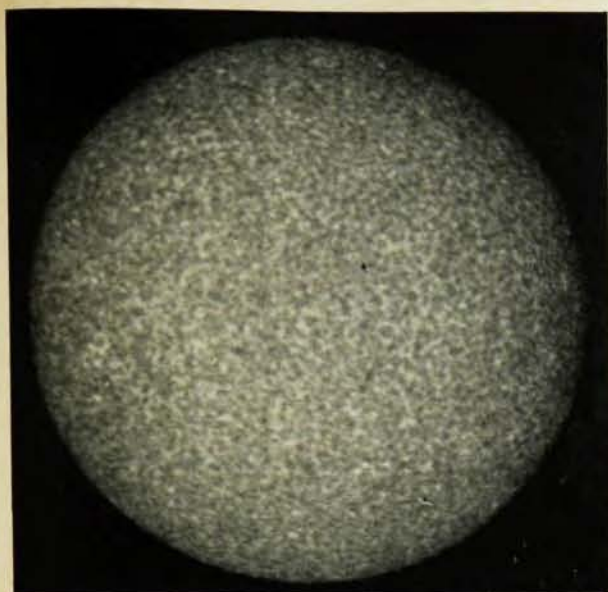




*I have seen everything that is done under the sun;
and behold, all is vanity and a striving after wind.*

Ecclesiastics 1: 14 (RSV)

SOMETHING NEW UNDER THE QUIET SUN

By Martin A. Pomerantz

This article constitutes a first progress report on United States participation in the International Years of the Quiet Sun,¹ a two-year, world-wide scientific enterprise, involving sixty-nine nations, that started on January 1, 1964. Before summarizing the current state of affairs, let us first view IQSY in historical perspective, and outline its aims and objectives. The immediate predecessor of IQSY in the evolution of international scientific programs, for which the zero point in time was 1882 (First International Polar Year), was the widely heralded International Geophysical Year (1957-1958).

IGY was, indeed, propitiously timed. In the first place, technology had achieved a state in which it was feasible to attempt the first direct ventures into that virgin territory which is generally known in the vernacular as "outer space".

Furthermore, although classical geophysics was already a well-recognized field, the level of research was relatively low both in terms of quantity and quality—this despite the fact that many outstand-

ing scientists were pursuing basic problems concerning the properties of the interior of the earth (as in seismology), or of its surface characteristics (as in oceanography), or of its atmosphere (as in meteorology). However, for the most part, efforts in these fields were of an applied nature, as exemplified by the fact that the term "geophysicist" was generally applied to one engaged in oil prospecting. The recognition by IGY of the purely scientific aspects of these and related fields (e.g., gravimetry, geodesy, and glaciology) fostered an approach not only utilizing the techniques of physics, but based upon the philosophy of physics, a field which had just attained new heights by virtue of the rapid postwar expansion.

Finally, although "pure" physicists had for many years been engaged in the study of solar-terrestrial relationships in the areas of geomagnetism, ionosphere, aurora and airglow, cosmic rays, and solar astrophysics, the level of activity on the sun during IGY shattered all previous records since Galileo first recorded the presence of sunspots in 1612.

As a consequence of all of these considerations, many exciting and (even in the popular sense) spectacular results emerged from IGY. The widespread publicity which it was accorded for this

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reason, as well as for its general newsworthiness as a "first", made IGY virtually a household word.

In contrast, IQSY comes at a time characterized not only by a quieting of the sun, but also, perhaps appropriately, by a quieting of the beating of drums. For, with the tremendous increase of scientific verbiage in the news media, and the rapid proliferation of international scientific programs, people now take this sort of thing for granted. Paradoxically, although the magnitude of the present effort appreciably exceeds the level during IGY in the areas it embraces, IQSY is proceeding quietly and, to some extent, unrecognized. Nevertheless, its ultimate impact upon the annals of science will undoubtedly be large, and, since an appreciable segment of the physics community is playing a predominant role in this vast undertaking, it is appropriate to direct to our colleagues in physics this preliminary account of some of the accomplishments thus far.

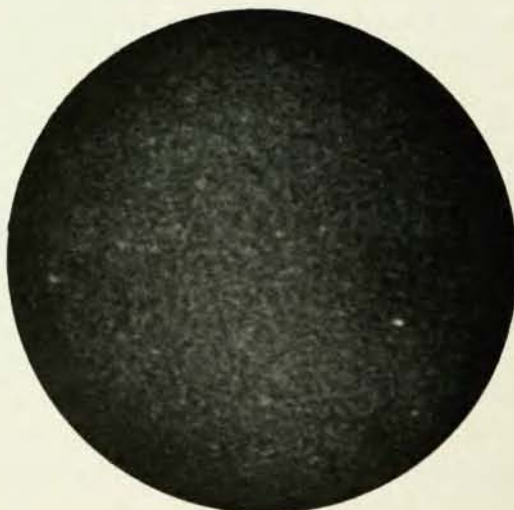
Scientific objectives

There are three criteria that identify research projects appropriate for inclusion in the IQSY program. Some of the studies now being conducted are feasible only at solar minimum, or are most advantageously undertaken when solar disturbances are infrequent. Others concentrate upon isolated solar events that are not complicated by the superposition, in time, of many different effects. Finally, there are studies in which data characterizing solar minimum are being obtained for comparison with those representative of the solar maximum conditions that prevailed during IGY.

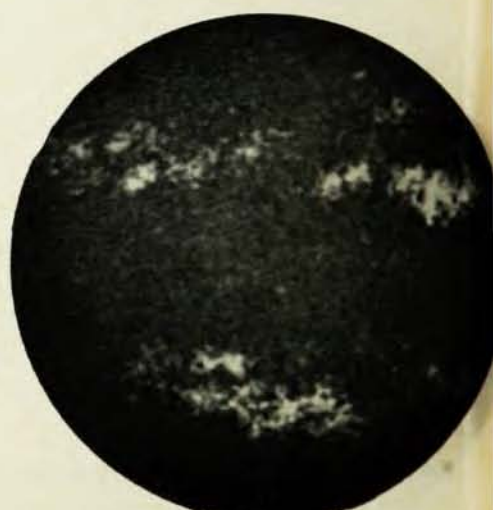
One of the broad general goals of IQSY is to increase our understanding of the control exercised by the sun on the earth and its environment. Another is to gain new knowledge about the sun itself. Finally, advantage is being taken of the relatively uncluttered conditions in the interplanetary space, and in the immediate environs of the earth, to examine in their "au naturel" state a variety of phenomena in the atmosphere, and beyond, that are affected by the various ejecta spewed out by the sun during disturbed periods. To accomplish these ends, all of the powerful new techniques and remarkable facilities which have been developed at an accelerated pace during the last few years are being exploited to the utmost extent. Indeed, the *raison d'être* of IQSY is to seize upon this new opportunity for a concerted attack on fundamental physical problems that can only be studied in nature's vast laboratory. The approach to the problems being pursued is precisely that of the laboratory physicist, except that nature performs the experiment. To cite one example, theoretical advances in plasma physics can be checked in some cases only by observing phenomena which cannot yet be scaled to laboratory dimensions.

