INTERNATIONAL GEOPHYSICAL YEAR

27 January 1959

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INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

Dr. Lloyd Berkner, President of Associated Universities, Inc., of New York (operators of Brookhaven National Laboratory and the National Radio Astronomy Observatory) was born in Milwaukee on 1 February 1905. He holds a B. S. in EE from the University of Minnesota (1927) and did graduate work in physics at George Washington University. He holds honorary doctorates from Brooklyn Polytechnic Institute, and the Universities of Calcutta and of Uppsala, Sweden, D. Sc., Dartmouth College, 1958 and D. Sc., Notre Dame University, 1958. In aviation he worked with the Department of Commerce in the installation of early radio range equipment. On active duty as a naval aviator in World War II he organized and headed the Radar Section and then the Electronics Materiel Branch of the Bureau of Aeronautics, subsequently serving on the USS Enterprise during the Okinawa operations. He holds the grade of rear admiral, USNR. He was the first Executive Secretary to the Research and Development Board, later Special Assistant to the Secretary of State for the first military assistance program of the North Atlantic Pact, and Chairman of the Special Survey Committee for the Secretary of State to examine into the problem of foreign relations, authoring the official State Department report "Science and Foreign Relations." He served with the Bureau of Standards and the Carnegie Institution of Washington in research relating to the physics of the outer atmosphere and radio propagation and has published 75 papers and volume on these subjects. He has participated for more than 20 years in the wor of international scientific unions and is past president of the International Council of Scientific Unions and president of the International Scientific Radio and vice president of the Special Committee for the International Geophysical Year. He is a member or fellow of the professional societies relating to his scientific fields. He is a member of the Board of Advisers of the Industrial College of the Armed Forces. This is his third lecture at the Industrial College.

INTERNATIONAL GEOPHYSICAL YEAR

27 January 1959

GENERAL MUNDY: General Harrold, Distinguished Guests, Gentlemen: Our subject this morning is a review of the evaluation, of the findings, and of the accomplishments of the recently completed "International Geophysical Year." This lecture was originally scheduled a little earlier, but it was necessary to postpone it because our speaker made a visit to the Antarctic in connection with his IGY duties.

Dr. Berkner is eminently qualified to speak to us on this subject. Not only was he the original proponent of the IGY but he has been one of its most active workers. Since his graduation from college he has specialized in scientific research. During the war he was on duty as a naval officer, and today he is a rear admiral in the United States Naval Reserve. He is also a member of the Board of Advisers of the ndustrial College of the Armed Forces.

It is a great deal of pleasure and a privilege to bring back to the wo Colleges for his third talk, the president of Associated Universities, ncorporated, Dr. Lloyd V. Berkner. Dr. Berkner.

DR. BERKNER: General Mundy, General Harrold, Members and Guests of the Colleges: It is a real pleasure to come back here. If you will pardon my repeating a story that I think you heard before, General Mundy, whenever I talk of geophysics I am always reminded of the story f the young Britisher who came over here a few years ago with his Jaguar. Geophysics is really a very complicated subject, because, as I will point out n the course of my lecture, it involves the use of all the sciences and it nvolves the interconnection of a whole series of phenomena. Things that happen on the sun which produce other phenomena that occur on the earth and react in a whole series of ways. The story, which I believe I have told o some of your predecessors in the College, relates to the young fellow who was driving the Jaguar over the mountains in western Massachusetts much too fast, about 90 or 100 miles an hour. He came over the top of he hill and he saw a small village ahead and he realized he couldn't slow own in time to pass through this village properly. Unfortunately, there was a crossroad passing through it. The village had just a filling station n one corner and a church on another, and a store on the third, and so on. There was something going across the crossroad, and, as he approached, he realized that it was a circus parade. Indeed, there were a series of lephants marching down this crossroad, each one holding the tail of the elephant in front of him with his trunk. As this fellow got to the crossroad he thought he would just clear behind the last elephant, but, just as he got there, a baby elephant appeared from behind the church holding its mother's tail. So the young fellow ran slam-bang into the baby elephant and landed in the ditch. As he was climbing out of his Jag, the circus manager came over and said, "Man you owe me $100,000." The Englishman said, "What? A hundred thousand dollars for a baby elephant? The manager said, "Baby elephant, hell. Don't you realize you pulled the tails out of six elephants?"

In speaking of geophysics you have the same kind of complicated interaction, and you never know quite how many elephants are going to be involved, how many phenomena are going to be interconnected in an intimate way.

The International Geophysical Year has been a great cooperative effort of thousands of scientists of 66 nations to study our earth as a planet. After several years of preparation and negotiation among these nations, the year started on 1 July 1957, and ended on 31 December 1958

By way of introduction, one might say that, of the nine planets of the solar system, planet Earth is probably the most interesting. In fact, if a space voyager arriving in our solar system were to choose which planet to explore first, planet Earth would probably be his number one choice; for planet Earth is just of the right size and density to hold an atmosphere of the kind that protects and supports the higher forms of life and is just the right distance from the sun to provide a suitable rang of temperature to encourage the advanced forms of life.

