good deal of effort has gone into trying to improve that situation, but that appears to be about the best that can be done by the contractor involved

LOCATION OF OPTICAL TRACKING STATIONS

The locations of these other 11 stations are also given on that map by the round circles, and you will notice that they tend to be scattered near the north and south 35-degree latitude lines. There is a good reason for that: Because the satellite is traveling more nearly on a horizontal line at that point instead of cutting across on a line which is inclined. Therefore, there is a greater possibility of seeing the satellite at a station located near the 35-degree latitude line than there is one located near the Equator. Also, they have located the stations at sites which are high and dry and which have, generally speaking, good weather.

These locations are, 1 in Florida in addition to White Sands; 1 in Curacao, Netherlands Antilles; 1 in Woomera, Australia; 1 in Tokyo, Japan; 1 in Cadiz, Spain; 1 in Arequipa, Peru; 1 in Vila Dolores, Argentina; 1 in Naini Tal, India; 1 in Teheran or Shiraz, Iran; 1 in South Africa; and 1 in Hawaii.

Mr. YATES. Will we have United States personnel at all of these places, or will these stations be manned by natives of the particular countries?

Dr. PORTER. In many cases the operators will be people who live there, with the exception that there will be at least one chief scientist or chief astronomer provided by the Smithsonian at each location. In some cases we will have to supply more personnel than that, but we will make every effort to use local people wherever we can.

OBJECTIVES OF SATELLITE TRACKING

There will be computation centers both at Cambridge for the slower reduction of telescopic data, and one in Washington for the fast reduction of the radio data, in order to get the predictions as to where to look with the telescopes.

From these tracking experiments we will learn some four specific kinds of things:

We will be able to measure distance between points on the earth, particularly the location of islands, and the measurement of intercontinental distances, and we will be able to replace long, costly and hazardous surveys across rough land areas such as the continent of South America. The accuracy of such distance measuring will be some 10 feet or better.

We will be able to measure the figure of the earth better than it has been measured before. As you know, the earth is not a sphere, but tends to bulge at the Equator. This will be done by measuring the perturbations which are caused by this lack of spherical symmetry of the mass of the earth.

We will be able to measure air density by measuring again the degradation of the orbit; that is, the amount by which the altitude decreases at each point in the orbit with time; and we will be able to measure, perhaps, some equatorial asymmetry and the distribution of mass at the crust. This will require very accurate readings and very many readings, but it would be interesting to come up with some observation that the earth is more massive at one point on the Equator than at other points.

We will be able to measure ion density by sytematically looking at the errors in the radio tracking data and from here on the usefulness of the satellite will depend upon its internal instrumentation for which subject I would like to turn to Dr. Van Allen, who is Chairman of the Panel on Internal Instrumentation.

Dr. KAPLAN. Since Dr. Van Allen is new to the committee I would like to state that he is one of the pioneers in the use of rockets for research. He has done really distinguished work and work for which, as I mentioned before, all nations have been grateful to the United States.

I think this is about the only field of science in which essentially only one Nation, the United States has published any particular results. It is a remarkable area and we have been fortunate in having him as Chairman of this working group on internal instrumentation.

Mr. THOMAS. We are anxious to hear from you, Doctor.

Mr. YATES. Doctor, you look very young to hold this responsible position.

Dr. VAN ALLEN. I will be much older before we get through.

STATEMENT OF DR. JAMES VAN ALLEN ON USE OF INSTRUMENTS WITHIN EARTH SATELLITE

Mr. THOMAS. You may proceed with your presentation, Doctor. At this point, however, we will insert a copy for the record of your prepared statement.

(The statement is as follows:)

STATEMENT OF DR. JAMES A. VAN ALLEN, CHAIRMAN, WORKING GROUP ON INTERNAL INSTRUMENTATION OF THE USNC-IGY TECHNICAL PANEL ON THE EARTH SATELLITE PROGRAM, NATIONAL ACADEMY OF SCIENCES

I should like to discuss with you the IGY earth satellite program, and especially the portion with which I have been most directly concerned—the experiments using scientific instruments within the satellite itself. The inclusion of such internal instruments make possible the investigation of a vastly richer field of phenomena than is possible with an essentially inert satellite which is observed by ground tracking stations alone. Moreover, nearly all of the projects designed for eventual practical applications of artificial satellites (for example, reliable long-range weather forecasting) depend essentially on observations made with on-board instruments.

Soon after the organization of the technical panel on the earth satellite program in the fall of 1955, many of us had the feeling that one of our first responsibilities was to bring to the attention of the scientific community at large the possibilities and opportunities for making observations with internal apparatus. Durng the past year and a half, a number of us have devoted considerable effort to conducting conferences, to addressing scientific and technical societies, and to writing and publishing articles in an attempt to bring this about.

One of the major steps in this effort occurred in January 1956. The upper atmosphere rocket research panel conducted a major symposium with 38 formal papers discussing specific tangible proposals for using a small satellite in a realistic way for observations of various physical phenomena. The proceedings of this symposium have recently been published in book form and I believe that this is one of the first substantial professional contributions to this field.

FORMATION OF WORKING GROUP

In January 1956, a working group on internal instrumentation was established by the USNC technical panel on the earth satellite program to deal with all aspects of on-board observing equipment and, in particular, to sift and appraise the numerous proposals which were by then being received.

The members of this working group are Dr M. Ference, now with the Ford Motor Co.; Dr. W. W. Kellogg, from the RAND Corp.; Dr. H. Friedman, Naval Research Laboratory; Prof. L Spitzer, of Princeton University; Dr. L. R. Alldredge, of the Johns Hopkins Operations Research Office; Dr. R W. Porter; and myself (as chairman).

SELECTION OF ON-BOARD EXPERIMENTS

Over 30 serious and competent proposals for satellite experiments in various fields have been received. A substantial effort has been devoted to the study and discussion of these proposals because, as everyone realizes, the possibilities of important and far-reaching research using artificial earth satellites far exceed the limits of the pioneering IGY effort. First of all, we have stringent limitations of technical feasibility in any one flight. Second, we are limited by the number of flights which will be made And, of course, we are further limited by the factor of success which must be applied to any single satellite launching attempt. As a consequence, the selection of the best experiments from among the large number of proposals has been the primary task of this working group

We have submitted each proposed experiment to 4 test questions or 4 test criteria. In the first place, we have undertaken to assess the scientific importance of the proposal This does not mean we have regarded ourselves as omniscient in deciding whether ionospheric physics is more important than, say, solar physics We have undertaken no such appraisal whatever. Rather, the point of view has been the following:

Is the proposed experiment, if successfully carried out, likely to yield observations which will significantly aid the understanding of a fairly large body of phenomena and, secondly, does it appear to have the potential for significant discoveries in this field of physics? Although these are both matters on which you seldom get unanimous agreement in any diverse group, there has been a fairly strong measure of agreement on those two criteria in assessing individual experiments

The second test question has to do with technical feasibility. This must take into account the weight of the apparatus, the power drain required, the feasibility of storage and transmission of the observed data, and a great miscellany of other technical questions (such as mechanical ruggedness or proper operation over a large and uncertain range of temperature). In this area the best guidance has come from our experience in the conduct of experiments with so-called conventional rockets during the past decade. Such experience has provided the most tangible technical and scientific foundation for the discussion of satellite possibilities

Thirdly, we have considered the competence of the group or agency making each proposal, basing this consideration primarily on the previous record of achievement by the institution in the general area involved.

Finally, we have put a test question something of this sort: Is the satellite essential to this observation? Does it provide only a moderate increase in effectiveness or does it provide an effectiveness which is enormously beyond that of any other conceivable method?

During the period in which we have been in operation as a working group we have sifted and resifted proposals as they have come in; we have asked for and received expert opinion from all available sources; we have had extensive personal presentations by the proposers; and we have undertaken to keep our appraisals both up to date and realistic in accordance with the way in which projects have developed. As a result of this process we have established what we may call the hard-core program of on-board experiments. These experiments encompass the following scientific fields: Meteorology, geomagnetism, ionospheric physics, cosmic rays, meteorites, and astrophysics. All of these proposed experiments are intimately related to the very extensive programs of ground observations which are being conducted throughout the world during the International Geophysical Year period.

In encouraging projects and in our recommendations for funding, we have had in mind also the longer range national future in this field of scientific endeavor. A further factor has been the possibility of unanticipated difficulties in any one of the hard-core projects. Hence, we have also sponsored certain other developments which have not appeared to be immediately available, but which will contribute significantly to the development of a broad competence in this area.

EXPERIMENTS CHOSEN FOR SATELLITE FLIGHTS

The four projects which constitute our so-called hard-core program as of the present date are the following:

The first is the solar ultraviolet intensity experiment, which uses a basically simple system. As you will see, all of the experiments chosen are basically simple. (In fact, in a certain way of looking at it, they are almost ridiculously simple in terms of the preparation which is required to accomplish them.) The ultraviolet apparatus consists essentially of only a selective wavelength, ionization chamber covering roughly the range of about 1,100 to 1,400 angstroms This is a scheme which has been worked out and very successfully used by Dr. Friedman at the Naval Research Laboratory in a number of rocket flights during the past several years. Its special scientific interest is in monitoring the intensity of the Lyman Alpha line (1,215.7 angstroms) which is the sole significant source of energy from the sun in this wavelength region between 1,100 and 1,400 angstroms This radiation from the sun has a profound effect on the earth's upper atmosphere, by which it is completely absorbed, and exerts a controlling influence on long-range radio communications, and probably on climatic trends. The set of observations planned for the satellite will observe the intensity of this radiation, its fluctuations, and the correlation of these fluctuations with related terrestrial conditions. No such continuous observations over an extended period of time have ever been possible before In addition to this primary experiment in what we call package I, there is a group of so-called environmental experiments being prepared by the Naval Research Laboratory. These have to do partly with matters of engineering in determining for the first time the actual physical conditions of a satellite in flight—measurements of temperature at various points within the body, measurement of the hail of micrometeorites whose magnitude is quite unknown at the present time, and measurements of the erosion of a test patch on the surface of the satellite.

The second experiment is one having to do with the monitoring, measurement, and observation of cosmic ray intesity above the atmosphere over as large a geographical area as possible. My students and I are preparing this experiment at the University of Iowa. The instrumentation consists essentially of a single Geiger counter whose counting rate is electronically stored and read out on passage over the meridian fence of radio tracking stations. In this experiment it is vital that the data be stored for all positions around the orbit; in this way we hope to obtain, for the first time, a comprehensive geographical survey of the total primary cosmic ray intensity within the satellite orbit band width. It is therefore necessary not only to transmit data upon passage through the prime measurement meridian but to store the data and to know at what point in space it was observed. This requires a precision internal time standard so that when the data are read out we know at which point in space a given counting rate occurred. Interpretation of these data will reveal the geographical symmetry of intensity and the deviations of this symmetry from that of the geomagnetic field. These deviations of symmetry are a sensitive measure of the magnetic fields surrounding the earth.

In addition to this, we will have, for the first time, the ideal observatory for observing fluctuations of intensity of primary cosmic rays. As you know, there are a large number of IGY monitors distributed around the world. Some of them are in operation already. They are studying the fluctuations of neutron intensity in stations at low altitudes. The IGY period of high solar activity will be an especially fruitful one for the conduct of satellite flights. It is almost certain—I think that I can say it is certain—that successful satellite observations will provide an enormous advance in this scientific field. New theory, or extension of existing theory, is necessary for the interpretation of these experiments. This work is well advanced.

There will also be included in package II sensitive gages on the outer skin of the satellite for measuring erosion due to meteoric impacts. These gages are being prepared by Dr. E. Manring of the Air Force Cambridge Research Center, Geophysics Research Directorate.

The third experiment comprises extensive measurements of the earth's magnetic field at high altitudes and over an extended geographical region. The instrument to be used is called a proton precessional magnetometer. This is a new instrument developed by Drs. M. Packard and R. Varian of the Varian Associates, Inc., in Palo Alto, Calif. This device is one of the most important new developments in geophysical instrumentation during the postwar period. It is uniquely suited for satellite work. Comprehensive observations of the total scalar magnitude of the earth's magnetic field and especially of its fluctuations by these means should lead to an entirely new level of understanding of the nature of the earth's upper atmosphere and of its astronomical environment The Varian Associates is doing the development of the necessary instrumentation for this experiment. Dr. J. P. Heppner of the Naval Research Laboratory is coordinating the program and is responsible for the interpretation of the observations.

I may remark at this point that both the solar ultraviolet and cosmic ray experiments rest on very extensive and successful rocket experience. The magnetometer experiment is now being subjected to extensive tests by a group of us at the University of Iowa and by a separate group at the Naval Research Laboratory.

In addition to the magnetometer, package III will also carry a 30-inch inflatable sphere developed by the National Advisory Committee for Aeronautics. This sphere together with its container and separable inflation tank weighs less than 0.7 pounds. Ground observations of the NACA sphere will provide a very sensitive method of determining the density of the earth's atmosphere at altitudes far above those of any previous experiment. Because of its light weight, the inflatable sphere will be some 200 times as sensitive to air drag as will the parent satellite.

Since the initiation of the satellite program, we have been seeking a meteorological experiment which has the necessary technical simplicity and the fundamental and far-reaching potential for comprehensive study of the world's weather. Two such meteorological experiments are now being developed for package IV. The first was proposed by Dr H Wexler of the United States Weather Bureau. The development of the equipment is being done by Prof. V. E. Suomi of the University of Wisconsin.

The basic idea of this experiment is to measure the variations of the heat balance over the tropical belt of the earth. Dr. Suomi plans to mount four special temperature sensing elements at symmetrical points on rods extended from the satellite. These sensors will be titanium spheres, about the size of ping-pong balls, and will be coated with materials sensitive to radiation of various wavelengths. One ball will be as nearly black as possible throughout the range of wavelengths of interest which include the earth's infrared emission, the solar visible and the reflected solar visible Another will be relatively black in the visible range and relatively white in the infrared. The third will be relatively white in the visible range and black in the infrared. Dr. Suomi proposes to use as the fourth sensor a "wave trap," a device which is sensitive to direction; thus the effect of solar radiation in a directional beam can be distinguished from the diffuse radiation.