While synoptic measurements are of great value, the network type of program is restricted in IQSY to the study of specific problems. For example, the choice of sites for new cosmic-ray stations has been dictated by considerations of the optics of charged particles moving in the geomagnetic field to provide optimum conditions for pinpointing anisotropies. Furthermore, in situ measurements

Series shows the change in activity from minimum to maximum to minimum. Notice the two high latitude zones of activity early in the cycle, the general mixture of high and low latitudes near the maximum, and the low latitude zones as the cycle advances. (McMath-Hulbert Observatory, University of Michigan Photo)



August 27, 1954



August 2, 1956

are now able to answer precise questions concerning areas, such as the aurora, where previously the only recourse was through essentially visual types of observations.

In terms of subject matter, there are eight IQSY disciplines. It is the essence of IQSY that most of the projects have broad interdisciplinary implications.

It is not our present purpose to attempt to describe in detail the entire United States Program for IQSY². In fact, it is possible to mention only a few specific examples of work that is now under way. Many of the projects involve extensive networks of stations accumulating synoptic data. Furthermore, a large number of experiments require the acquisition of data over an extended period of time before the results can be evaluated. Consequently, with rare exceptions, it is premature at this time to cite conclusions. However, from currently available information, we are at least able to report generally on several representative facets of the US participation in IQSY. The specific projects delineated in the following outline of the programs of the eight IQSY disciplines were selected solely on the basis of ready availability to the writer of information concerning their current status.

Meteorology

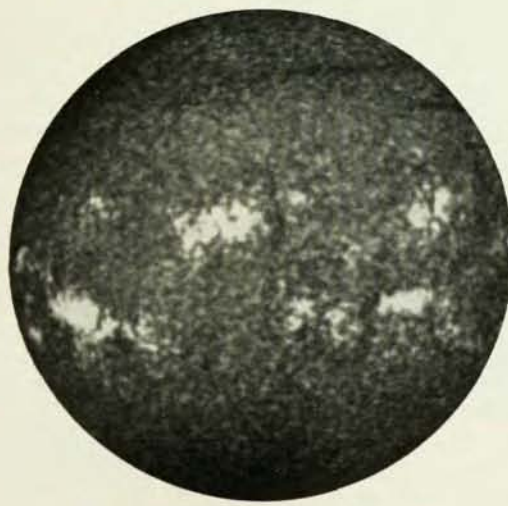
The subject of sunspot-cycle influences on weather and other phenomena at the bottom of the atmosphere has been most controversial. Even aside from questions which arise when the analyses are subjected to searching statistical scrutiny, the ex-

tensive literature, replete with claims for solar-cycle variations, has not led to any generally accepted conclusions. Nevertheless, it has been realized for a long time that the ionosphere is under solar control. Furthermore, satellite observations have now dramatically revealed that upper-atmospheric temperatures are, in fact, influenced by the level of solar activity, as well as by distinct solar disturbances. In particular, significant energy transfer is achieved through particle fluxes as well as through electromagnetic radiation from the sun. Thus, measurements at extreme altitudes, rather than in the traditional realms of classical meteorology, now afford the possibility of directly and quantitatively observing the intermediary whereby solar effects are propagated to the lower atmosphere.

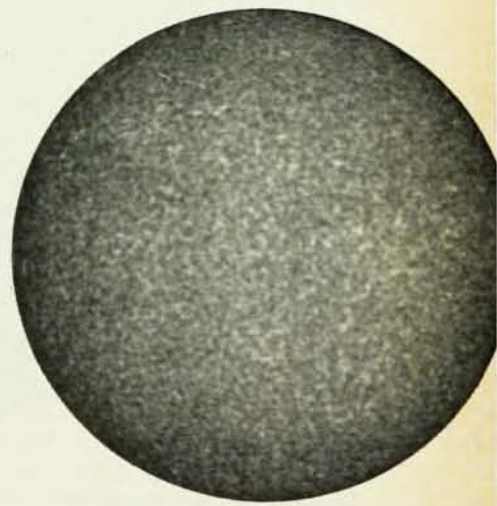
For the construction of mathematical models incorporating the physical, dynamical, and thermodynamical characteristics of the atmosphere, it is necessary to take into account the energy transfer that occurs not only horizontally, but vertically as well. The requisite three-dimensional synoptic picture of the atmosphere is now being attained. To achieve this goal, the meteorological program during IQSY is concentrating upon phenomena at high altitudes, that is, above the 100-millibar level, or in the upper 10 percent of the atmosphere. Effort is being devoted to problems involving the couplings between the upper atmosphere and the lower-lying realms of conventional meteorology. Soundings are being carried out not only with balloons capable of attaining very high altitudes, but also with rockets launched in a coor-



May 25, 1958



July 17, 1961



June 26, 1964

dinated manner for determining meteorological parameters up to 60 kilometers and even higher. Minor atmospheric constituents such as ozone, water vapor, and particulates, significant in the radiation balance process, are being studied, and thermal radiation measurements are being made throughout the atmosphere.

Typical of the IQSY meteorological program is the analytical work being conducted at the US Weather Bureau (S. Teweles). In accordance with the objectives of IQSY, the member countries of the World Meteorological Organization (WMO) agreed to exchange rawinsonde data (from a balloon-borne sounding device) for levels up to 10 mb on a daily schedule beginning January 1, 1964. With stratospheric data available currently for the first time, meteorologists of the Weather Bureau's Stratospheric Meteorology Research Project (SMRP) are now able to pursue several new scientific endeavors. The special IQSY responsibilities of SMRP include:

1. Daily regional and world-wide alerts on the status of wintertime phenomena known as stratospheric warmings.
2. Ten-mb wind trajectories for the polar circulating balloon observatory (POCIBO) project described later in this report.
3. Daily computer analysis of the height and temperature patterns at the 100, 50, 30, and 10-mb levels.

These activities have been providing rocket-sonde, rawinsonde, ozonesonde (a balloon-borne

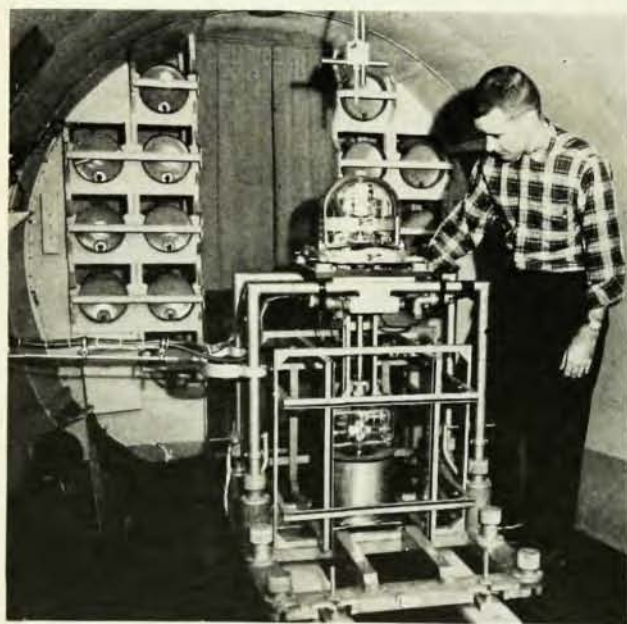
technique for measuring ozone content) and constant-level balloon stations with the knowledge necessary for obtaining additional information during periods of stratospheric unrest, or for launching special equipment under favorable conditions.

Preparation of alert messages and POCIBO trajectory forecasts have been greatly facilitated by the availability of the IQSY computer-analyzed stratospheric constant-pressure map series for the northern hemisphere. Although the system for producing these stratospheric maps was still in the developmental stage during early 1964, the maps provided a wealth of information not otherwise available. These maps and magnetic tapes of grid-point data will be made available to other interested meteorologists.

Geomagnetism

An accurate determination of the configuration of the earth's magnetic field is not only of classical interest with respect to its mathematical representation by spherical harmonic analysis, but is important because it governs all charged-particle phenomena in the vicinity of our planet. Among other things, it controls the orbits of incoming cosmic rays, and prescribes limited impact zones in which particles can arrive from the sun. Of course, it also gives rise to the radiation belts. A complete description of the main field, which arises from the phenomena in the interior of the earth, can best be based on data obtained during solar minimum, when disturbances produced by processes in the upper atmosphere are not predominant. The World Magnetic Survey, a project aimed at mapping the field by all available means, is linked closely to IQSY, and is making use of data now being obtained with magnetometers carried over land, on ships, and aboard rockets, aircraft, and satellites. As an example, we may cite the US Naval Oceanographic Office Project MAGNET (G. R. Lorentzen) which is currently conducting world-wide surveys with a vector airborne magnetometer.

Thus far, during the first half of 1964, three round-the-world cruises, covering 100 000 miles of survey tracks, have been conducted by a Super-Constellation aircraft. Complementing the magnetometer observations, the relationships between cosmic-ray intensity and the geomagnetic field are being studied with a complete cosmic-ray station. It consists of a neutron monitor and a meson telescope, and is being operated aboard the plane in collaboration with the Bartol Research Foundation (M. A. Pomerantz).



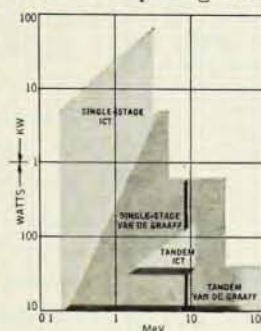
Magnetometer detection mechanism as installed in the US Naval Oceanographic Project MAGNET survey aircraft. This instrument detects the magnitude and direction of the earth's magnetic field. (US Navy photo)

CHARGED PARTICLES



Development of higher energy Van de Graaff particle accelerators which retain high beam precision, stability, and homogeneity, remains a continuing contribution by HVEC to "energy-oriented" research.

To provide even greater freedom of experimentation, HVEC is also anticipating the need for the higher beam intensities required in power-oriented research projects. Invented by Dr. R. J. Van de Graaff, the new Insulating Core Transformer (ICT) accelerator now provides high beam currents with all the desirable beam char-



THE ICT CONCEPT:

new high-current machines
emerging from HVEC research

acteristics of Van de Graaff machines. As the graph shows, the high power levels available from the ICT accelerator now make possible a new realm of precision experimentation.

The Insulating Core Transformer

The ICT is essentially a three-phase power transformer with multiple secondaries, each of which is insulated from the other. Rectified current from the secondaries is series-connected to achieve total voltage. In the ICT, electrostatic and electromagnetic fields exist in the same space, as contrasted to the conditions in a conventional transformer. The result is a highly efficient dc power source capable of stable operation at elevated potentials and power levels.

A number of ICT accelerators and power generation systems are now available.

Single-Stage ICT Accelerators

Two types of single stage ICT accelerators have been developed for research use. The first incorporates an ICT power source coupled to the acceleration assembly through a coaxial cable.

	PROTON ENERGY (KeV)	CURRENT (MAX.) (Analyzed)	TANK HEIGHT Feet	TANK HEIGHT Meters	TANK DIAMETER Feet	TANK DIAMETER Meters
ICT 300	300	15 mA	4'4"	1.32	4	1.2
ICT 500	500	10 mA	5'3"	1.60	4	1.2

The second system utilizes a rigid transmission line to transmit electrical power to the accelerator terminal.

4 MeV ICT	ENERGY (MeV)	CURRENT	DIMENSIONS Length	
			Feet	Meters
Positive Ions	1.5-4	3 mA	26'6"	8.08
Electron Conversion	1.5-3	10 mA	26'6"	8.08
3 MeV ICT Electrons	1.5-3	20 mA	29'	8.84

8 MeV ICT Tandem Accelerator

The 8 MeV ICT Tandem provides proton energies continuously variable from 3 to 8 MeV at a maximum guaranteed beam current of 2 μ A. The ICT power source is capable of providing 12 mA at 4 mv which, in combination

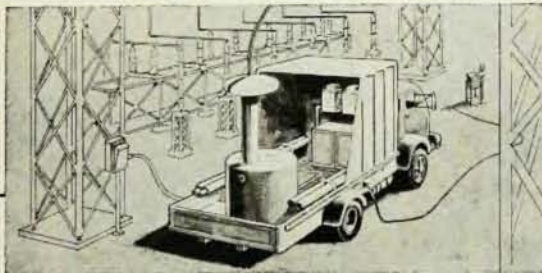
with newly developed components emerging from HVEC, will enable the accelerator to keep pace with future research requirements. The 8 MeV Tandem is convertible to single-stage ion or electron operation.

ICT Electron Processing Systems

Developed primarily as high-current sources of electrons for industrial processing applications, these systems allow extreme flexibility of operation. Two models are available: 300 kv at 30 mA maximum beam current and 500 kv at 20 mA maximum beam current.