The other meterological experiment is being developed by W G Stroud of the Signal Corps Engineering Laboratories This experiment is an alternate for package IV and consists of a system for gathering synoptic data on the cloud cover of the earth within the latitude belt covered by the satellite. The essential elements are two photoelectric scanners whose lines of sight sweep across the lower atmosphere as the satellite spins on its axis. The detailed electronic system is rather intricate The overall result of these observations can best be described as resembling a sequence of pictures of vast cloud areas of meteorological interest, obtained in succession as the satellite moves along its orbit Cloud formations will be distinguishable. This type of information will be of great value for observation and study of hurricanes, typhoons, and broad weather trends. During the period that a satellite can observe and transmit this type of data vastly more accurate short-time weather forecasting will be possible.

ADDITIONAL EXPERIMENTS

In addition to the 4 primary projects, there are 6 other proposals for on-board experiments which have been recommended for funding The support of these other projects is provided in the sense I mentioned earlier, namely, as a general reservoir of possibilities—first of all, to insure against failure of any of the primary list; secondly, to provide for the possibility of further opportunities for flights during the IGY, and finally to contribute to the longer range national competence in this field of research.

The first of these six backup experiments is a proposal for detecting extreme ultraviolet solar radiation. This experiment was submitted by Dr. H. E. Hinteregger of the Air Force Cambridge Research Center. This same organization has sponsored another proposal by M. Dubin for relatively detailed meteoric measurements. This latter experiment was brought to an advanced stage of development before the investigators were asked to reorientate their project to a lightweight erosion experiment for inclusion in satellite package II.

Messrs. W. W. Berning and N. W. Arnold of the Army's Ballistics Research Laboratories have been working on methods for determining the electron density at the satellite altitude, a physical quantity of very great interest in ionospheric physics.

Measurement of accumulated meteoric erosion is possible by a technique developed by Dr. S. F. Singer of the University of Maryland. This technique utilizes a radioactive material on the surface of the satellite and measures the diminution of the counting rate as the material is eroded away by impact with meteoric dust.

Finally, there are two additional proposals for cosmic-ray measurements. One of these is proposed by Dr. G. Groetzinger of the Research Institute for Advanced Studies, Inc., and Dr. M. A. Pomerantz of the Bartol Research Foundation. Groetzinger and Pomerantz are developing equipment to determine the intensity of primary cosmic ray nuclei of heavy elements and the fluctuations of this intensity. The other cosmic ray experiment has been proposed by Prof. H. V. Neher of the California Institute of Technology. This experiment proposes to make cosmic-ray measurements similar to those of package II, except that an ionization chamber is to be used rather than a Geiger counter. A second part of this proposal comprises an experiment of Dr. W. A. Baum, also of the California Institute of Technology, for measuring the integrated light coming from different parts of the extra-terrestrial sky. The extragalactic part of this light is much weaker than the airglow, zodiacal light, and light from our own galaxy. Although measurements at the earth's surface are incapable of making the distinction between the extragalactic and other forms of extra-terrestrial light, there is a reasonable chance that this separation can be made by measurements from a satellite which is above the atmosphere for a substantial length of time. These measurements, if successful, should distinguish between various cosmological models of our physical universe.

I have, finally, two other comments to make. One is that for certain purposes an orbit of the presently planned inclination, namely about 35° to the geographic equator, is much too flat for many classes of experiments. A flat orbit does not enable us to penetrate the auroral zone. There is a rich field for satellite observations in the auroral zone, which we are unable to undertake at the present time.

LIFETIME OF EXPERIMENTS

Second, on the subject of the lifetime of the experiments, the general plan of experiments so far has been to use chemical batteries in the interests of proved reliability. If additional studies, and especially the first successful flight, enable us to conclude that the lifetime of the satellite itself will be as much as 6 months or more, then there will certainly be a very great demand for the inclusion of solar batteries as the basic source of energy in the apparatus. As you undoubtedly know, much work has already been carried on in this country in the development of solar batteries. The problem for us is to adapt these batteries to meet our very rigorous weight requirements; work on this problem has been going on, and I am optimistic that it will be successful soon. Success in this field would permit extension of observations in the "on-board" experiments probably limited only by the life of the satellite itself.

Mr. Thomas. You may proceed with your oral presentation, Doctor.

GENERAL REMARKS

Dr. Van Allen. Mr. Chairman and gentlemen, one of the axioms of science is that the understanding of nature rests on the shoulders of techniques. From my point of view as a working scientist, the satellite is merely a technique. It is a very marked advance and I think it is fair to say that it is a revolutionary advance in geophysical techniques.

What I intend to speak about is the nature of the satellite as a scientific technique. I am, personally, very sensitive to its value, as I can illustrate rather simply.

For about 11 years a number of my colleagues and I have been plugging away all over the face of the earth, extending almost to the ice islands in the northern latitudes along the Arctic Ocean, and to the Equator, studying the incidence of cosmic rays on the earth.

We are now preparing an experiment and if this works, we will supplant easily 11 years' work with 1 day's worth of satellite observations. In fact, 1 day's work of observations with the satellite will supplant not only our own work over an 11-year period, but the work of many other groups all over the world. I think this illustrates why it is that we consider this a powerful technique, far beyond anything of which we are capable at the present time.

UNIQUE SCIENTIFIC ADVANTAGES OF SATELLITES

There are several quite general aspects of the use of the satellite as an observing station. The best way to look at this is, first of all, we will have an observatory far above the atmosphere so that we are in a position to receive in raw condition all the radiations which are coming to the earth from outer space. The most important one of these, of course, is the sun's radiation, but even it is very much watered down and diluted by the time it reaches an observatory on the ground; we will be able, so to speak, to get a first look in the study of the sun's light by being well above the atmosphere.

This, we have been in the position of doing with rockets beginning in 1946, but we get a very brief and fleeting look in each flight. So, the essential advantage of a satellite in this field is not its altitude alone, where, of course, a certain minimum altitude is necessary—about 200 to 300 miles—but the essential value is that it stays up there for a long period of time so we can make systematic studies of long duration.

The other essential aspect of the satellite as a technique is that it looks down on the earth. In other words, it enjoys a vantage point which all of us, I think, would personally like to have if we were studying, for example, the course of a hurricane's path off the east coast. We can look down from 300 to 800 miles and see a far larger area of earth in one view than anyone has been able to do heretofore. We could look down and see the entire United States, for example, from a satellite if we were personally on board.

This is the sort of thing which we propose to do with instruments, and it is obvious that in the first satellite a small load of instrumentation is all we can expect to carry.

As Dr. Porter pointed out, a satellite which has no instrumentation on board is already a useful device. He has described how it is that we would be able to make improved determinations as to the shape of the earth and any irregularities in its features for, by way of example, geodetic purposes. It will be a kind of a surveyor's sighting at one point with respect to the earth's overall surface, thus establishing a map grid which transcends anything we have any prospect of by any other means.

Also, simply by following it from time to time, we will be able to determine from the rate at which it runs down and loses velocity what the air density is at these particular great altitudes. It has been pointed out that the density of these altitudes is very minute, but this density is important, and it will result in limiting the life of the satellites. This is the controlling element in its life as far as we understand at the present time.

We should also be able to study from observation from the ground alone the structure of the ionic elements of the atmosphere which are responsible for all long-range radio communications.

INTERNAL INSTRUMENTATION

Now, when one turns to the possibility, however, of putting active instruments on board (devices such as photoelectric cells and counters of various sorts), then we have a much richer field of study. As I think I can illustrate from the history of the development of this work, we have an enormously newer range of possibilities for observing various physical phenomena which have to do on the one hand with radiation arriving at the top of the atmosphere from the sun, and stars, and from outer space generally, and secondly, in looking downward at the earth and getting a comprehensive view of what is happening there.

WORKING GROUP ON INTERNAL INSTRUMENTATION

This committee, of which I have been scoutmaster, was established a bit over a year ago and it came about in the following way: We had a large symposium in January of 1956 to survey all of the scientific uses of earth satellites. This was a real professional undertaking. (I might say I do not subscribe to some 99 percent of what is written about this subject——exploration of space—as having any validity.)

The proceedings of this meeting we have now published in a book. This book was published in November of this past year, and is available for anyone who has $12. I am not selling these books, gentlemen, but partly as a result of this conference we have been snowed under with proposals for putting apparatus on board and, as you realize, there is no limit to the number of people who may observe the satellite. Anyone of us could go out in his own yard with a telescope and look at it and anyone with a radio receiver can listen to the signals from it, provided he does not live in Chicago.

Mr. Yates. Did you say Chicago?

Dr. Van Allen. Yes, sir. Iowa City is much better.

As a practical point, there is no limit to observations of the satellite, and everyone in the world can be looking up with no interference.

However, when one considers what may actually go on board, then the competition is very severe, indeed, and, if I may say, it is somewhat similar to trying to decide who should be the first man to go to the moon. This is not quite so stringent, but we have been buried by proposals for apparatus to be carried on board. Our job has been to sift these and select the ones which seem to have the most value. We have undertaken to do this based upon several criteria which I might briefly mention:

CRITERIA FOR EXPERIMENT SELECTION

The first and most important is the scientific importance of the proposed experiment. By this we mean, do the proposed observations, if they are successful, promise to illuminate a large body of phenomena on the earth and will they really clear things up and make sense out of a great many diverse phenomena?

Second, we must apply the criteria, naturally, of technical feasibility within our very limited baseload, which is only 21 pounds. How can a practical device be made which will incorporate all the diverse requirements mentioned? These requirements are, of course, that it be very light in weight, and that it have an extraordinary degree of reliability because it must be shot off away from any possibility for human tuning or touching. In other words, if it does not work, there is nothing you can do about it. It must stand a very severe ride on the rocket at very high vibrations and high acceleration. During its operation the temperatures will vary greatly. On the dark side of the earth it will be in the shade and will become very cool—some 80° below zero. When it is in the sunlight, it will tend to rise to about 150° to 200°. The apparatus must work in spite of these enormous temperature changes. There are a great variety of technical questions, of this sort. Furthermore—since no one is present to read meters and make measurements and jot down results in notebooks—the apparatus must be capable of producing all the observation work which must be transmitted by a very simple radio set to the ground.

Then, we have applied also the fairly obvious criteria of the competence of the group making the proposals and what their record has been in previous work of this character. Our best foundation for this has been work done with high-altitude rockets—originally the V-2 rocket, then with the Aerobee rocket, and other smaller rockets during the past 10 years. All of these observations, we have felt, should be technically related to the general IGY program and the ground observations being made throughout the world.

After all of this sifting—and we have had a meeting of this committee about once every month for the past year and a half—we have finally come to what we call our hard core of selected experiments. I shall not detail these, but let me give you the fields in which these experiments will be made:

FIELDS OF SATELLITE EXPERIMENTATION

The first has to do with the so-called ultraviolet radiation from the sun which is completely absorbed in the upper atmosphere above 50 miles, and which has a very profound influence on long-range radio communications, and on the general so-called heat balance in the upper atmosphere and in the formation of ozone.

The second class of experiments has to do with measurement of cosmic radiation. There is very-high-energy radiation which comes to us not only from the sun but mainly from other stars.

Third, we plan to measure the earth's magnetic field at high altitudes and over an extended geographical region.

Mr. THOMAS. Doctor, how in the world are you going to put an instrument in there where you are going to measure the intensity of the radiation from the stars and the sun and the moon and what have you? How are you going to be able to do that?

COSMIC RAY EQUIPMENT

Dr. VAN ALLEN. Well, I think the apparatus with which we intend to do that is here. When one speaks of hardware, here is a real piece of hard hardware.

Mr. THOMAS. How much does that weigh?

Dr. VAN ALLEN. This weighs about 10 pounds.

Mr. THOMAS. That is going to be 50 percent of your base load; is it not?

Dr. VAN ALLEN. Yes, sir; that is true.

Mr. THOMAS. Please explain it in a layman's way, so that everybody that reads this record will understand it.

Dr. VAN ALLEN. This is one which we are building at the University of Iowa. It has, first of all, the so-called Geiger counter in it, which is the same instrument which is used for uranium prospecting, and for all types of radioactive measurement. It is a simple device, and has been known for a good many years. It was invented in Germany in about 1920.

Approximately the lower half of the instrument is entirely filled with batteries for powering the apparatus. It must, of course, be self-powered at the start. We do expect in due time to use the so-called solar batteries which will draw their energy directly from sunlight. These will be mounted on the outer shell and the sun will generate the electricity that will be used for power later.

However, that is not developed enough to count on. We may be able to work that into the early satellites, but as of now we are using only chemical batteries.

Mr. THOMAS. What about radiation from the stars and the other galaxies?

Dr. VAN ALLEN. No matter where it is coming from, we catch the whole thing.

Mr. THOMAS. You are not able to separate it, are you?

Dr. VAN ALLEN. No, sir. If we can stay up there for several weeks, we have the radiation from the sun which falls on the earth in a different pattern from the rays of the universe, and we can distinguish the sun's output from the rest of the output.

Mr. THOMAS. Are you not up above that layer?

Dr. VAN ALLEN. Yes, sir. There is a characteristic of so-called impact pattern for radiation from the sun which we can point out.

Mr. THOMAS. You may proceed.

Dr. VAN ALLEN. The remainder of the apparatus consists of the electronics circuits. There is a little radio transmitter here which is connected to the antennas which I will show, in a moment. There is also a little radio receiver which can be commanded from the ground to read out information. Our scheme in this apparatus is to store up information in a magnetic tape recorded something similar to a household recorder, except very much smaller, and more specialized. Here is a photograph of this equipment. It is a very small magnetic tape recorder about the size of a postage stamp. It goes inside the satellite.

We also have a tuning fork which gives us an internal time standard, so we can tell at what moment a given event happened when it is played back. Most of our data will be played back over the picket fence to which Dr. Porter referred.

We will store up roughly 100 minutes of everything that happens and then, upon crossing this picket fence—the series of stations through which the orbit must pass, this will be triggered by a telemeter on the ground.

Mr. THOMAS. It is just fabulous.

Dr. VAN ALLEN. We will, in effect, tell it to speak up and tell us what happened all day around the world.

This instrumentation is incorporated in this second level. The other circuits are ordinary circuits which scale down counting rates and perform other detailed electronic functions inside.

Mr. YATES. Has all of this equipment been tested?

Dr. VAN ALLEN. It has never been flown.

Mr. YATES. Do you know it will work on the ground?

Dr. VAN ALLEN. Oh, yes; on the ground. We have flown a great deal of apparatus of this sort in rockets and we have a very large reservoir of practical experience with high-altitude rockets and we have a very severe set of tests.

This equipment is mounted on a shake table and shaken, in a way that no human being could stand for very long, to see if anything comes loose. It is also subjected to a very large temperature range. We have a new deep-freeze test which we put this apparatus through, and we have carried it all up and down this entire range of temperatures, in order to be sure that everything works. This [indicating] is a sample of the apparatus, Mr. Chairman.

OTHER "ON BOARD" EXPERIMENTS

There will be several other fields. One is in geomagnetism for measuring the magnetic field of the earth at very high altitudes, for judging what the influence of the sun is on the variation of the magnetic field on the earth. We are also planning to carry the National Advisory Committee on Aeronautics' inflatable sphere for sensitive drag measurements; and, finally, we have a set of meteorological experiments which have very great application.

METEOROLOGICAL EXPERIMENTS

One of these has to do with measuring the radiation balance of the earth and the balance between the amount of sunlight falling on the earth to the amount of sunlight being reflected from the earth and the amount of heat being radiated from the earth. Dr. Wexler is especially familiar with this equipment, and he may care to speak about it later.

However, this is one of the real fundamental meteorological experiments which people have been hoping we could do for many years.

A second experiment has to do with surveying the cloud covering of the earth over enormous areas. As I mentioned before, when you are up 500 miles, you can see the whole of the United States from that one point, and you can study the entire cloud cover of the whole United States, or any similar areas of the earth. By coming around every 1½ hours, we can see how things are changing, how hurricane patterns are moving on the face of the earth, and essentially perform the function of a snapshot taken at 1½-hour intervals.

In this way, one can plot the path and progress of storms, and so forth.

Mr. THOMAS. How will you record all of that information?

Dr. VAN ALLEN. This will be done by the instruments in the satellite. Of course, we have no means of physical recovery. We will not get anything physically back, and everything must be transmitted by the radio set.

Here [indicating] is the camera. Let me describe it for you. There will be, essentially, a little telescope looking out in this direction, and instead of looking through the telescope we will have a photoelectric cell—something like an exposure meter for a camera—and as this cell looks down on the earth it will switch across the earth like this [indicating] and will plot out the reflected light from the earth as it traces across. If one looks down at a snowbank, he will get a great deal of reflected light.

Mr. THOMAS. How will you transmit the picture?

Dr. VAN ALLEN. It has an electrical signal. It is like a light meter, and there will be an electrical signal which will be recorded on magnetic tape which will be played back again over the picket fence.

The details of this are very intricate, but the idea is to record the electrical light meter readings on tape and then quickly read through the whole tape as it goes over the command station and this will be read out. In one orbit around the earth there will be about 400 feet of tape played back, on which this data will be present.

Mr. YATES. How will you know the difference between a snowbank and a cloud in terms of that?

Dr. VAN ALLEN. Clouds will move and a snowbank will not.

Mr. YATES. But you will not know whether the cloud is moving or not.

Dr. VAN ALLEN. Yes; by successive orbits. They photograph the same bright area and if it is snow, it will stay fixed, but the cloud will move. It is all done by measuring the amount of light intensity.

Mr. YATES. That is the reason I asked the question.

Dr. VAN ALLEN. On the first satellite rotation, we will not know the difference, but it keeps tracking every time around.

Mr. YATES. Will the time come in your judgment within the foreseeable future when you will be able to recover satellites of this type?

Dr. VAN ALLEN. I think it likely will, but it is not so terribly important. We have such beautiful electronic equipment for transmission of data, and with solar batteries we hope in due time—I do not know just how soon this will be——

Mr. THOMAS. It is like reading yesterday's newspaper when you get it back; is it not?

Dr. VAN ALLEN. That is more or less right. However, with solar batteries we can have more permanent and sufficient power and continually transmit information all of this time. So, we will have effectively a permanent auxiliary recorder in due time. That is quite beyond our expectations for this period, however.

Mr. THOMAS. Will you please proceed, Doctor, with your discussion of this item which is the size of a postage stamp?

Dr. VAN ALLEN. I think there is no doubt in our minds that the general meteorological applications are of the utmost practical importance in the long run; and in the short run, during the next year or two, we hope to make a start on that. I think many of us are quite unable to visualize what this is going to develop into from a practical and human point of view, but there are certain things already fairly clear. I think the weather patrol function is a very clear possibility already.

OTHER PRACTICAL APPLICATIONS

The second one is as a communication or television relay for transmitting television programs from one hemisphere to another, say, over water and oceans, which is quite impossible right now by any other means.

I am sure there are a great many others. We all have, I think, the deep feeling that this is only a start. It certainly has very important possibilities in many areas.

Mr. YATES. Who helped you prepare that cosmic-ray equipment? Did your students assist you?

Dr. VAN ALLEN. That is correct; a number of graduate students and myself developed this.

Mr. YATES. How many in all were involved?

Dr. VAN ALLEN. We have actually six students working with me on this.

Mr. YATES. How long a period of time did it take?

Dr. VAN ALLEN. We started last June, actually.

Mr. JONAS. Have you consulted Robert Strom, this 10-year-old boy, about this?

Dr. VAN ALLEN. No, sir.

We are only one of the universities that is working on this subject. The University of Wisconsin has a very active project, too. However, we started about a year earlier, and we have been helping them a great deal. In fact, they are adopting a good part of our apparatus as their scheme.

Mr. JONAS. Are they working on an experiment for a satellite?

Dr. VAN ALLEN. Yes; but they are working on one of the meteorological experiments.

Mr. JONAS. A different one than you have covered?

Dr. VAN ALLEN. Yes, sir. Many of the interior features are in common. I think you all realize that we regard this as a fairly heroic undertaking on the whole, and the success of the whole thing is quite uncertain.

Mr. THOMAS. That is an understatement, but go ahead with your presentation.

MODELS OF SATELLITES

Dr. VAN ALLEN. We do not even, of course, know that we will even get one successful flight during IGY. However, since it has already been testified to earlier, I might mention that according to a report which appeared in the New York Times there has been one flight already made from Patrick on September 20, 1956, which did reach 680 miles altitude, and flew about 3,300 miles down toward Africa. This was a public report.

- Let me show another model or two.

The first satellite is planned to be, grossly speaking, a sphere; and this is an exhibit model and not a real one. It is designed to show the general arrangement. The colored cylinder would be, for example, our apparatus which we speak of as the inner body, and the outer body is the shell which will actually be of magnesium. This [indicating] is a real one. This is the real shell which probably will not be flown, but this does represent the real shell. This one [indicating] shows the interior arrangement. Now, in addition to the inner part of the structure there will be various devices in some cases mounted on the skin looking out toward the sun. Then there are 4 radio antennas, of which this is 1. During the launching process, these are folded up over the head of the satellite, and then these arms fall out so that the actual overall appearance of that in flight will resemble a ball with four rods projecting from it.

These are the radio antennas which look like spokes from a wheel.

ADVANTAGES OF SPHERICAL SHAPE

The scientific apparatus is about one-half of the total load. The reason for using the sphere, first of all, is for uniform visibility and optical visibility. As the sun shines on it, of course, sunlight will be reflected, and an observer on the ground may see it by reflected sunlight. A sphere has the same appearance, no matter how it rotates, and so it has a uniformity for all observers.

The second reason for using a sphere is that regardless of how it turns or rotates it always produces the same form in countering the air and has the same drag, so that one may determine with accuracy the air density.

Gentlemen, I believe that that completes my presentation.

Mr. Thomas. That is a wonderful statement.

Mr. Boland. Will the satellite be descending all the time as it revolves around the earth?

Dr. Van Allen. If it is high enough, and if the air drag is small enough, then it will have essentially a permanent orbit.

The way I visualize this, I think most easily, is to think of a bent wire encircling a sphere and then with a little ball running around the wire, and as the earth turns within this wire, it paints different stripes on the earth.

Mr. Yates. Mr. Chairman, I have one additional question before we recess for lunch.

Mr. Thomas. You may proceed.

CSAGI AGREEMENTS ON SATELLITES

Mr. Yates. Earlier, it was pointed out that the Russians are also launching satellites.

Dr. Van Allen. Yes, sir.

Mr. Yates. I received the impression that there will be an effort to have a uniformity of satellites so that you can correlate your information.

Will the Russians be using a core such as you have shown us or will they develop their own core?

Dr. VAN ALLEN. I was one of the United States delegates to Barcelona last September on this subject. In fact, I was chairman of the group discussing cooperative arrangements, and the agreement was to use the same radio frequency so we might receive their telemetering signals and tracking signals and they might receive ours with their stations.

However, there was no agreement whatever about what goes inside, nor on the physical configuration of what goes in it.

Mr. YATES. Would it not have to be almost similar in order to have a scientifically acceptable response?

Dr. VAN ALLEN. Not exactly. For example, we can easily visualize making this in the form of a cylinder, and that is the most efficient design so far as our purposes are concerned. The sphere, so far as the internal apparatus is concerned, puts a restriction on weight, but its importance is for external observation.

Furthermore, there is no agreement as to the nature of the orbit, and we understand that the Russian orbit will likely be more nearly pole to pole.

Mr. THOMAS. Thank you, Doctor.

Gentlemen, let us recess at this time for lunch, and reconvene at 1 o'clock this afternoon.

AFTERNOON SESSION

Mr. THOMAS. The committee will please come to order.

Now, Dr. Kaplan, whom do you desire to call on next?

Dr. KAPLAN. The next speaker will be Dr. Roger R. Revelle, of the United States National Committee for the International Geophysical Year Technical Panel on Oceanography, National Academy of Sciences.

Mr. THOMAS. Doctor, we are delighted to have you with us. It has been a long time since you have been with us.

Dr. REVELLE. Yes. I have a prepared statement that I would like to submit for the record at this point

STATEMENT OF DR. ROGER R. REVELLE ON OCEANOGRAPHY

Mr. THOMAS. It will be inserted in the record at this point.

(The statement referred to is as follows:)

STATEMENT OF DR. ROGER R. REVELLE, USNC–IGY TECHNICAL PANEL ON OCEANOGRAPHY, NATIONAL ACADEMY OF SCIENCE

GENERAL REMARKS

It was my privilege to appear before this committee in 1956 and tell you of some of the plans of the United States National Committee for Research in Oceanography. I should like now to tell you about the progress in this program, but directing my remarks to the broader applications of this research as they relate to studies of the earth's heat and water balance. This inevitably involves one in discussions about meteorology and glaciology and their interrelationship with oceanography. It is a fascinating subject to me, and I believe you will find it most interesting.

HEAT BALANCE

The earth receives almost all of its external energy from the sun, in the form of electromagnetic radiations ranging from the long-wave heat radiation to very short-wave ultraviolet and X-radiation. Some of this energy, particularly the short ultraviolet and X-radiation, is completely absorbed by the molecules in the atmosphere. Some of the heat radiation is absorbed by carbon dioxide and water vapor in the atmosphere. Most of the visible radiation reaches the ground but some of the visible light is reflected back to the outer atmosphere. The light that reaches the ground contributes to the energy of the atmosphere in the following way: Since the ground, especially vegetation and soil, is not a very good reflector, much of the incident visible light is absorbed, heating up the ground. Any substance which has a temperature greater than its surroundings will radiate energy to those surroundings. Thus, in the case I have just described, the ground, during the daylight hours, will radiate energy in the form of long-wave heat radiation back to the atmosphere where some of it is absorbed by water vapor and carbon dioxide.

Some of the energy from the sun is stored by heating of the air and ground. Another important mechanism is the great storage of heat by water vapor. As you know, it takes energy to make water boil. It takes the same energy to make water evaporate or vaporize. In fact, it takes about a half million calories to evaporate 1 quart of water, and this energy is available when the water vapor condenses, as it does during a rainstorm or when clouds are formed.

As you can see, the relationship of the atmosphere and the earth to the energy we receive from the sun is a complex one. Therefore, we must consider the atmosphere as a heat engine where the heat energy from the sun is turned into mechanical motion: the convection of the atmosphere or winds. This heat engine is further complicated by the fact that the energy received from the sun varies from a maximum near the Equator to a minimum near the poles. As we know that the temperature of the earth and atmosphere is not changing appreciably from one year to the next, we assume that the earth-atmosphere system is essentially in equilibrium; as much energy is ultimately radiated back to space daily as was received from the sun. In the equatorial regions more energy is received than lost; in the polar regions the reverse is true. The heat engine of the atmosphere provides a mechanism for accomplishing the balance necessary to maintain our thermal equilibrium; winds and circulation move warm air northward to the polar regions.

The oceans also play an important role in the heat budget of the earth. Ocean water is warmed by sunlight in the Tropics and cooled in the polar regions by melting ice and snow and by the radiation of energy back into space. Cold water in the polar regions sinks and flows along the bottom of the great oceanic basins toward the Equator where it displaces warmer water. Thus the ocean has a general circulation with similarities to that in the atmosphere. There are vital differences, however. The surface currents in the ocean are related to the wind systems of the atmosphere in that wind at the surface can drive the water into large current systems such as the Gulf Stream, a current which has a profound effect on the climate of the countries bordering on the stream.

While the winds in the atmosphere can blow almost at will, hindered or deflated here and there by mountain ranges and deflected by the earth's rotation, the ocean currents are far more restricted. The circulation is limited to the oceanic basins, or flow between basins through straits, and is further influenced by the topography of the ocean floor where great mountain chains contain or deflect the flow of water.

SCIENTIFIC PROGRAM TO STUDY HEAT BALANCE

Our study of the heat balance is being attacked on may fronts. First, we are studying directly the circulation of the atmosphere and ocean. The atmospheric circulation is being studied in great detail; the United States Weather Bureau is concentrating on special observations along the 70th to 80th west meridians; Five IGY stations to fill in gaps in this chain are now being installed. Instruments which measure the solar radiation and the heat flow are being provided for many of the existing United States Weather Bureau meteorological stations, as well as instruments to measure the reflectivity of the ground and clouds. Second, oceanographers have met several times in the past year to plan joint ship expeditions where the circulation of the ocean will be studied by measuring surface and deep-water currents. At present, several research vessels are oper-

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ating in the South Atlantic to take advantage of the more moderate weather conditions which prevail at this time of year. These ships are collecting information which will be useful in planning next year's cruises. The *Vema* of the Lamont Geological Observatory has completed a considerable amount of work in the Southwestern Atlantic operating with Argentine and Brazilian ships. Many thousands of miles of depth soundings and magnetic measurements have been made; over 20 hydrographic stattions have been occupied and cores of bottom sediments have been taken at these stations. The *Vema*, after completing work in the western part of the South Atlantic, is now making a traverse across the South Atlantic from the tip of South America to Capetown.