Series 7 ICT Power Supplies



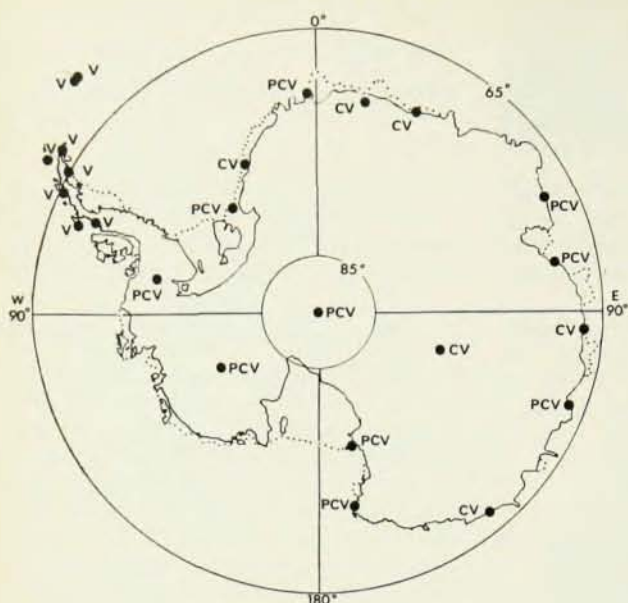
ICT equipment has crossed many barriers to dc operation at high particle energies and currents. There is no indication that a ceiling exists to further advances of similar importance.

Available with output ratings ranging from 240 kv at 80 mA to 600 kv at 20 mA, these highly stable power sources are suitable for use in high energy beam separator systems, r.f. transmission systems, plasma research and high voltage testing programs.

For detailed information, please write to Technical Sales, High Voltage Engineering Corporation, Burlington, Massachusetts.



HIGH VOLTAGE ENGINEERING



Auroral stations in Antarctica. P, photometer; C, all sky camera; V, visual observation

Magnetic disturbances on a variety of time scales are closely related to many geophysical phenomena, and are relevant in understanding the interactions of the earth's field with arriving radiation and matter. In addition to a more extensive network of ground-based magnetic observatories than has existed heretofore, special equipment for measuring rapid variations (micropulsations) is now in operation. Electric currents flowing in the earth and high in the atmosphere are being measured.

Rocket and satellite-borne instruments are probing the magnetosphere and beyond. The boundary region of the magnetosphere, the magnetopause, and the transition region between the sun's atmosphere and the earth's, which probably affects many phenomena below, is now being explored

directly. The first NASA interplanetary monitoring platform (IMP-I) is providing data from a number of different experiments that have already led to important new findings.³ For example, the first direct evidence was obtained for the existence of a collisionless magnetohydrodynamic shock wave in the space enclosing the earth and its magnetosphere.

Aurora

The auroral light resulting from the interactions of charged particles with the upper atmosphere has been studied indirectly for many years by visual means and with cameras, photometers, and spectrographs on the ground. Direct measurements are now being made of the properties of auroral particles and of their environment. With instrumentation carried by balloons, rockets, and satellites, it is feasible to determine the energy and spatial-temporal distributions of the particles that produce auroras, and to study the mechanisms of their acceleration and precipitation.

At solar minimum, auroral displays occur only in a relatively narrow zone in the polar regions. For that reason, polar-orbiting satellites and balloon and rocket launches from appropriate sites are required, and ground stations must be located at high latitudes. The above map shows the excellent synoptic coverage which has been achieved for IQSY in this case, thanks to the remarkable research facilities now available in Antarctica. A new scheme for describing auroral forms (important in studies of the morphology of aurora) was adopted for IQSY and is proving quite satisfactory.

Airglow

The geocorona, a ring of hydrogen that girds the earth and is detectable through the Lyman α light which it emits, has assumed a special importance



A view of the Eight conjugate point station Antarctica (NSF Photo)

because it is subject to spatial distortions produced by the flow of the solar wind past the earth. Other airglow emissions are yielding important information about the structure and chemical composition of the upper atmosphere. Rocket-borne instruments provide vertical-height profiles, and satellites permit more thorough monitoring of the spatial and temporal variations. Taking advantage of the reduced auroral background, ground-based stations are extending the geographical range of the observations during IQSY. Furthermore, absolute photometric measurements are being extended down to lower thresholds than heretofore.

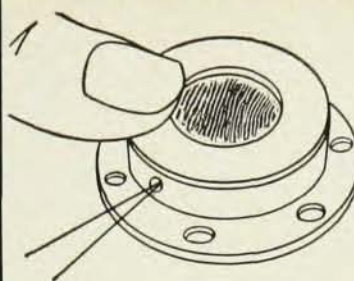
Ionospheric physics

Several programs of continuous observations of the ionosphere by different techniques are being conducted by a world-wide network of stations. The topside sounding method is also being utilized, and the Alouette satellite is still providing useful data. Another new technique utilizes high-powered radar for sounding the ionosphere to very great distances in order to obtain information on electron and ion temperatures. Whistlers (signals of descending audio frequency generated in association with lightning strokes and propagating along the geomagnetic field lines) and ionospheric (signals thought to be generated in the magnetosphere or ionosphere by streams and clouds of charged particles) are providing important new insights into the characteristics of the outer ionosphere and the entry of charged particles into the geomagnetosphere.

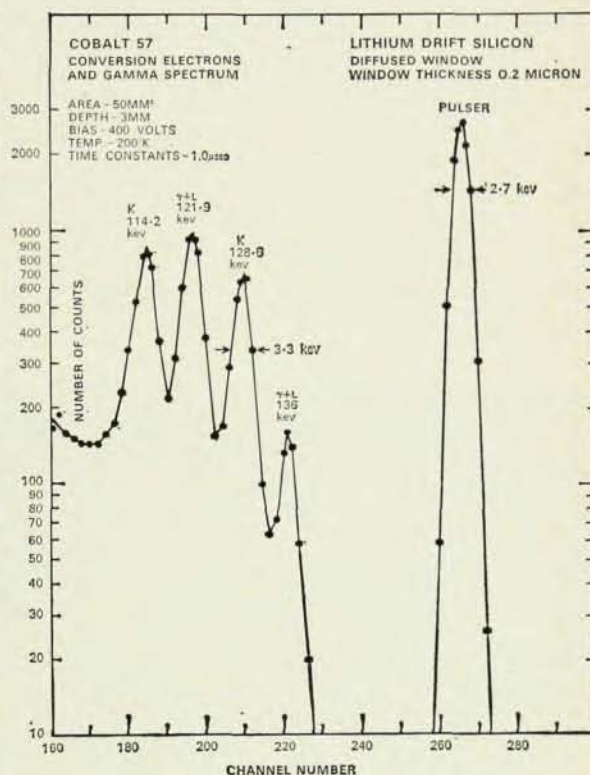
Observations at conjugate points (opposite ends of a line of force) provide a wide complement of observations of upper-atmosphere phenomena. These include absorption (riometer), vertical incidence soundings, geomagnetic variations and micropulsations, very low and extremely low frequencies, airglow emissions, and auroral all-sky camera photography. With the cooperation of Canadian colleagues, two pairs of stations (Eights Station in Antarctica and Baie Saint Paul in Canada— $L = 4$; and Byrd Station in Antarctica and Great Whale River in Canada— $L = 7$) * have been established for this purpose. Observations on a more limited basis are also being obtained at other pairs (South Pole Station in Antarctica and Frobisher Bay in Canada— $L = 15$; McMurdo

* L is the radial distance from the center of the earth to a magnetic shell if the field of the earth were a centered dipole. In practice, the L value is roughly the distance, in earth radii, from the line of force which it specifies to the earth's center.