Meanwhile the *Crawford*, operated by the Woods Hole Oceanographic Institution, is in the midst of a 4-month cruise, also in the South Atlantic. Four out of seven planned deep water hydrographic stations have been occupied where water samples are being collected over depths from the surface to near the bottom for later chemical analysis at the home laboratory. The *Atlantis*, also of Woods Hole, has just completed a cruise to the Gulf Stream where she operated with the *Discovery*, a vessel of the National Oceanographic Institute, Great Britain. The two ships were testing a scheme for directly observing deep current flow with the use of a neutrally buoyant float. This float sinks to a previously determined level and then moves with the current at that level. The ships track the movement of the float and, with accurate navigation techniques, are able to plot the positions on a chart, thus mapping the currents During the IGY these ships will be joined by the research vessel *Jakkula*, of the Agricultural and Mechanical College of Texas.

In the Pacific, the major ship operations will begin this summer when ships of Scripps Institution of Oceanography and the University of Washington will cooperate with ships of Canada, the Pacific Oceanic Fisheries, investigators of the United States Fish and Wildlife Service, and others. Scripps is planning a two-ship expedition to the South Pacific, ranging from the longitude of Tahiti and south past Pitcairn's Island nearly to the tip of South America. This cruise will take about 4 months, from November 1957 to early March 1958.

Two detailed surveys of currents near the surface will be undertaken with many ships in 1958 These vessels will operate near the Equator in the latitude range 95° west to about 180°. The *Brown Bear* of the University of Washington will be operating in the North Pacific; one interesting part of their plan is to measure water movement through some of the passages in the Aleutian Islands Archipelago

Ships of Navy Task Force 43, operating in the waters of the Antarctic, have accomplished much new oceanographic work in these regions It is expected that their participation will continue with the coming resupply expeditions

Besides studying atmospheric and current circulations, other parameters will be measured such as the nature of the incoming radiations, the radiation balance at the surface in many types of terrains and the reflectance of the surfaces; at one of the ice-floe stations in the Arctic Ocean the program includes studies of the heat exchange between the sea, the ice, and the lower atmosphere. Two of the chemical constituents of the atmosphere that play a vital role in the heat balance will receive particular attention. Last year when I talked with you about some of the problems in understanding the heat budget of the earth, I described how man is releasing vast quantities of carbon dioxide into the atmosphere, and suggested that if this concentration increases very much it may lead to a general warming of the climate. I can report to you now that we have made considerable progress in developing instrumentation and plans for studying the average atmospheric content of carbon dioxide and some of the factors affecting the equilibrium of carbon dioxide between the atmosphere and the ocean. Since June of 1956 we have been testing and modifying at Scripps Institution an instrument which measures the concentration of carbon dioxide in air The instrument operates on a principle directly related to our main purpose in studying carbon dioxide: The absorption of long-wave heat radiation. With this infrared analyzer, as it is called, we can measure concentrations as low as one part of carbon dioxide to one million parts of air. We are going to install this instrument on several ships to measure concentrations far away from land masses.

One of these instruments will also be used in research aircraft operated by Woods Hole for studies of the vertical and horizontal distribution. Another instrument will be placed at a relatively unpolluted location at high altitude, perhaps Mauna Loa, T. H, or White Mountain, Calif., where we will secure a continuous record of carbon-dioxide content for several seasons. Finally, an instrument will be kept at Scripps Institution for calibration purposes and to analyze the samples that will be collected throughout the United States network.

Ozone is the other principal element in the atmosphere important to our studies. Ozone is formed when oxygen absorbs ultraviolet light high in the atmosphere. It is suspected that during solar disturbances the quantity of ultraviolet radiation which reaches the earth is greatly increased, causing more energy to be stored in the ozone layer. This energy then feeds downward to the lower layers of the atmosphere which regulates most of our terrestrial weather. Dr. Victor Regener, of the University of New Mexico, has developed an ingenious device which measures directly the amount of ozone present at the surface of the earth after passage of the ultraviolet radiation through the primary absorbing layers. Dr. Regener is experimenting in reducing the size and weight of this equipment to allow it to be flown in large balloons so that a vertical study of the ozone distribution can be made.

As a final remark concerning the heat-balance studies I should like to mention that we are also making measurements of heat flow from the interior of the earth through the thin crust underlying the oceans into the bottom of the oceans. The source of this internal heat energy of the earth is probably radioactive disintegration of the various heavy metals in the interior of the earth. It is far from easy to make these measurements in the ocean because of difficulty of handling delicate equipment at the end of a 10,000- to 20,000-foot-long cable. Many of the ships operating in the deep waters, however, will attempt these measurements.

WATER BUDGET

As you know, the oceans cover about 75 percent of the earth's surface. Another large repository of water is ice—mainly in the ice sheets of Greenland and the Antarctic. Since the overall volume of ice melts or accumulates slowly, and the general circulation in the oceans is slow, it is possible to read some of the history of the climate of the earth by examining ice deposits, deep ocean currents, and the sediments in the oceans which have been deposited over the past millions of years.

A 1,000-foot deep hole was drilled last year in the ice cap of Greenland; examination of the 4-inch core from this hole revealed some interesting information. The material at a depth of 1,000 feet is estimated to have been deposited in the 15th century; it is interesting to note that material from this core has been found which is thought to be volcanic ash from the Katman explosion in 1912. Strata down to depths of about 450 feet have also been examined and give some idea of the fluctuations in ice accumulations over the past several centuries. Similar holes will be bored in the Antarctic ice later this year and in following seasons.

It has been estimated that if all the ice were to melt, sea level would rise by several tens of feet. We may have to revise that figure upward, pending the outcome of studies in the Antarctic. We do know, however, that in times past sea level has been vastly different from present levels.

Tide gages are a convenient way to measure the average variations in monthly and seasonal sea levels; the United States Coast and Geodetic Survey maintains a considerable network of tide-measuring stations but new stations are now being installed at about 70 island and coastal locations in the Atlantic and Pacific to increase the coverage in the oceanic regions.

An important new measurement is being added to make sure that we have a reliable measure of sea level. I refer to what we call "steric observations." These observations are the recording of temperature values in the vicinity of the tide-gage stations down to depths of about 1,000 feet, plus the collection of water samples for chemical analysis; with this information it is possible to derive measurements of water density, which will permit a clearer interpretation of the differences of ocean levels which exist between the Atlantic and Pacific.

Changes in sea level have another interesting effect: the length of the day appears to be changing somewhat over a period of years. Some of this change in the rotation of the earth, noted from astronomical observations ranging back to the time of the Egyptians, may be accounted for by taking into consideration changes in sea level.

ARCTIC OCEANOGRAPHY

As a final statement on our progress toward IGY operations I should like to tell you something of the work that is now being started in the frozen Arctic

Ocean. One of the most dramatic of all oceanographic expeditions took place in 1893–96, when Fridtjof Nansen froze his ship, the *Fram*, into the ice of the Arctic Ocean and drifted across the polar basin. Nansel measured the drift of the pack ice and thereby the surface currents of the Arctic Ocean. Taking advantage of the aircraft to set scientists down on the frozen ice, we are now establishing two stations: one on Fletcher's Ice Island north of Canada and the other on the icepack itself. Oceanographers will be able to study leisurely the drift of the ice and the details of the sea and bottom underneath the station. In a cooperative effort between meteorologists, glaciologists, and oceanographers, the thermal relation of the sea, the ice, and the atmosphere will be also studied in detail. Also, and for the first time, we are getting some idea of the tides and changing sea level in the Arctic Ocean from ingenious new tide gages at Point Barrow and Barter Island.

Dr. Revelle. I am embarrassed to appear in this distinguished company of physicists because I am just a sailor. I believe that I told you the last time, Mr. Chairman, I think the best definition of an oceanographer is a sailor that uses big words.

In general, oceanographers are people who do their science at sea from ships, and during this International Geophysical Year program, as we told you before, there will be a great many ships at sea throughout the entire period.

IGY TIDE MEASURING STATIONS

But we are also marooning a lot of sailors on desert islands. That is what I want particularly to talk about right now. This has been quite a problem in terms of personnel.

In some cases, for example, in the Galapagos Islands along the coast of Ecuador, we have had a special advantage because that is where Charles Darwin made some of his great discoveries about the evolution of the species. His great book, the Origin of the Species, was published 100 years ago this year. The result is that all the biologists are fascinated with the idea of getting back to Galapagos Islands. So we are going to be able to man two stations in the Galapogos Islands with biologists whom we have taught to do geophysics. As in the case of many other of the islands in the Pacific, they are being done in cooperation with, and in fact as a part of, the programs of other countries. As an example, the Galapagos Islands belong to Ecuador and they are furnishing a ship and some of the observers and workers and we will furnish the scientific guidance.

Another example is Juan Fernandez Island, which was Robinson Crusoe's island. That is a real desert island and is being manned by the Chileans, but again we are helping them with getting the equipment installed. In fact, we are providing some of the equipment.

Easter Island is another example which also belongs to Chile. This is a place where those stone tikis come from. It is a famous place of a lost civilization, certainly of an old Polynesian civilization. The Chileans are manning that with American guidance and assistance.

Here [indicating 15° to 20° S., 150° to 155° W.] in this area in the South Pacific we have the famous island of Tahiti, which people have been writing about for 200 years since Captain Cook's voyages, and this [indicating 15° to 20° S., 135° to 145° W.] is a complex of islands belonging to the French, the so-called low islands or dangerous islands.

Mr. THOMAS. Where are you in the South Pacific.

Dr. REVELLE. Here [indicating, 15° S., 150° W.]. Here are the Society Islands and others. This [indicating] is the eastern part of what the French call French Oceania, 25° to 30° S., 130° to 140° W. The French are manning several stations there and we are sending down some of our people to work with them, particularly in outlying islands such as the Tubai Islands, 25° S., 140° to 150° W., over here where we have to charter a South Sea island trade schooner to get around.

Mr. THOMAS. That is four stations.

Dr. REVELLE. We have altogether in the Pacific, insofar as America is concerned, in cooperation with other countries, some 40 islands.

Mr. THOMAS. They are all not located in that same general area?

Dr. REVELLE. No, sir. To cite other examples, there is Fiji, which is a New Zealand possession. There are several islands down here in the Tasmanian Sea. With regard to this complex of islands [indicating] in the Western Pacific, some are British and some are American. We have observers stationed on a good many. There is Marcus Island off the coast of Japan, where we are working with the Japanese to man several kinds of observatories there.

Mr. THOMAS. Do you do any business in the Atlantic?

Dr. REVELLE. We have exactly the same thing in the Atlantic. There are a few islands going down the spine of the Atlantic—the Azores, the Canaries, the Ascension Islands and others. There are the Barbadoes and Bermudas, all of which will be island observatories, as we call them, really to study the ocean and the air over the ocean.

The responsibility for these Atlantic islands is being taken by the Lamont Observatory of Columbia, and in the Pacific by the University of Washington, the Fish and Wildlife Service of the Federal Government, and the Scripps Institution.

One of the most difficult, and I think also one of the most exciting of these islands will be the Line Islands here in the central Pacific, which are just about in the center and go right across the Equator. Jarvis, particularly, is a complete desert. It is just a rock about 2 miles long and about 15 feet high and no trees on it at all. It is just a bare whitish mass.

Mr. THOMAS. No vegetation at all?

Dr. REVELLE. The highest vegetation is just about 2 feet high. There is no water at all. This is in a way an American possession. The Coast Guard goes down there once a year and shows the flag and goes away again. We are actually going to have people all the time on Jarvis Island throughout the entire International Geophysical Year, and on Palmyra, too, which is also a deserted island. It now has some Air Force people on it. Ordinarily no one is there.

Here at Christmas Island the British maintain a cable station. We have been working with them. They have about 70 people there.

In order to do this job we got a remarkable man, named Martin Vitousek, to take the responsibility; he has a doctor of philosophy degree from Stanford in mathematics and used to teach at the University of Hawaii. He decided he would rather be a South Sea Island trader than a university professor; so he bought himself a 70-foot schooner and has spent the last 5 or 6 years cruising the South Pacific, earning a living by carrying copra and taking people around who want to make movies, carrying people from island to island. He is fascinated with the project and has dreamed up a half-dozen scientific things to do.

Mr. THOMAS. What age man is he?

Dr. REVELLE. He is about 30 years old.

I think that the interesting thing there is a romantic problem of getting people to live on these South Sea Islands. Some of them have a few natives and some of them have none at all. These people will take a year or a year and a half out of their lives. This is exactly the same problem, even more rigorous and perhaps more dramatically, faced in the Arctic and Antarctic. One of our chaps will fly out once a week from Point Barrow to the polar ice in a bush plane and land on the ice to take observations, basing at Point Barrow. This is a difficult but somewhat different operation from that encountered by the people living on the ice floes.

Mr. THOMAS. Do you cover from north to south all the way?

Dr. REVELLE. Yes. We are really concerned here with establishing a network of observing stations over the entire ocean.

Mr. THOMAS. You are going to talk about something we know something about, when we are going to get rain, and so forth.

STUDIES OF EARTH'S HEAT BALANCE

Dr. REVELLE. I think the best way to introduce this subject is to point out to you gentlemen something which is not often thought of, and that is that the earth itself is a space ship. We were talking this morning about the beginning of space travel, about the beginning of man's leaving the earth and going to the stars, but, in fact, we have lived here on this space ship of our earth for a good many hundred thousand years, and we human beings are specifically adapted to it. We are built to take advantage of the earth. Our whole physiology and psychology really depend upon the characteristics of the earth. This is something, of course, that we do not know about, or did not know about when we human beings were developing. Until recently people did not even know the earth was round.

Mr. THOMAS. You are talking like an environmentalist. I thought that you believed in heredity.

Dr. REVELLE. We are certainly shaped by the earth on which we live. A simple example is the fact that we breathe oxygen. This planet of ours is the only planet in the solar system that we know of that has free oxygen on it.

Mr. THOMAS. That will not be free long. The Federal Government will tax it.

Dr. REVELLE. That has very definitely determined our physiology, the fact that there is oxygen and the fact that there is a great deal of water on the earth. Again, this is the only planet that has large bodies of liquid water on it. The fact that water has such a great capacity for storing heat means that it can absorb a great deal of radiation and not change its temperature very much.

Mr. THOMAS. How do we know that these other planets do not have any nice war springs and cold springs and a few little creeks?

Dr. REVELLE. At least the astronomers have never been able to find the evidence. I personally would like to go to Mars and find out for myself. I think the evidence is fairly good that there is a very small amount of water there.

Mr. THOMAS. Has it been proven there is not?

Dr. REVELLE. One simple piece of evidence is this: On Mars there is a kind of frost cover around the North Pole, but the atmosphere on Mars is so dry that this ice cap, if you will, actually disappears every summer and moves through this very dry air and settles again on the South Pole of Mars. So the ice cap on Mars is quite different from ours. It actually migrates from pole to pole during the Martian year, and this shows that the atmosphere at Mars is dry as dust, drier than it has recently been in Texas.

Mr. THOMAS. You have announced a very fundamental principle of weather when you said that these vast bodies of water are a reservoir for tremendous heat loads.

Dr. REVELLE. That is correct, sir, and you are obviously going to push me as to what we are going to study. I will come to that right now.

What we are concerned about in the meteorological, the oceanographic, and the glaciological programs is what happens on the earth because of the radiation coming from the sun.

In other parts of the IGY program the nature of this radiation, what actually comes into the earth, will be studied. The next question is, What will the earth do with it? It makes climate, the ocean currents and the ocean circulation, which provide a fertile area for the fisheries.

HISTORY OF CLIMATIC CHANGES

Now, the interesting and curious question is this: The amount of energy coming in from the sun each year can be fairly accurately calculated, but nobody knows how much goes back. In principle, if nothing was changing on the earth, just as much heat would go away from the earth as comes in. In fact, this is generally assumed to be the case. We know that in many times in the past it has not been the case. For example, we know that about 10,000 years ago the earth was a lot colder than it is now and that a lot of heat was locked up in the ice.

Quite abruptly, about 10,000 years ago, the earth apparently heated up quite a bit. A great portion of the icecaps melted, perhaps in a rather short space of time, and a few thousand years later the climate was actually considerably warmer than it is today. This happened several times in the relatively recent past from the standpoint of the geologists; that is, within the last few hundred thousand years.

There were at least four occasions when ice covered a large part of the Northern Hemisphere. There were great icecaps coming down well below Chicago and over most of northern Europe and over a good part of Asia.

This is perhaps the most dramatic example we have of the fact that the climate of the earth changes very markedly from time to time, and a long-range question which is often talked about is this: Will the ice come down again? Will we enter into a new dark age of ice? I do not think this is a very practical question for people living in this generation, but the shorter time climatic changes, it seems to me, are of great importance.

Let me give you an example of my own experience. In California we are very much concerned about our water supply. We do not have enough water. Southern California is just barely livable at best. Our population is growing so fast that we are trying to get water from the northern part of the State and perhaps farther north, and of course from the Mountain States where the Colorado River originates.

Now, the people in the northern part of the State and those other States are very much concerned about this; they are afraid that perhaps at some time in the future they will not have enough water. They have too much now, but they may end up not having enough. This could very easily happen if we had a rather slight climatic change over the next 50 to 100 years.

FORECASTING CLIMATE

President Eisenhower recently said, and I quite agree, that water is perhaps becoming the most important resource of the United States. One of the fundamental parts of this water supply problem is the possibility of the water supply of the United States becoming slightly greater or slightly less as a result of climatic changes. The meteorologists have gradually developed during the past 50 to 100 years a fairly good ability to forecast weather. Dr. Wexler can tell you, if he looks at a map, about 80 percent of the time what the weather is going to be tomorrow—whether we are going to have a rainstorm or a thunderstorm, or, early in the season, a snowstorm. No meteorologist has the least idea how to forecast climate.

If you ask a meteorologist what the average rainfall or temperature will be 10 years from now, let alone a hundred years from now, he would not be able to tell you in the slightest degree. Yet the forecasting of climate is in fact, I think, a more important job—more important to the future of our own species than the forecasting of weather.

The problem is somehow to develop a means of forecasting.

Mr. THOMAS. You used the word "climate" there for the long range, and "weather" for the day-to-day basis?

Dr. REVELLE. That is right.

EFFECTS OF FOSSIL FUELS ON CLIMATE

The last time that I was here I talked about the responsibility of climatic changes due to the changing carbon dioxide content of the atmosphere and you will remember that I mentioned the fact that during the last 100 years there apparently has been a slight increase in the carbon dioxide because of the burning of coal and oil and natural gas.

If we look at the probable amounts of these substances that will be burned in the future, it is fairly easy to predict that the carbon dioxide content of the atmosphere could easily increase by about 20 percent. This might, in fact, make a considerable change in the climate. It would mean that the lines of equal temperature on the earth would move north and the lines of equal rainfall would move north and that southern California and a good part of Texas, instead of being just barely livable as they are now, would become real deserts.

Mr. THOMAS. Why now?

Dr. REVELLE. Because the precipitation would be considerably less than now.

The problem here is that the carbon dioxide seems to absorb—we think it does absorb—the so-called infrared radiation, the radiation going back into space, away from the earth. In order to get as much heat out as comes in, you have to increase the temperature of the earth by a relatively small amount, about 1½ degrees.

There is what the electronics people would call feedback.

Mr. YATES. Is this more likely to occur in an industrial area?

Dr. REVELLE. This will occur on a worldwide basis in order to be really effective.

Mr. YATES. It all has to fill in?

Dr. REVELLE. That is right.

The point here is, as far as I am concerned, nobody really knows whether this is so or not.

Mr. THOMAS. I have flown out of Germany into Spain several times and I have always had some man point out to me when you get over country that looks like Arizona and New Mexico. Two or three hundred years ago this was all in heavy forest, the land was covered with green vegetation. It had a nice rainfall. Now, in the last 50 or 100 years the weather pattern has changed; is that true?

Dr. REVELLE. I do not know about Spain, but I am sure it is true of the Middle East. I am sure it is true of the so-called cradle of our civilization.

Mr. THOMAS. Why?

Dr. REVELLE. That is true of the whole area of Egypt, Mesopotamia, Greece, and Asia Minor. There has been a progressive drying up of great areas of the world. This has made, as you gentlemen know very well, historic happenings. It has really led both to the rise and fall and complete decay of many civilizations.

Mr. THOMAS. From a weather point of view how did that happen?

Dr. REVELLE. No one knows. We do not have any idea. That is just exactly the problem that we are trying to attack.

Mr. THOMAS. There is no theory behind it, or anything?

Dr. REVELLE. There are many theories. It is awfully hard to make a choice between them or to know how to test them. This carbon dioxide thing that I was talking about is in fact a way to test some of these theories.

Mr. THOMAS. You did not spell out very clearly your carbon dioxide theory. Spell it out again. Carbon dioxide absorbs the infrared rays that are bouncing back from the earth, and when they are absorbed, that absorbs the heat and therefore what?

Dr. REVELLE. It raises the temperature. It is like a greenhouse. When you go into a greenhouse the temperature is higher than it is outside. The reason is because the glass lets the light in, the visible light. It will not let the heat out, so the temperature in the greenhouse has to rise until you have a balance, so that the heat escaping is equal to the energy coming in in the form of light. This may happen in the atmosphere; in fact, we know it does with water vapor. We know the atmosphere around the earth makes the earth a gigantic greenhouse and this is why: instead of having about minus 100° on the cold side and plus 200° on the warm side, such as you will have on the satellite, we have a fairly equitable temperature between day and night. The earth's atmosphere acts like an insulating blanket.

Mr. YATES. I think that there is a step missing in your explanation that is not quite clear to me even if it is to Mr. Thomas, and that is, what is the end result of this infrared radiation? Is there a lesser moisture content?

Dr. REVELLE. The pattern of the circulation would be changed. The problem is not that we do not have plenty of evaporation over the ocean.

Mr. THOMAS. What does the heat have to do with it?

Dr REVELLE. People talk about making fresh water out of sea water. God does that for them far better than any man ever could. He evaporates three feet of water on every square foot of the ocean every year. The problem is that the distribution system is bad. The water coming from the ocean moves over the land but mostly over the northern and southern parts of the land, and this circulation pattern, or transport of water vapor from the sea to the land and the precipitation on the land, apparently shifts with the temperature; at least we think it does, and there seems to be a broad belt called the horse latitudes between the equitorial regions and the belt of cyclonic storms where the precipitation is minimal. If you increase the temperature of the earth, the north latitude belt, which covers most of the western part of the United States and the Southwest, would move to the north. Does this make any sense?

Mr. THOMAS. Yes.

Dr. REVELLE. Only God knows whether what I am saying is true or not. What I am driving at is that this business of the carbon dioxide production is in fact a way of studying climatic changes.

OCEAN CURRENTS

Mr. THOMAS. What have you been studying near the bottom of the ocean? What do you find there, and what effect does that have?

Dr. REVELLE. That is another part of this same problem. One of the problems that we have in forecasting is to find something in which there is a lag so you can see what is happening in one part of the system and tell how that is going to affect another part of the system. A place where there may be a lag is in the deep water of the ocean. The ocean absorbs a great deal of the energy of the sun.

Dr. Wexler recently made a very simple calculation. He has shown, if there were 1 percent less heat escaping than comes in during the year, that the temperature of the deep water of the ocean would have to rise only one-hundredth of a degree Fahrenheit or less to account for this. It is a change in the temperature of the deep water that you could not even measure. If this happens for a hundred years, you would get a change of about 1°. This is something that can be measured. This may be an actual lag in this kind of a heat engine—the steam engine of the ocean and the atmosphere—which we can measure and which in turn will give us a means of forecasting changes in climate. So one of the important problems that the oceanographers are going to attack during the International Geophysical Year—and they are attacking it on a very large scale with some 70 ships from over 30 countries—is just this problem of deepwater circulation of the ocean.

How fast does deep water get up to the surface? How is its temperature changed? What is the machinery by which the ocean part of the steam-engine operation goes on and how does it interlock, what sort of a connection is there between the ocean part of the engine and the atmospheric part of the engine?

About this problem of the deepwater circulation and the deep currents in the sea: you would think the oceanographers would know about it already, but in fact they know very little.

Mr. THOMAS. What makes the water circulate a mile deep or 5 miles deep? Is it heat?

Dr. REVELLE. That is, frankly, a question I cannot answer.

Mr. THOMAS. Does heat have anything to do with it?

Dr. REVELLE. We have a fairly good idea of what makes the Gulf Stream go. It is driven by the wind of the atmosphere. This is also probably true of the equatorial currents, the currents in the various surface layers of the sea; but we think the deepwater circulation—that is, the water 500 yards below the surface—is driven by heating and cooling at the surface, and that it is in fact heating and cooling by evaporation at the surface. It is a kind of steam engine in fact, a steam engine of very low efficiency.

Mr. YATES. When you speak of the Gulf Stream, how deep does it go? Does it extend to the bed of the ocean?

Dr. REVELLE. No. The Gulf Stream is confined to the top 500 meters, or 500 yards. Just a few weeks ago a British oceanographic ship actually made measurements of the current in the deep water right under the Gulf Stream, under the rapidly moving surface current, and they found the deep current going about half a knot in the opposite direction.

As I was just about to say, this deepwater circulation in the past has been almost impossible to measure. Meterologists can send a pilot balloon up into the air, follow it with a theodolite, and tell what the winds are at all elevations, but the problem of the oceanographer we think is more difficult because he does not have any fixed platform. His ship does not stay put, and therefore he is always lost. That is what it really amounts to.

Mr. THOMAS. As the water gets cool it goes to the bottom; does it not?

Dr. REVELLE. Yes, as the water gets cool it goes to the bottom, but it somehow warms up and comes up again. The cool water sinks and the warm water tends to rise. The cool water sinks at the high northern and southern latitudes and moves along the bottom all the way through the ocean. This takes quite a long time. It takes somewhere between 30 years and 10,000 years. That is the kind of uncertainty we have in this problem. This is the problem that we are going to attack with a vengeance during this International Geophysical Year.

I might say that I just heard yesterday some good evidence that it probably takes about 500 years to make this turnover of the deep water, based on radioactive carbon measurements.

Mr. YATES. I hope that you make the whole survey.

Mr. THOMAS. What does this great ice mass have to do with it? You have given that the once over too, have you not?

Dr. REVELLE. In the Antarctic?

Mr. THOMAS. Yes.

Dr. REVELLE. I will come to that in a minute.

OCEAN DEPTHS A REPOSITORY FOR RADIOACTIVE WASTE

One of the major practical problems besides this problem of climatic changes, that is, the storage and loss of heat from the deep water which may be a way of getting at the prediction of climate, is the problem of the peaceful development of nuclear energy. The question here, at least with the reactor techniques that we are developing now, is that we are going to have large amounts of radioactive waste. One very simple figure that we should remember here is that the full-scale development of atomic energy, using nuclear fission, would result in radioactive waste products equal to the explosion of somewhere between 10 and 100,000 hydrogen bombs a year.

The problem is what to do with all this radioactive waste. People have thought of all sorts of things to do with it. Perhaps the best thing is to put it all in salt mines. Right at the present time there are countries such as England and the United States, and probably Japan, which are dumping some of this radioactive waste in the ocean. In the long run a good deal of it will have to be dumped into the ocean. The problem is, how do you dump it most effectively and do the least harm to fisheries, to people swimming on the beaches, and to the rest of the resources of the sea.

I am convinced that a great deal can be done by dumping it in deep water and insuring its spreading in deep water. This is something we can only find out by really understanding the circulation of the deep water. This is really a garbage-disposal problem and the ocean is the logical place to dispose of a great deal of garbage.

IGY STUDIES IN GLACIOLOGY

Coming back to glaciers, the problem of the glaciers is, of course, the problem of how they form and how they disappear—how fast do they form and how rapidly do they disappear? For example, if the ice were to melt all of a sudden over Antarctica within the next 50 or 100 years, this would flood out all of the coastal cities of the United States. The sea level would rise about 50 feet. This probably cannot happen anywhere that fast. The question is, How fast can it happen? How fast can glaciers form?

There is some evidence from borings in Greenland that the ice forms at the rate of around 2 feet per year. One thousand feet would form in about five hundred years. Ten-thousand-foot glaciers such as we have apparently in Antarctica, an icecap covering an entire continent, might take 5,000 years to form at this rate. They cannot form too fast. It might be possible to melt them a lot faster. The question of the gain and loss of ice to the glaciers is one of the key problems of this glaciological program.