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Sound in Antarctica and Shepard Bay in Canada ($-L = 20$). Stations in Alaska (with L values ranging from 2 to 7) are conjugate to Macquarie Island, Campbell Island, and South Island, New Zealand.

Advantage is being taken of the increased transparency of the ionosphere for extending radio-astronomical observations of galactic and extragalactic sources down to frequencies as low as a few megacycles per second. Furthermore, radio surveillance of several planets is being undertaken in an effort to detect responses to solar disturbances similar to those observed at the earth. Jupiter is of particular interest in this regard.

Cosmic rays and trapped particles

The lower end of the energy spectrum of galactic cosmic rays is being investigated in considerable detail, since the shielding effect of the sun-imposed modulation mechanism is now minimal. At other phases of the solar cycle, this effect prevents them

from reaching the inner solar system. In particular, isotopic and charge composition, as well as the controversial problem of the shape of the primary energy spectra of the various components at the low end, are being studied by a variety of techniques.

Widely dispersed ground-based equipment includes new neutron monitors and meson telescopes with exceedingly high counting rates. These afford an unprecedented statistical precision in detecting temporal variations of small amplitude over various time scales with a heretofore unattainable resolution. Time variations and spatial anisotropies, including those of solar origin as well as sidereal effects, are being studied during IQSY under practically ideal conditions.

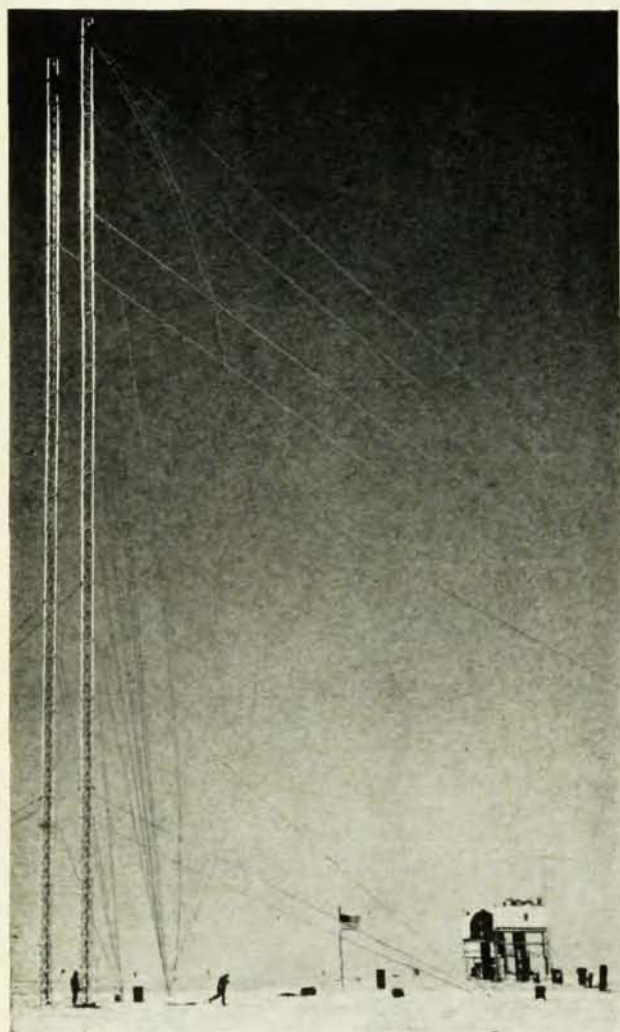
Solar-produced particles are being investigated by means of apparatus on the ground, by balloon-borne instruments launched in the polar regions, and by instrumentation aboard spacecraft.

Many varied investigations of the geomagnetically trapped radiation are being conducted with a host of satellite-borne instruments. Conditions for determining the base-line characteristics of the radiation belts are now optimum since their configuration is probably most stable at solar minimum. Solar effects, and particle injection, storage, acceleration, and precipitation mechanisms are also being investigated.

For example, particle detectors aboard IMP I have found electrons with energies > 30 keV in the shock front (arising from the super-Alfvénic flow velocity of the solar wind through the interplanetary magnetic field) where it interacts with the geomagnetic field. The energy spectra, fluxes, time variations, and other features of solar and galactic cosmic rays, and of the particles comprising the solar wind, are also being studied with this spacecraft.

Again, by way of example, progress in several other IQSY projects of an interdisciplinary nature, but having strong cosmic-ray overtones, can be reported at this time.

Discrete solar-particle-emission events are now being detected under a program for monitoring the D region of the ionosphere by means of forward-scatter radio-wave propagation, which is being carried out as a collaborative effort of the National Bureau of Standards (D. K. Bailey) and the Bartol Research Foundation (M. A. Pomerantz). Pairs of transmitting and receiving stations are functioning satisfactorily in the Antarctic (Byrd-McMurdo, McMurdo-Vostok, Byrd-South Pole, and South Pole-Halley Bay) and in the northern hemisphere (Annette-Fairbanks, Barrow-



Transmitting antenna, South Pole (NBS photo)

Anchorage, Frobisher Bay-Great Whale River). These cover a wide range of geomagnetic threshold rigidities for determining the energy spectrum of the solar-produced cosmic rays from a few million electron volts upwards, and of geographical locations for investigating possible impact-zone effects.

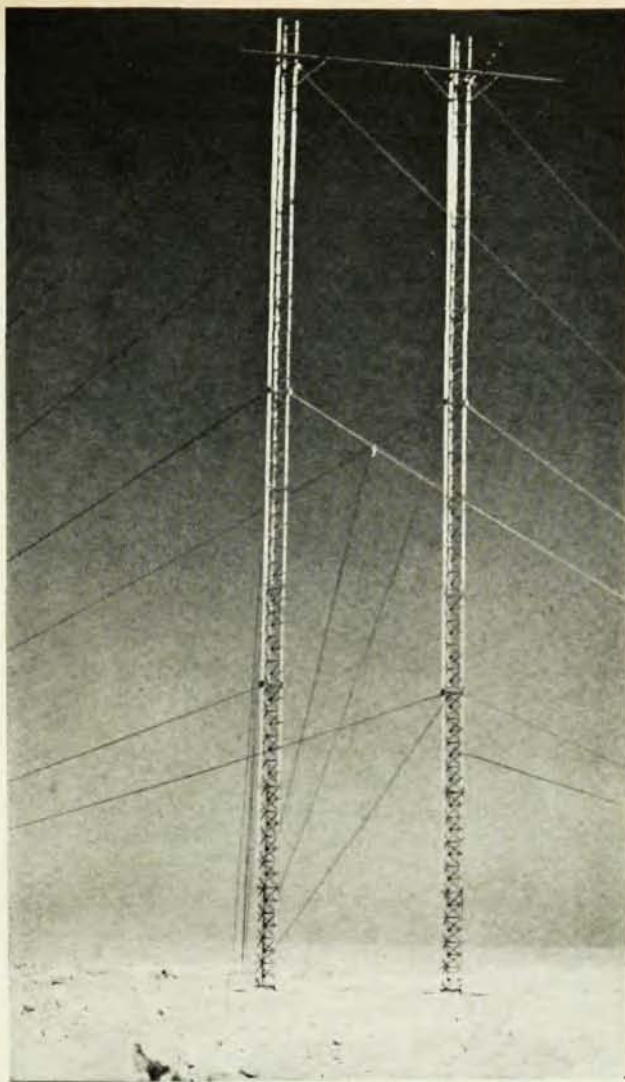
Implementation of this program called, among other things, for heroic feats such as those accomplished by the Navy's Seabees (Construction Battalion Eight, Task Force 43) in erecting antenna towers up to 180 feet in height (two towers, 18 feet apart, were required for each 30-foot-long antenna boom) under the unfriendly Antarctic conditions. The existence of previously undreamed-of logistical capabilities for conducting scientific research in Antarctica provides one of the prime motivations for IQSY.

Another undertaking, the plans for which have just become crystallized, is the IQSY balloon expedition to the equatorial region ("IQSY-EQEX") in India during the spring of 1965. Bertram Stiller of the Naval Research Laboratory is serving as scientific coordinator for the program. Responsibility for the administration, operational and logistical planning, and conduct of the expedition rests with the National Center for Atmospheric Research (NCAR). The scientific payloads will be provided by investigators from a number of institutions. Indian colleagues, particularly at the Tata Institute, are cooperating with United States scientists in organizing the expedition. Because of technical problems associated with the effect of the low temperature of the equatorial tropopause on thin polyethylene balloons, a number of test launches are being conducted at the present time. These will also provide information concerning the relevant meteorological parameters.

Among the experiments contemplated thus far, are the following:

University of Minnesota (J. R. Winckler). A self-recording ion chamber will be flown to provide an equator value for the total ionization, as part of a complete latitude curve being obtained during solar minimum.

(C. J. Waddington). A large-area nuclear-emulsion stack mounted in an emulsion camera will make it possible to investigate the very high charge nuclei of the primary cosmic radiation in much greater detail than has otherwise been feasible. Heavy nuclei are more strongly affected than other cosmic-ray primaries by physical processes (such as ionization loss) that depend on the charge of the nucleus. A detailed investigation of the characteristics of this component of the galactic cosmic radiation can indicate whether such physical processes play an important role in either the acceleration or propagation through interstellar matter.



Receiving antenna, South Pole (NBS photo)

Naval Research Laboratory (M. M. Shapiro). By means of nuclear research emulsions with various sensitivities and a large area, the charge spectrum of primary heavy nuclei ($Z > 3$) will be determined for the first time at the geomagnetic equator—with an almost negligible correction for fragmentation in the overlying atmosphere. These data, together with similar exposures during IQSY at high latitudes, will make possible a comparison of spectra, fluxes, and ratios of light to medium to heavy groupings for heavy primary cosmic-ray nuclei over a wide range of energies. This is also relevant in studies of mechanisms which may play a role in the propagation of the cosmic radiation through interstellar space.

Southwest Center for Advanced Studies (K. G. McCracken). The energy spectrum of the cosmic radiation in the range 15-40 BeV, about which little is known at present, will be studied. This is of fundamental interest not only with respect to the cosmic-ray energy distribution over a generally unexplored range, but also from the point of view of the so-called specific-yield functions which describe quantitatively the response of ground-based neutron monitors to primary flux variations.

New York University (S. A. Korff). The flux of fast neutrons will be measured in order to provide

data of importance in understanding the problem of neutron equilibrium in the atmosphere. This will complement measurements made at other latitudes to take into account the variation of both the multiplicity of neutron production and of primary flux. Since some of the neutrons, especially at high elevations, diffuse outward from the top of the atmosphere, the measurements are also expected to throw some light on the albedo of the atmosphere for neutrons at various energy intervals. Furthermore, the integrated total number of neutrons produced in the atmosphere at various latitudes is relevant to the interpretation of radiocarbon data. The number of neutrons at various altitudes appears to depend very considerably upon the level of solar activity, and this experiment is expected to indicate the magnitude of the dependence.

University of Rochester (M. F. Kaplon). A detector for measuring the integral intensities of various charge groups of the primary cosmic radiation will provide information on the rigidity dependence of the solar-cycle modulation. It will also measure the splash albedo; the comparison of the data with those obtained with an essentially identical detector aboard the satellite OSO C should help in further assessment of albedo problems.

Washington University (M. Friedlander). The geomagnetic cutoff and the energy spectrum of α particles up to about 10 BeV/nucleon will be determined. The charge spectrum of the multiply charged particles will also be studied. A novel arrangement, consisting of photographic emulsions directly underneath a spark chamber which is triggered by a scintillation-counter telescope, will be utilized.

Air Force Cambridge Research Laboratory (J. T. Eley). A three-detector telescope (one Cerenkov and two scintillators) will be employed to measure the charge spectrum and the time variations of the flux of the heavy primary cosmic radiation.

University of California (K. A. Anderson). Taking advantage of the low γ -ray background expected near the equator, x-ray emission from the quiet sun in the energy region 10-80 keV will be sought with low-background collimated x-ray counters.

In some cases, by-products not specifically relating to IQSY, but nevertheless of fundamental interest, will result. It may also be possible to accommodate several other experiments, and it must be emphasized that, since the detailed plans are still developing, the above list may not be complete.