I talked about the storage of heat. Here you have a reverse fact. It actually takes heat to melt the ice, so a good deal of excess heat could go into the melting of ice without any change in the temperature of the earth.

Now, here in the glaciers you have a kind of library of what has happened in the past locked up and frozen. It is a big icebox in which all of the geophysical events of the last 1,000 years are preserved. We may be able, by taking borings and studying the dust and the oxygen and nitrogen ratio and the carbon dioxide content, to get some idea of what has happened over the past 1,000 years on the earth. It is sort of a record.

Mr. THOMAS. You are talking a little fast there, Doctor. You mean that you are going to measure the hydrogen and the oxygen and your other elements that will give you some idea as to what has been taking place? What do you mean by that? I tried to quote you literally.

Dr. REVELLE. That is correct. For example, how many volcanic explosions have there been per decade, or century, or all over the past few thousand years? Here you have a layer of volcanic ash that will settle and form a distinct layer in the ice and you can pick it up all beautifully preserved.

Mr. YATES. From what distance away?

Dr. REVELLE. From any distance away. For example, with regard to the great explosion of Krakatoa in 1883, there is a distinct layer of volcanic ash from this explosion in Greenland.

Another example is such things as changes in the ratio of gases in the atmosphere. Take a third example: We know, and the earth satellite people are in fact very much interested in this, that the earth is constantly receiving very fine meteoric material not only from the shooting stars but also from outer space. Here again you have this wonderful uncontaminated layer of snow and ice which is just a series of pages turning over. In them have been kept a continuous record of the amount of meteoric dust coming into the atmosphere.

Dr. THOMAS. It is frozen there?

Dr. REVELLE. It is frozen in, that is correct, and it is clean.

Mr. YATES. I come back to my question. I asked whether the ice contains records of atomic and hydrogen explosions.

Dr. REVELLE. Undoubtedly it does. Of course, that would be very near the surface.

Mr. YATES. Is that what you propose to read?

Dr. REVELLE. That will be measured too, the radioactivity.

Mr. THOMAS. You are going to have to cover every 6 inches.

Dr. REVELLE. Yes, from a continuous core of ice. It is a remarkable thing.

MEASUREMENTS OF ATMOSPHERIC RADIOACTIVITY

Coming back to this problem that you just raised about radioactivity, there are many different things that can be said about this. One of them, of course, is everybody on earth is concerned about radioactivity; one of the programs of the International Geophysical Year will be to attempt to get a good measure of the amounts and variability of fallout, looking at this primarily not from the point of view of the radiation problem, but from the point of view of what can it tell about the atmosphere, how does the atmosphere mix—not only horizontally, how much transport of air is there across the Equator—but how does it mix vertically? We have pretty good evidence now, based on these fallout studies, that the upper atmosphere and the lower atmosphere mix quite slowly. Anything that gets in the upper atmosphere stays there for about an average of from 7 to 15 years. This is quite a remarkable additional piece of information about our atmosphere which will help us in many kinds of meteorological problems.

Mr. YATES. How long will the radiological particles last? Eventually they will come down. Would they be dead at the time they come down?

Dr. REVELLE. It depends upon the isotope.

Mr. YATES. You talked about 7 to 15 years that it would stay up there.

Dr. REVELLE. We are certainly going to get some on the earth, that is quite right. We know pretty much what the total is.

Mr. THOMAS. This has been going on a long time, before we discovered the hydrogen or the atom bomb.

Dr. REVELLE. I am talking about that produced by the bomb explosions.

Mr. THOMAS. There is some from nature; is there not?

Dr. REVELLE. There is also some from natural radioactivity and I would like to say a word about it.

Mr. YATES. Before you do, I would like to find out whether or not we ought to have a suspension of the hydrogen tests pending the conclusion of the International Geophysical Year and a determination of how they may affect us. Will you chaps be able to tell us a lot more, be able to let us know with some degree of finality as to whether or not these things are actually hurting the earth and the people who live on it?

Dr. REVELLE. I think that we can say fairly well about this right now—and I was a member of the National Academy Committee which considered the biological effects of radiation, and so was Dr. Wexler, and it is my personal belief——

Mr. YATES. What conclusion did you come to?

Dr. REVELLE. It is the conclusion of at least my part of the committee that the fallout produced by the weapons explosions is far below the danger point, from a pathological point of view.

Mr. YATES. Dr. Pauling said that it was affecting us now.

Mr. THOMAS. He said that there were 1,000 cases of bone cancer that were going to develop next year, or the year after next.

Dr. REVELLE. There is a great deal of controversy about this among scientists, but I personally think all the scientists who have studied the problem carefully are in accord that the level of fallout is way below the danger point at the present time from a pathological point of view.

The question of the hazard of radioactive fallout from explosion of nuclear weapons is a complicated one. The explosion of a large (megaton) "dirty" weapon over a thickly populated region would bring a very serious hazard to human beings in an area of more than a thousand square miles. As a result of the testing of nuclear weapons over the ocean there may be a fallout of high radioactive intensity into the nearby waters. This "close in" fallout presents a serious hazard to vessels that may be accidentally in the area. A considerable part of the radioactivity produced by the explosion of a large weapon is carried great distances by the winds aloft. Some of it remains in the stratosphere for periods of several years, where it is slowly dispersed and slowly settles over much of the earth's surface. My personal belief is that the total measured quantity of this "distant fallout" over any populated area has so far been much too small to present any pathogenic hazard. There are differing opinions about the possible genetic dangers but the effect is certainly less than that caused by variations in natural radioactivity and cosmic rays from one part of the earth to another.

Mr. YATES. Why would Pauling come out with a statement like that? Was that an emotional outburst?

Dr. REVELLE. I would not want to say.

Mr. THOMAS. He was just giving his opinion.

Dr. REVELLE. I would not want to say anything more than what I have said.

Mr. YATES. Let me ask you this further question: You spoke about the survey made by the committee of which you and Dr. Wexler were members. Was this a unanimous report of the committee?

Dr. REVELLE. Yes.

Mr. YATES. That is very persuasive. How many members were there on the committee?

Dr. REVELLE. About a hundred. It was divided into 7 groups.

Mr. YATES. And you were free agents in coming to your conclusions?

Dr. REVELLE. Yes.

Dr. WEXLER. I might say, beginning May 27 the Joint Committee on Atomic Energy is to hold an extensive number of hearings on the fallout problem right from the fundamentals and all the way through the biology.

Dr. REVELLE. From the standpoint of the geophysicists, these tests are really quite useful. Everything you do has hazards and dangers. These people on these island stations in the Pacific and in Antarctica and other places are all subject to very considerable danger. Science in some respects is a hazardous business. The amount of information that we get from a sudden shock to the atmosphere, like suddenly introducing radioactive tracers into the air, is really very great.

Mr. YATES. Is it possible that various locations on the earth may be affected to a much greater extent or degree than others? I am thinking particularly of the Japanese, who are in the apparent center of these various tests. Is there any justification for their position?

Dr. REVELLE. Certainly, there is a considerable variability between different parts of the earth in the amount of fallout, and some places in the United States have a lot more than others. This is a thing that we do not understand very well.

Mr. YATES. In those places that have the extra amount of fallout—is the fallout dangerous to the point where the tests should not be conducted because of the excess fallout that occurs?

Dr. REVELLE. I believe it is not.

Mr. YATES. It is not?

Dr. REVELLE. That is correct.

The Japanese, of course, are right in the path of several different air masses moving from the testing sites. The interesting thing is that we have gotten a lot higher fallout in several places in the United States than anywhere in Japan.

Mr. YATES. You do not say so?

Dr. REVELLE. Yes.

Mr. YATES. Even in those places it has not yet accumulated to the point where it is dangerous, in your judgment?

Dr. REVELLE. That is my belief; yes.

Now, this, as I say, is a subject that certainly does need further investigation. This is the best judgment that anybody can make at the present time. One of the things that is produced by some kind of bomb test is tritium, which is radioactive hydrogen. It is also produced by natural processes, by cosmic rays in the atmosphere. The total amount of tritium in the atmosphere is about 2 pounds, and yet this is something that can be measured by just taking a sample of water, by the wonderful new modern radiochemical technique; the results of these measurements have shown that in fact the amount of tritium in the atmosphere is about 10 times what it ought to be if it is produced by cosmic rays.

It looks as if in fact we are getting tritium blown into our atmosphere from the sun. You all know that the sun is a gigantic hydrogen bomb and it is sending many different kinds of particles into the atmosphere. The same thing is true of helium which is coming into the earth from the sun; this is one of the remarkable new results which will be added to the IGY program to try to find out what kind of particles are coming into the earth from the sun, particularly radioactive particles. This will, of course, be an oceanographic as well as a meteorological problem, as well as a satellite problem.

INTERNATIONAL ASPECTS OF IGY OCEANOGRAPHY

I would also like to say a few other things. One of them is this: From the standpoint of international collaboration, international assistance to underdeveloped countries, the IGY program is truly a remarkably successful thing. For example, I am thinking of some of the South American countries where I have had some personal contacts, particularly Chile and Peru.

Peru has the most fertile area on earth outside of its doorstep. The fish there in those waters are literally teeming. The fish population is so great that the guano birds of Peru catch about 3 million tons of fish a year, about as much as the entire Japanese fisheries. This represents a great potential resource to the Peruvians. In order to develop this resource they have to understand it and they have to understand why the ocean is so fertile there, where the fish are, how many they can catch, what happens if they catch too many, and what happens possibly to the guano birds. They really need to be able to study the ocean in all of its aspects.

Partly as a result of this IGY program, we are working with Peruvians and having Peruvian students come as graduate students to the Scripps Instiution; then we are sending some of our students to Peru and helping them to develop their marine biology and oceanography. We are doing the same thing in Thailand. Again, partly because of the IGY, although not entirely, the Siamese are sending students to this country; they are getting our people to come there and work with them to develop their own oceanographic program.

In the case of advanced countries like Japan, we are enabled, in part because of the IGY program, to work very much more closely with them and to learn their techniques, to teach them ours and to develop the kind of unity and integrity of these earth sciences which are so important both to the Japanese and to us. I think this is having a real effect in other aspects of the United States-Japanese relations, too.

In the case of the Russians, we have the Russian oceanographic program which is tremendous; and the reason ours is so large is partly because of healthy competition in this field. I think it is not completely impossible to suggest that in this field, the earth sciences, you have to some extent both cooperation and competition between different countries.

FUTURE OCEANOGRAPHIC RESEARCH

Finally, I would like to say that as far as the meteorological programs are concerned and the marine sciences in general, you gentlemen may expect me to come back here again and ask you for some more money later—not in connection with the IGY, but in the future; we are developing plans in the international scientific field through the International Council of Scientific Unions.

Mr. Berker, who is present, is a member of the special committee, called the Special Committee on Oceanic Research. The object of that committee will be to continue in these fields the study of earth fluids, the ocean, and the atmosphere over the ocean; a long-range program is planned just like the IGY program with these practical objectives of studying climatic changes and studying the problems of developing marine resources.

Mr. Thomas. That is wonderful.

OCEAN TIDES

Mr. Boland. Can we get something into the record on ocean tides?

Dr. Revelle. There is an awful lot to be said about them. One thing I can say is this: That the tides in the ocean are very much more complicated than one is taught in school. The level of the sea rises and falls for all sorts of reasons. One of the reasons it rises and falls is because of the wind that pushes the water in one direction or another; the air-pressure changes; the volume of the water changes as it heats and cools, and the volume simply moves from one place to another for obscure reasons.

We find in Canton Island in the Pacific Ocean, where we have a tide gage station, that you have a 3.8-day tide: about 6 or 7 inches going up and down, with a very regular period of 3 or 4 days. That has nothing to do with the sun or the moon at all. Also there is across the Pacific a wave guide and this tends to make the water pull up and down with periods of this order.

We have just been able to install a tide gage at Point Barrow and keep it operating since last July. This is a very difficult thing to do because whenever the ice comes in, it tends to tear out a tide gage and we have to develop a new technique for doing it. We find in the Arctic Ocean that there is a surge of about 3 or 4 days which looks as if it had to do with the time it takes a current to be propagated across the Arctic Basin and back again. This may be of very real importance in studying the movement of the ice in the Arctic.

Mr. YATES. Is there regularity in the flow?

Dr. REVELLE. It is a typical tide which can be predicted with great accuracy and a long time ahead. These tides are due to the fluctuations in the heat engine that we are talking about; these are for the most part irregular and they are really a way of studying the changes in the ocean currents and in the wind system.

Mr. YATES. It is interesting that you can put some of this knowledge to work. For example, up in New England at Passamaquody.

Dr. REVELLE. All of the knowledge is available there. I would not say that science is going to help you there with this particular problem, for we understand the tides there very well. These are astronomical tides. This has passed to an economic and engineering problem rather than a scientific problem.

Mr. THOMAS. Thank you very much, Dr. Revelle.

Dr. KAPLAN. We have one more presentation by Dr. Harry Wexler; who is the Director of the Meteorological Research of the United States Weather Bureau.

STATEMENT OF DR. HARRY WEXLER ON ANTARCTIC PROGRAM

Dr. WEXLER. Mr. Chairman, with your permission, I would like to leave a copy of my prepared statement for inclusion in the record.

Mr. THOMAS. Without objection, that may be done

(The prepared statement is as follows:)

STATEMENT OF DR HARRY WEXLER, CHIEF SCIENTIST, USNG-IGY ANTARCTIC PROGRAM, NATIONAL ACADEMY OF SCIENCES

The opportunity to bring you up to date on the progress of the United States International Geophysical Year program in Antarctica is particularly exciting to me. I have only recently returned from an extended visit to the United States stations in that region, which I made last January and February in my capacity as chief scientist for the United States IGY Antarctic programs. This trip was made in company with Dr. Laurence M. Gould, director, United States IGY Antarctic programs, who is well known to you He has asked me to convey his regrets for being unable to be present with you and to explain that only unavoidable prior commitments have prevented his appearance.