Still another ambitious program of balloon launchings, being carried out by the University of Minnesota (J. Winckler), is designated POCIBO (polar-circling balloon observatory). Balloons floating at altitudes of about 35 kilometers are being released from a point close to the center of the meteorological vortex system that develops over the geographic poles. The balloons, carrying scientific instruments capable of studying various features of the atmosphere, of the primary cosmic radiation, and of other radiations incident on the

polar-cap regions, will circulate around the vortex with the wind stream. Trial launches during March at Point Barrow, Alaska, tested the techniques and revealed certain problems with the large plastic balloons. Means for surmounting these difficulties are now being investigated.

Aeronomy

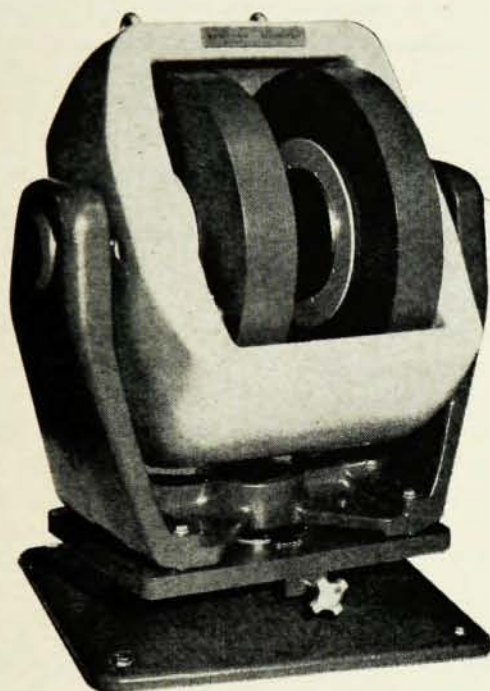
This discipline deals with the physics and chemistry of the atmosphere, and, hence, overlaps all of the others. All in situ measurements with rocket and satellite vehicles in the upper atmosphere are specifically within its scope. The observations include temperature and density structure, winds, composition (neutral, electron, and ion), electron-density profile, photochemical reactions that result in molecular dissociation, ionization and the creation of chemical species, diffusion of constituents, and the response of the atmosphere to solar input. A variety of techniques and instruments are employed. IQSY provides an unparalleled opportunity for obtaining a complete description of the undisturbed upper atmosphere to serve as a base line for comparison with the conditions which prevail during periods of unusual solar activity.

As a concrete example of the progress thus far in the IQSY synoptic rocket-sounding program for the exploration of the structure of the lower atmosphere, we can report that a total of nineteen Nike-Cajun or Nike-Apache rockets have been successfully launched during 1964 by the NASA Goddard Space Flight Center (W. Nordberg). Three of these soundings measured winds from the lower ionosphere by means of the photography of luminous trails produced by means of the sodium-release technique. Three others carried pitot tubes to measure pressure, temperature, and density between 40 and 120 km. These were launched at Ascension Island (7°S). The remaining thirteen measured temperature, pressure, density, and winds up to 90 km by the acoustic grenade technique.

The explosive grenades were fired at three sites, sometimes simultaneously: Churchill, Canada (59°N), Wallops Island, Virginia (38°N), and Ascension Island (7°S). During one such concurrent series on February 4 and 5, and during an individual sounding at Wallops Island on March 7, stratospheric warmings, to which we have referred earlier, were in progress. Preliminary analysis of these data indicates the expected latitudinal variation of temperature at the 50-km level with a very pronounced mesopeak in the tropics and a rather weak one at Churchill. Temperatures at Churchill at this level are about 40°K lower than

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in the tropics. However, this trend reverses at altitudes above 60 km. This series of synoptic soundings, which will continue throughout IQSY, is part of a world-wide program of simultaneous launchings by a number of groups in different countries.

The sun and the interplanetary medium

It is obvious that, to accomplish the purposes of IQSY, it is necessary to maintain a constant surveillance of the sun. Disturbances manifested by the emission of electromagnetic radiations over a wide range of wavelengths are being detected by continuous optical and radio patrols. X-ray and ultraviolet emissions to which the atmosphere is opaque are being monitored by satellites.

The IQSY observing program has a three-fold purpose. Solar data are, of course, essential for the interpretation of the results of most IQSY projects. The patrols also provide information that serves as a basis for solar activity forecasting, such as for rocket or balloon launchings, as well as for issuing on a day-to-day basis shorter-term alerts and warnings of solar events that may be impending or in progress. Alerts and warnings, as well as daily coded summaries of current solar and geophysical data, are disseminated by the World Warning Agency.⁴ Finally, the data are essential in studies of the sun itself.

Many aspects of solar physics relating to the sun's structure are being investigated, and new techniques, such as the use of high-power radars capable of producing echoes from the corona, are being employed.

The entire spectrum of solar electromagnetic and particle radiations is being studied with detectors on the ground, and aboard balloons, rockets, and spacecraft, to derive information on the

chemical composition, fluxes, and energy spectra of solar particles.

The interplanetary medium, permeated by plasma carrying frozen-in magnetic fields, is being investigated. The corpuscular radiation which constitutes the solar wind as well as the associated magnetic fields are being measured directly. The interplanetary magnetic field which originates at the sun is being measured continuously by equipment aboard IMP I. The early results have indicated a spiral structure in space arising from the rotation of the sun as it spews out plasma. The fact that the field lines remain anchored to the sun gives rise to the "garden-hose" effect.

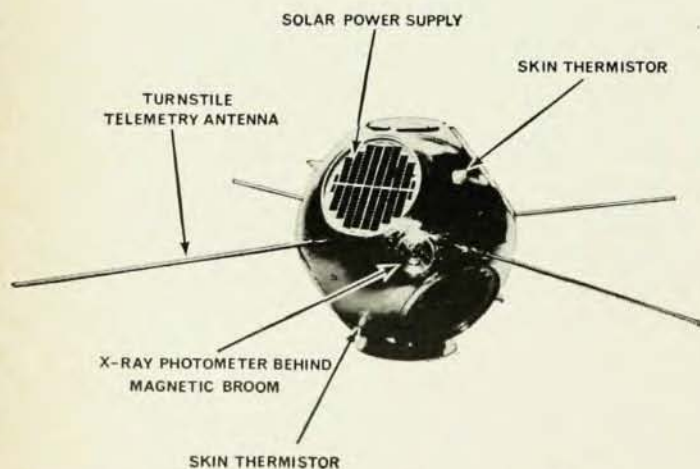
Other means of studying the nature of the interplanetary medium include such diverse approaches as observing zodiacal light with balloon-borne instruments, probing the cislunar gas with radar, recording the time variations of galactic cosmic rays modulated by plasma ejected from the sun, and observing the time history and directions of arrival of solar cosmic rays.