My enthusiasm for this program is unbounded, and I have great admiration for the magnificent efforts of Navy Task Force 43 and those of our other military services which have surmounted incredible difficulties in achieving complete success in setting up the stations. The facilities, our scientists, and their equipment are all now successfully esatblished at the six United States stations, and the success of the scientific effort now rests with us. I have complete confidence that during the IGY our scientists, together with those of the other nations, will truly explore and reveal new frontiers of geophysical science for the first time. The results we shall obtain cannot escape being of prime importance both for basic science and for many practical applications

During the period in which I was observing the final establishment and preparation of the 6 United States IGY Antarctic stations, expeditions of 10 other nations were visiting the Antarctic Continent, unloading hundreds of tons of supplies for other stations, and a total of 40 continental stations are now established for the coming Antarctic winter months. Other expeditions resupplied and relieved the personnel at 21 stations previously established on isolated islands of the sub-Antarctic area. To this network of 61 scientific stations, other nations will add 3 more stations during this coming year's operation.

Although this last year's Antarctic operation formally began with the departure of the ice breakers and cargo ships in late October and early November 1956, activity preceding these events included the processing of 420,000 pounds of scientific equipment and supplies at Davisville, R. I. A comprehensive program of orientation was held during October 1956 for USNC-IGY Antarctic scientific personnel at the Navy Construction Battalion Center, Davisville, R. I. Scientific leaders for the 6 stations were appointed as follows: Mr. A. P. Craey (also Deputy Chief Scientist), Little America Station; Mr. G. R Toney, Byrd Station; Dr. P. A Siple, South Pole Station; Mr. C. R Eklund, Wilkes Station; Capt. Finn Ronne, Ellsworth Station; and Dr. J. A. Shear for the Adare Station, operated jointly with New Zealand.

DEEP FREEZE II

The arival of the U. S. S. *Custis* at Little America on January 29 with IGY scientific personnel for Little America and Byrd Stations represents the real initiation of the IGY Antarctic scientific program, although some scientific observations were made by last year's wintering party. IGY personnel were simultaneously moving to their posts at the Adare and Pole Stations, and within a short time IGY personnel at Wilkes and Ellsworth Stations were beginning to install their equipment. A total of 83 scientific personnel, including 11 Naval meteorological technicians, are now engaged in the final preparation of scientific equipment. At the present time, some preliminary scientific observations have been made, a month prior to the commencement of the international IGY test period. which begins June 1 Preliminary air reconnaissance for the glaciology-seismology traverse parties, which will begin their activities in October 1957 from Little America, Byrd, and Ellsworth Stations, have been conducted.

To coordinate the final effort for the establishment of these stations, an international CSAGI Conference on the Antarctic was held in Paris during July–August 1956. As during the three previous CSAGI Antarctic Conferences, plans for the scientific programs and logistics operations were exchanged and discussed. Of perhaps greatest importance was the coordination of the complex international communication network, which not only will provide an essential communications link among all the Antarctic stations, but will also serve as an integral part of the Antarctic IGY Weather Central, for which the United States has assumed the international responsibility. This weather central, established at Little America, will serve as a clearing house for Antarctic weather information. Weather data will be collected on a regular schedule from all Antarctic stations, from nearby ships and aircraft and from overland traverse parties For the first time a coordinated forecast of weather data of the far southern latitudes will be available to all nations. This information is critical to the success of the scientific programs and to the logistics operations necessary to support them.

THE UNITED STATES PROGRAM

As is evident from our role in the IGY weather central, the USNC-IGY Antarctic program is a most important part in the overall network of Antarctic scientific stations. The geographic distribution of the United States Antarctic stations not only presents the opportunity of vastly increasing our store of knowledge in the geophysical phenomena under observation, but also occupies locations most essential to the filling out of the overall pattern of observations under study during the Geophysical Year. The Amundsen-Scott IGY South Pole Station (90° S.), located within 1,000 feet of the geographic pole, acts as the terminal link of the longitudinal pole-to-pole network of scientific stations particularly important to the disciplines of aurora and airglow, meteorology, and ionospheric physics. Byrd IGY Station, located in the interior of Marie Byrd Land (80° S., 120° W), will give a unique opportunity to study the meteorological phenomena of this section of the continent, which appears to be an important factor in influencing the weather of the Southern Hemisphere Little America IGY Station at Kainan Bay on the edge of the Ross Ice Shelf (78°12′ S , 162° 15′ W.) and Ellsworth IGY Station on the edge of the Filchner Ice Shelf (77°43′ S., 41°07′ W.) not only act as ports of debarkation for inland traverse operations, which will carry out extensive glaciological, seismic and gravity observations, but are also so located on the Southern auroral belt as to be essential sites for aurora and airglow and geomagnetic observations. With Adare IGY Station, a joint New Zealand-United States Station, located at Cape Hallet (72°25′ S., 170°55′ E), these 2 stations join Byrd Station as important links in the meteorological network, which will record the phenomena of the world's most constant low pressure area. Wilkes IGY Station, established on Clark Island in Vincennes Bay is relatively close to the geomagnetic pole. The site also offers extremely easy access to the polar ice cap, a feature which has already been utilized by glaciological traverse parties, who have established a satellite camp 50 miles inland. To support the establishment of the Pole Station and

the Byrd Station an air facility was established at Hut Point on Ross Island in McMurdo Sound from which aircraft delivered all the necessary supplies to the Pole Station and much of the food and fuel for the Byrd Station.

IGY SOUTH POLE STATION

The current season of Antarctic operations for the South Pole Station began during October 1956 when naval and Air Force aircraft landed on the bay ice in McMurdo Sound after a 2,200-mile flight from New Zealand. A number of preliminary reconnaissance flights over the South Pole and Beardmore, Scott, and Liv Glaciers resulted in the establishment of an auxiliary air facility at the foot of the Liv Glacier on October 29. Two days later in—58° F. temperature, a ski-equipped Navy airplane with Rear Adm. George Dufek, commander of supporting Task Force 43, aboard, made the first historic landing at the South Pole. Extreme weather conditions prevented further operations until November 20, when the first airlift of construction personnel and equipment was delivered to the station site. By February 21, 760 gross tons had been dropped during a total of 65 missions. At present 18 men, 9 scientific and 9 support personnel, occupy the station. All personnel have been engaged in the completion of the station facilities in temperatures which have already dropped to —89° F. In the installation of equipment for the disciplines of aurora, glaciology, geomagnetism, ionospheric physics, meteorology, and seismology, which will be conducted at the station, some of the usual problems associated with establishment of scientific efforts in the field have been encountered, as well as some unique to this location. The extreme temperatures have caused constant frosting over the aurora and airglow domes, which has had to be corrected by experimentation at the station site. Airdrop damage of the ionospheric equipment necessitated the rewiring of several circuits, all of which must be directed by communication between Little America, the South Pole, and with the continental United States Some items were lost in the airdrop and have had to be replaced by equipment improvised at the station. But despite these problems, all disciplines have now installed their equipment and are currently operating on a trial basis.

BYRD STATION

While great attention was focused on the Pole Station operation, a dramatic attempt was being made to establish a station in the interior of Marie Byrd Land. On November 9 a reconnaissance trail party composed of an experienced Army team supported by naval aircraft equipped with oversnow vehicles departed from Little America This party encountered almost impassable crevasses about 100 miles out on the trail, which for some time threatened to jeopardize the success of the whole operation. After considerable reconnoitering, and days of patiently bridging crevasses, however, this region was crossed. After 5 weeks of intensive and hazardous work along the 650-mile route, the train arrived at the site of the Byrd IGY Station. Two heavy tractor trains and the delivery of 240 tons of fuel and equipment in February by the United States Air Force brought the supplies, scientific equipment, and personnel needed to establish the station.

The late construction schedule, the constant wind-blown snow and cold temperature have made the completion of this station a difficult task. Despite these conditions, the 12 scientific and 10 support personnel have completed the erection of buildings and special scientific structures. The meteorological program is already underway and the aurora, geomagnetic, ionospheric, and seismic equipment has been installed. We expect momentarily to receive word that measurements in these fields have begun.

One of the most notable achievements at this station is the completion of a 650-mile glaciology-seismology traverse from Little America station. A seismic profile which was begun 200 miles out from Little America has shown that the ice depths increase from 2,000 to 7,000 feet approaching the station. A profile in the immediate vicinity of the site has determined that this station, which is only 5,000 feet above sea level, is located upon 10,000 feet of ice.

LITTLE AMERICA STATION

With the arrival of the U. S S. *Curtiss* at Kainan Bay on January 29, 25 IGY scientific personnel occupied the Little America Station. Included among these were Soviet and Argentine meteorologists, who will participate in the work of the weather central program. The IGY meteorological program was the first to get under way at Little America with surface and upper air observations beginning January 29. Installation and preparation of the aurora, geomagnetic, glaciological, and ionospheric physics equipment are now completed, and data are being obtained on a trial basis.

ELLSWORTH STATION

A reconnaissance of the Filchner ice shelf from Gould Bay to Cape Adams in January 1957, during which ships of the Weddell Sea task group constantly battled heavy pack ice, disclosed no satisfactory station site on which to establish the Ellsworth IGY station. After exploring the barrier edge which ranged between 150 and 200 feet in height unbroken for some 200 miles, a site east of Gould Bay was selected for the station and on January 25 offloading of cargo began. Offloading and preliminary construction were completed in the record time of 14 days and the ships departed on February 12. A total of 39 personnel, 14 scientific personnel, 14 support personnel, and 11 naval air personnel, have since been engaged in the installation of all scientific equipment for aurora, ionospheric physics, and meteorology. Despite the extremely short construction period, installation of all scientific equipment has been completed and the station scientific program began to operate on a trial basis on April 15. Seismic and gravity equipment has been installed in an oversnow vehicle and preparations are being made for a possible glaciological-seismic observational traverse toward the Moltke Nunataks.

WILKES STATION

After a reconnaissance of Vincennes Bay, a site on Clark Island was selected on January 29 for the Wilkes IGY Station. Offloading was completed by an amphibious operation and the ships departed on February 17. While 13 support personnel complete the station facilities, the 14 scientific personnel are in the process of finishing the installation of the scienitfic equipment. The selection of this site is most fortunate as it not only permits an unlimited horizon for aurora observations, but the presence of bedrock has supplied an excellent location for the seismic program. The aurora, meteorology (including two daily balloon flights) and ionospheric physics programs are in full operation and the geomagnetism and cosmic ray programs await only the final preparation of special facilities before recording will begin.

The glaciological team has already established a route to the ice cap and has proceeded to a point 50 miles inland at an altitude of 4,000 feet. Ablation and accumulation stakes were set along the trial and snow studies made. The aurora ionospheric physics, and meteorological upper air programs are currently beginning operations.

ADARE STATION

Cargo for the joint New Zealand-United States Adare Station at Cape Hallett was offloaded on January 10. By January 29 all buildings had been completed. The 8 scientific and technical personnel, including 3 New Zealand scientists, and 5 support personnel, have been installing the scientific equipment Three-hourly surface meteorological observations were begun on January 10, 1957, and twice-daily upper air observations began April 1. The auroral, geomagnetic, seismic, and ionospheric physics programs are expected to begin observations this week.

Dr. WEXLER. Dr. Kaplan earlier referred to the extensive travels I made in connection with the IGY.

However, I am proudest of the fact that I am the only American who traveled from the United States to Japan by way of the Antarctic. When I arrived there I received a message to proceed to Tokyo to participate in this conference at the end of my stay in the Antarctic. I found the Japanese excited about the Antarctic.

I traveled with Dr. Gould, who is the director of our Antarctic program, and he asked me to convey to you his very sincere regrets for not being able to be with you here today to speak about his favorite subject.

It is really an honor and a privilege to have been with Dr. Gould and to have traveled over the scenes that he saw many years ago during the first Byrd expedition when Dr. Gould was second in command. We actually flew over a good many of the areas that he sledged over in 1928 and 1929. He saw many of the same mountains and complained that they apparently had moved some of the mountains since he was last there.

ESTABLISHMENT OF IGY ANTARCTIC STATIONS

As you know this activity of the past season was actually crucial in putting down the main bulk of our scientific stations which, in addition to those of other nations—the other 11 nations which will occupy stations in the Antarctic—will amount to some 40 stations.

Our own endeavor began 2½ years ago in the winter of 1954 and 1955, when the preliminary reconnaissance was performed to pick out spots for our 2 first stations. They are at McMurdo Sound, where the Navy later established an air facility, and then Little America, which is the headquarters of our scientific activity. Some other reconnaissance was carried on in other areas, looking for other sites.

The next season, 1955–56, the Navy under Task Force 43 actually set up the 2 stations at McMurdo Sound and Little America.

This past season the main emphasis was on putting in the remainder of our six scientific stations. Actually, Little America was our first scientific station, and McMurdo Sound was a support station.

The other five put in, in the past season, in a series of operations, has really made history in polar exploration. They are the South Pole, the station set up with the magnificent aid of the 18th United States Air Force; the Byrd Station at the center of Byrd Land, where there is an interesting observation which came out about the depth of ice; the Adare Station which is a cooperative station with New Zealand; the Wilkes Station, and the Ellsworth Station.

Dr. Gould and I are very happy to report that Task Force 43 has put these stations down in exactly the spots that the scientists wanted them. That was done in spite of the fact, as we can testify, that there was a good deal of sweat and difficulty that accumulated during the process of doing this. It could not have been done but for wonderful coordination among the armed services. You have really to see the armed services at work outside of Washington to realize that this unity is an accomplished fact. When you get down to this area they all look alike and they all work very closely together. There is no interservice rivalry. Admiral Dufek was the first to call on aid, wherever he could find it, regardless of affiliation. It was due to this matchless teamwork that they were able to do so much. All of the services and civilians involved in these new stations that were put down combined to make this an unprecedented operation.

For example, at the Pole the Globemasters took many tons of cargo in 61 missions from McMurdo Sound over to the Pole and dropped the tonnage required to equip that station. The smaller R4D planes of the Navy took the scientific personnel and more expensive equipment which could not be dropped.

From Little America tractor-train operations following a path laid out by United States Army experts, 650 miles over a very heavily crevassed area from the Ross ice-shelf area to the polar plateau, and made possible that station which, however, could not have been established if the Air Force had not flown in fuel and food from the McMurdo Sound station. All told, the Air Force flew 81 missions bringing in a thousand tons of food, fuel, and equipment to maintain both of those stations.

PRESENT STATUS OF UNITED STATES ANTARCTIC STATIONS

The scientists, themselves, are all at the spot with their equipment and there have been very few cases of loss or damaged equipment. In fact, at Little America there was none. At Byrd station some radiosonde equipment was damaged during the drop. However, we are able to get along by cutting down the number of our observations from 2 a day to 1 a day until the resupply operation takes place in November. At the Pole station, the equipment loss has been negligible and improvised techniques of repair and substitution have been made to keep the station running.