Is the sun cooperating?

Since the course of solar activity is not amenable to precise prediction, and it was necessary to plan IQSY far in advance, a great deal of soul-searching was required before scheduling the period during which the enterprise was to be conducted. Even so, it is already clear that the question "when will solar minimum occur?" or, alternatively, "when did it occur?" can be answered only in retrospect sometime hence.

Among the indices of solar activity that are compiled on a routine basis, the relative sunspot number enjoys the longest history. Regarded as an index of the activity of the entire visible disk, it is determined independently each day without reference to preceding days. Sunspot numbers have been compiled in accordance with a standardized procedure for more than 200 years.

The solar radio flux at a frequency of 2800 Mc/sec has also been adopted as an index of over-all solar activity. Centers of activity, such as calcium plage, and sunspot regions, are described in terms of area and brightness, or magnetic classification, respectively. Coronal line-emission indices for the green (Fe XIV at $\lambda = 5303 \text{ \AA}$) and red (Fe X at $\lambda = 6374 \text{ \AA}$) coronal lines are also determined on a regular basis. In addition to identifying centers of activity, these are integrated to obtain rough measures of the emission of the entire solar disk. Solar flares are also observed systematically, and, similarly, the individual data are combined to provide the flare-activity



Naval Research Laboratory solar radiation satellite

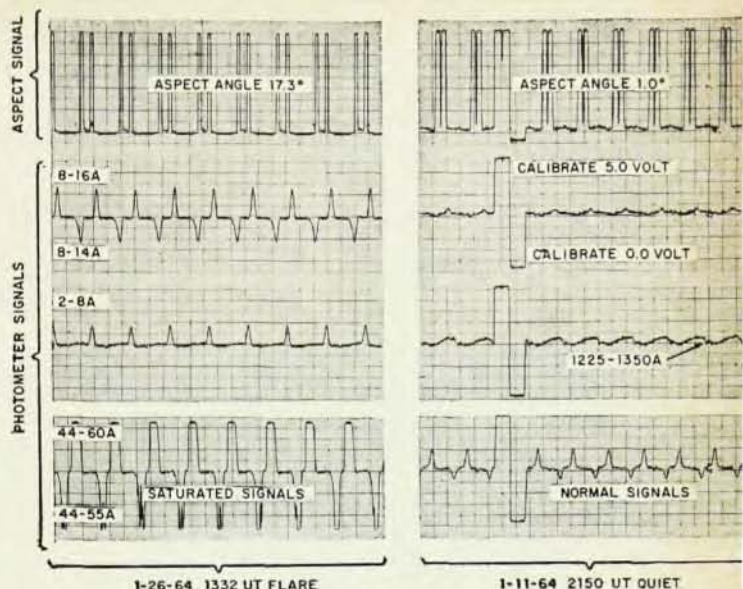
index. Finally, a number of geomagnetic indices, based upon ionospheric observations and geomagnetic activity, represent terrestrial effects of solar disturbances.

Since no adequate physical picture of the solar-cycle variation has yet been developed, the only recourse for prognosticating the course of solar activity during the remainder of IQSY is to play the numbers game. The McMath-Hulbert Observatory (H. Dodson Prince) is keeping close tabs on this problem,⁵ and, in addition, is providing exceedingly useful solar-activity forecasts each week for the three or four weeks following. Although the latter quite new venture is sometimes fraught with frustrations, it provides the only means by which experimenters can take advantage of the relatively brief intervals of true solar calm with which we may have to be content.

The last solar maximum (cycle No. 19) broke all previous records; the average monthly sunspot number reached 201, exceeding by 28 percent the highest previous value. Whether such an extreme maximum should be followed by an equally unprecedented high minimum, or by a very quiet minimum, cannot be predicted from past statistics.

The time and level of the minimum between successive maxima depend both upon the decline of old cycle centers and the formation of new cycle centers. The first spot of cycle No. 20 was observed on August 28, 1963. Eight spot groups of the new cycle have been observed during the first six months of IQSY. Since the evolution of the new cycle following the stage of development already reached is usually quite rapid, it is suggested that the minimum may be close at hand, or even past. In the latter case, the residual activity will have been unusually high, for the sunspot numbers dropped below ten for the first time in April 1964 and, although remaining there, did not drop as low as five. Observations of the 2800 Mc/sec flux, and of calcium plages, also lead to the same conclusion.

Solar x-ray flux measurements, obtained occasionally with rocket-borne instrumentation during the last solar minimum, are being monitored continuously by the Naval Research Laboratory (H. Friedman) solar radiation satellite launched in January. This IQSY satellite is making measurements of the x-ray flux in the bands 2-8, 8-14, 8-16, 44-55, and 44-60 Å. A photometer is included to make measurements in the 1225-1350 Å band. The first signals received from this new satellite revealed that the fluxes were as weak as were ever observed in 1954, during the last solar minimum. The x-ray emission in the shortest wave-



X-ray photometer signals telemetered from solar radiation satellite during periods of solar quiet and flare (US Navy Photo)

length band (2-8 Å) was already too faint to detect. At 10 Å, the sun was only 1/50th as bright as at solar maximum, and at 50 Å, only 1/10th as bright. This low level has remained almost constant, and it appears that this may be the minimum to be reached during IQSY.

If the sun continues to behave in this fashion, the planners of IQSY may well be tempted to crow over the correctness of their choice of dates. For, after deep consideration, a decision was reached in 1962 to advance the starting date from April 1 to January 1, 1964. Furthermore, this particular solar minimum may be unique in that we can enjoy the best of both worlds. On the one hand, the desired periods of solar calm, essential for achieving some IQSY goals, are occurring. And, on the other, there are enough distinct solar events to whet the appetite of any IQSY physicist.

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1. Martin A. Pomerantz, "International Years of the Quiet Sun 1964-65", *Science*, **142**, 3596 (1963).
2. A preliminary United States Program for IQSY was issued in February 1963. A revised edition will be issued in the near future and will be available from E. Dyer, Executive Secretary, US IQSY Committee, National Academy of Sciences, Washington 25, D. C.
3. See, for example, IG Bulletin, No. 84, June 1964.
4. The "IQSY Calendar" is published by and may be obtained from International Scientific Radio Union, 7 Place Danco, Brussels 18, Belgium. Copies are also available from the IQSY Secretariat. The calendar is reproduced in IG Bulletin No. 74, August 1963.
5. Helen W. Dodson and E. Ruth Hedeman, "Solar Minimum and the International Years of the Quiet Sun", *Science*, **143**, 237 (1964); and Helen W. Dodson, E. Ruth Hedeman, and Frederic L. Stewart, "Solar Activity During the First Six Months of IQSY" (to be published in *Science*).