The conditions at the pole have exceeded predictions as to the temperature. We expected it to be cold but not quite so cold early in the season. When Dr. Gould and I flew over the pole the temperature was about 25 below zero Fahrenheit. By the beginning of March, the temperature had dropped to 69 below. The latest reading, as of a few weeks ago, is 89 below, which is not the world's record, but a few degrees from that; the unusual thing is that it is accompanied by strong winds, 15 to 20 miles an hour. Yet, the men work outside and do their camp duties, scientific observations, and so forth, for as long as 3 or 4 hours with little discomfort.

CHARACTER OF SNOWFALL AT SOUTH POLE

The snow at this station is quite frequent but in the form of small ice crystals, diamond dust, not the big flakes that we have, and apparently that nourishes all that tremendous volume of ice. We suspect that most of the accumulation of snow which is transformed into thousands of tons of thick ice comes in the form of ice crystals so small you can hardly see them fall. For example, the first 45 days at the pole the Navy CB commander said that it did not snow once. We could not understand that. When our trained meteorologists got there, the first observation they made was, "My goodness, it certainly is snowing here a lot." It is very fine crystals and not like a snowstorm back home.

Mr. THOMAS. It is not slippery, is it?

Dr. WEXLER. It is slippery enough for skis to go over it and sleds, small sleds.

Mr. THOMAS. I stopped down in Goose Bay and I was talking to some of the people there about it. They said that it is the same type of snow, a little bit misty, but it is not slippery. I said, "I notice that you do not have any rubbers on." He said, "It is not slippery. Those particles are tiny but it is not slippery by any means."

Dr. WEXLER. You have to make it slippery by melting the ice. Until the time that the temperature gets to these very low values, they had used skis to glide over the ice.

Mr. YATES. Do you have the same conditions here as in Goose Bay?

Dr. WEXLER. In Goose Bay I think the snow would be in the form of big crystals, the hexagonal crystals that we get in warmer climates. In Little America, when it snows there, the crystals were normal size and shape. There was enough water to cause the ice crystals to grow to normal size.

OTHER RESEARCH AT THE SOUTH POLE

At the Pole Station, this would be the most interesting from the scientific point of view because it is a unique spot. The atmosphere will be alternately exposed to sunlight for 6 months and then cut off for 6 months. This will do strange things to the atmosphere, not only from the standpoint of decreasing the height of the atmosphere, but also in decreasing ionization in the ionosphere which is a layer in the atmosphere that owes its properties to ultraviolet radiation from the sun. The ozone layer that we talked about earlier, that forms a thin layer of gas which protects the human race from the harmful effects of ultraviolet radiation—that ozone layer should not be there either. We have instruments to measure these things; our studies will throw a good deal of light on motions in the atmosphere if we find that there is still a good ionosphere and there is still a good ozone layer. This means that there is a transport from warmer regions to very cold regions.

METEOROLOGICAL STUDIES AT BYRD STATION

The Byrd Station location was occupied with these ideas in mind. On the basis of earlier results, the region of the Byrd Station was thought to have a set of weather disturbances that radiated from the center of Byrd Land. That is the reason that the station was put there and our expectations have been fulfilled; of all the stations that the United States has put up, the weather is the worst in that particular spot. We do not know whether this is the graveyard or the cradle of weather. Some of the observations we made this year show that storms tend to wind up here, which is contrary to the opinion of the British meteorologists. They thought that storms originated here. It may be that as storms die and give up their energy here, new storms may take on energy of the dying storm and go out to influence areas far away. We will look into that, of course.

IGY STATIONS OF OTHER NATIONS

I would like to draw your attention to these other stations shown in blue with white circles. The blue stations represent those of other nations; for the most part, they have been put in. The Bunger Oasis is a sort of a U. S. S. R. substation. Then the Soviets have an inland station which they established last year and they have now gone out to establish this station, Vostok at the South Geomagnetic Pole. We have received no definite word as to whether they have reached that particular station. On their schedule for their next season's operation is the establishment of the Sovietskaya Station. That is at a place called the Pole of Inaccessibility.

The Australians have had a most interesting station in operation for a long time at Mawson, and they have recently set up another station at Westfold Hills.

Japan has come back to the Antarctic for the first time since 1912 and they have set up a station on the Prince Harald Coast.

The Belgians will come in during the coming season and again Belgium will return for the first time since the turn of the century to establish a station at Breid Bay, between the Japanese and the Norwegians.

The British station at Halley Bay is shown here.

The Argentine base at General Belgrano Base has been in operation for some time. However, we do not know the details of the scientific program going on there. It is only 30 miles from the United States station at Ellsworth. The Argentine and United States programs will complement each other very nicely and give us an opportunity to study the fine mesh type of changes in weather and ionosphere phenomena which cannot be done elsewhere. There are numerous stations here in the Palmer Peninsula established by Argentina, Chile, and Great Britain on the northern shores. Most of those are for surface meteorology.

There is also a substation here from which the British will make a traverse to the pole to meet a party coming from the New Zealand Scott Station somewhere on the polar plateau.

All of these nations have coordinated their scientific programs; they have, for the most part, started observations, some of which have been exchanged, especially in the field of meteorology. The International Committee has assigned to the United States responsibility for an IGY weather central.

SCIENTIFIC IMPORTANCE OF ANTARCTICA

We all ask ourselves periodically why we are interested in the Antarctic. All of us who have gone there find that we ask ourselves this question and there are many answers. You can say that it is a big gap in the earth's surface and we want to know everything that is happening on the earth; if we are going to explain the world's weather, we have to know what happens there. The Antarctic has a lot more interest for us than just filling up a blank area. If it were just that number of square miles someplace else it would not be quite as important as this particular area, because it represents several unique features.

It is the world's greatest repository of ice; 85 percent of the world's ice is locked up in this mass here. It has properties very similar to this great ice sheet that Roger Revelle mentioned earlier. In our study of what happens to such an ice sheet as it grows and declines, there is nothing better than getting on one of these ice sheets.

One of the most important problems is glacial traverses. This is the sort of observation that will be made over a large area of the Arctic. Our own program will get going this October. That will include Little America, McMurdo Sound, and then go on over to the head of the Ross Ice Shelf. Other nations will also go ahead with their various traverses. Then by putting all of this data together we will get an estimate of the amount of ice locked up in the Antarctic and whether it is increasing or decreasing in volume.

In addition to this tremedous quantity of ice, there is a cold air tract here of terrific proportions. There is nothing underneath to moderate temperatures as in the Arctic. The air gets extremely cold as the temperatures shows in the South Pole. Going down the side here, the air moves the warmer air from the ocean and then the winds resulting from all of this movement are very large, larger than hurricanes in geographical extent.

The violent storms felt on this coast here can give rise to winds with speeds of 60 miles an hour and with wind speeds of over 100 miles and hour observed quite often. The effect of such violent contrasts of temperature and storms may affect the rest of the atmosphere all out of proportion to the rest of the world. There may be pulses that propagate over a good portion of the hemisphere. We never did have the data before to test this and we will get it in the IGY. There are still a lot of things we cannot explain by that simple sort of looking up a one-way street, so to speak. There may be disturbances that propagate across the Equator and some storms that we cannot explain by any of our known theories. We have to get observations in this area, which is one of the most energetic sources of disturbances in the hemisphere.

The Antarctic is also unique in that all of these poles are involved. The French have a station here at Adelie Land; the station is in operation as is their satellite station, Charcot, at the South Magnetic Pole. The South Geomagnetic Pole, where the Russianss have established their Vostok station, is a different sort of magnetic pole. There is also a Pole of Inaccessibility, which is the most difficult place to get to anyplace in the Antarctic.

ANTARCTIC OCEANOGRAPHY

The oceans around the Antarctic—since Roger Revelle talked about meteorology so energetically, I thought I might invade his territory a little bit—is the only unobstructed stretch of ocean found anywhere.

In the northern hemisphere we have land masses that interrupt it. But in Antarctic waters it has been thought that the ocean may exhibit properties quite similar to the atmosphere. As you know, we have the jet stream that is not only important for aerial navigation and the movement of storms, but the change in the convolutions of this jet stream is responsible for drought in one region and flood in another. As these waves move along, droughts may change to floods and vice versa.

In the southern oceans we have a phenonenon quite similar to the jet stream which the oceanographers call a convergence—that is supposed to be a region where the temperature drops off very sharply as you go to the Antarctic Continent.

The examinations of data picked up by the United States ships and New Zealand ships during the supply missions for the Antarctic stations have revealed that properties exist there that have not been written about. It is not merely a sharp dropoff but a recovery of a temperature.

As you drop off, you reach a minimum temperature; and then the farther south you go temperature rises, and when you get down to the Antarctic it drops down again. There is a minimum temperature band which extends down to a thousand feet below the surface; this shows that there must be a welling of cold water up to the surface all the way around here in a narrow belt of 50 miles wide which supplies a lot of the nutrients that the fish have to have in the Antarctic. Oceanographers have never explained how these nutrients come to the surface.

This is a long story but I wanted to say that this jet stream in the ocean may have waves and eddies in it similar to the waves and eddies that they find in the atmosphere jet stream and may reveal to us storms, cyclonic eddies, and movements and convolutions on a far slower time scale; this effect will help us in our study of much faster moving, rapidly changing transient atmosphere jet streams which are very difficult for us to study in all of their complexity in the atmosphere.

One of the things we are going to try to do is to energize oceanographers into a coordinated international program of using the ships that go down there just for logistic purposes to take cross sections across the Antarctic convergence so that we can draw a weather map of the oceans. I mention that because this is one of the unexpected byproducts that drops out of what is really a purely logistic attempt to set up stations. This is one of the things we want to pursue. There will be a good many of these accidental discoveries, like this ice depth in Byrd Land—things that we cannot predict. However, a year from now if we should meet again, I am sure that we will have dozens of new and surprising things to talk about.

Dr. WATERMAN. Mr. Chairman, I would like to thank you for the opportunity to present a piece of excellent work done by Dr. Kaplan and the United States National Committee; and we have also been very fortunate in having Dr. Berkner who is a representative of the International Committee of the IGY as Vice Chairman. As you can see, this is a complicated problem but it has been excellently carried out by all concerned.

Mr. THOMAS. You say it so eloquently that we of the committee will simply say "Ditto." We have been delighted and honored to have you with us.

STATUS OF PROGRAM FUNDING

At this point we will insert in the record the page entitled "International Geophysical Year Fiscal Plans and Obligations as of April 30, 1957."

(The page referred to follows:)

NATIONAL SCIENCE FOUNDATION

International Geophysical Year fiscal plan and obligations as of Apr. 30, 1957

Program	Proposed budget	Obligations as of April 30, 1957	Estimated obligations May 1, 1957–June 30, 1958	Estimated obligations fiscal year 1959
Aurora and airglow	$1,920,500	$1,333,840	$558,160	$28,500
Cosmic rays	1,166,000	838,535	231,000	96,465
Geomagnetism	1,563,000	1,346,625	190,375	26,000
Glaciology	950,000	686,908	243,092	20,000
Gravity	545,000	251,950	256,140	36,910
Ionospheric physics	3,166,000	2,425,400	700,600	40,000
Longitudes and latitudes	17,400	11,000	6,400	0
Meteorology	2,789,000	2,271,593	475,407	42,000
Oceanography	2,038,000	1,584,805	423,195	30,000
Rocketry	2,659,000	2,454,300	204,700	0
Seismology	944,000	653,490	254,000	36,510
Solar activity	305,000	222,500	66,200	16,300
World days	125,100	115,100	10,000	0
International Geophysical Year data center	944,000	30,100	913,900	0
Earth satellite	18,362,000	15,427,015	2,184,985	750,000
Subtotal	37,494,000	29,653,161	6,718,154	1,122,685
Technical direction	1,506,000	791,606	496,394	218,000
Grand total	39,000,000	30,444,767	7,214,548	1,340,685

Mr. THOMAS. I notice that your budget total shows a figure of $39 million. You have furnished to the committee a breakdown of the various areas in which you will spend this money, and I note that as of the 30th of April 1957, for the earth satellite program item you have obligated $15,427,015; seismology, $653,490; oceanography, $1,584,805; cosmic rays, $838,535; glaciology, $686,908; gravity, $251,950; ionospheric physics, $2,425,400.

What it all adds up to is that you have a balance of about $8.5 million as of April 30, 1957.

I note here that as of June 30, 1958, you will have a $1,340,685 balance, and you intend apparently to spend that in the fiscal year 1959. What I am getting at is that you gentlemen have done some rather scientific spending here to make your money come out just exactly. I do not know whether you were short a dollar and a quarter, or plus a dollar and a quarter. Congratulations.

Dr. WATERMAN. These are estimates for 1959.

Mr. THOMAS. They are very fine figures and we hope that they turn out all right for you. I hope that all of the projects get off the ground, as you apparently certainly are turning handsprings to make them do.

Do you think we will get wound up by June 30, 1960?

Dr. WATERMAN. With the exception of the IGY data center; yes, sir.

Mr. THOMAS. That is your evaluation process. That will take your people 3, 5, or 10 years before you get through with it?

Dr. WATERMAN. Barring some unforeseen calamity on these projects, it looks as if they will go forward as scheduled with the amounts that were indicated on our program for the National Science Foundation, with the possible exception of 1 or 2 programs.

Mr. YATES. Should any of the documents furnished to us be made a part of the record? I wonder whether or not Dr. Waterman or any other scientists believe they should.

Mr. BOLAND. Can all of this testimony be inserted?

I think this a very wonderful explanation and a magnificent demonstration by the gentlemen who appeared here of what the International Geophysical Year program plans to do. Mr. Yates and I were discussing the excellence of their performance. I think this is information that would be worthwhile.

Mr. THOMAS. We will do just that.

Dr. KAPLAN. We are very happy to help in any way possible.

Mr. YATES. You may wish to amplify the testimony as it appears so it can be made a public document.

Dr. WATERMAN. Dr. Berkner has a little additional item he thought you would be interested in.

Dr. BERKNER. I thought you would be interested, Mr. Chairman, to hear of the recognition of the special scientific work that has been done by Professor Kaplan and Dr. Revelle, in that they have recently been elected members of the National Academy.

Mr. THOMAS. That is very fine news. Thank you gentlemen for coming at this time when the International Geophysical Year is about to begin. We hope you will continue to keep us informed.

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INTERNATIONAL GEOPHYSICAL YEAR PROGRAM

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