While primitive forms of life may exist on other planets of the solar system, notably Mars, and probably or possibly Venus, the situations and structures of these planets seem far less favorable for any very advanced form of life. Therefore, in the study of the solar system, Planet Earth certainly holds the spotlight.

Quite aside from the academic interest of the astronomer and the geophysicist in the earth as a planet, improvement of knowledge of the enviroment that the earth provides as man's home, of course, gives him many advantages in the control of and adaptation to that environment.

The study of the earth by observers on its surface is of course very difficult. A single observer cannot see our earth as a whole planet as h sees Mars or Venus, but instead we must station observers at a large mber of places over the whole of the surface. Their observations ve to be made with methods that are sychronized at the same time and en fitted together to see the whole planet in each special aspect that is der study, and of course the standards of measurement have to be the me.

The atmosphere above us admits only a very narrow band of light d another limited band of radio waves. Actually, our atmosphere is ke a heavy curtain that on one hand protects us from the lethal rays of e sun and other objects outside, but on the other hand keeps us from eing very much of the things that are happening there. Only a few jects, such as large meteorites and very powerful cosmic rays, ever cceed in breaking through this atomshpere. It has been only in recent ars that we have penetrated the atmosphere with rockets to see more early the character of the space outside, and, during the IGY, of course, an launched his first earth satellite to keep this whole space under continuous observation. If you look below us, we can drill wells only about x miles deep at the maximum, and greater depths cannot be observed ectly.

Thus, you might say, as we live on the surface of the earth we are nfined to a very thin layer, like the ham in a sandwich, with a thick d quite insulating atmosphere above and an almost impenetrable floor neath. So the science of geophysics has been developed not only to amine this thin layer in which we live but also to permit the exploran of the regions above us and below us, and it is closely connected, course, with the science of astronomy.

To understand the earth as a planet, the 66 nations agreed, during IGY, to establish thousands of geophysical stations and to observe the le earth and its external environment in many scientific aspects. om the observations of this network combined together for the whole th we are able to describe the earth's phenomena as they develop tant by instant. Special effort has been devoted to observations in the re inaccessible regions of the earth. By the beginning of the IGY entists in the Arctic had started research at more than 100 stations. n from both the United States and the USSR had established extraordiy scientific stations on floating ice floes only a few feet thick that were ting with the ocean current across the Arctic Ocean.

In Antarctica 12 nations have established more than 50 scientific ions to examine the southern extremities of the earth--this almost wn seventh continent of more than 6 million square miles--the size of th America.

I might say as an aside that I was at Byrd Station, which you see on this map, a few weeks ago (figure 1, page 5). Just as I was arriving--I thought I was in the most isolated spot in the world, away up on that plateau with nothing but a desert of ice in every direction--Steve Barnes, the chief scientist, came running out to me as our plane landed, and said, "Lloyd, come on in quickly. There's a telephone call for you." It turned out that is was Hugh Odishaw calling from the IGY office in Washington, and he said, "Our ice floe station in the Arctic has just split apart. The Air Force has evacuated the personnel and the records, but everything else is lost." He continued, "What do we do? Shall we appropriate another $100, 000 to establish another ice floe station or not?" This station is indeed being reestablished.

Elsewhere over the earth thousands of stations in every latitude were beginning the special IGY observations for a better understanding of our planet (figure 2, page 6). Men were preparing to explore the atmospher and the regions beyond, and scientists in the United States and USSR, of course, were preparing for the launching of the first artifical satellites which were later to circle the earth, to make important observations of its environment in space as it courses on its orbit around the sun. I will speak much more on the satellite later (figure 3, page 7).

Geophysicists use the tools and methods of every other science to study our surroundings (figure 4, page 8). Here you see the various disciplines that were studied during the International Geophysical Year. Indeed, there was one more not on this slide, and that was the radioactivity of the atmosphere, which was used as a tracer for the following of its circulation. They describe their findings about the earth in the language of mathematics. When an earthquake shock is generated from a sudden crack or slippage in the earth's crust, the shock from the earthquake generates a series of waves known as seismic waves that spread from this break, this crack that has caused the earthquake, through the surrounding earth. They travel along the earth's surface and through its interior, and can be seen with instruments nearly everywhere over the surface. The shape, speed, and direction of these seismic waves, received at different places, can provide us with a surprisingly detailed picture of the regions of the earth's interior through which they have traveled. Likewise, the vibrations in the earth produced by the sharp explosion of very large hydrogen bombs gives us additional knowledge of a small and very heavy interior core of the earth centered well within th central molten core. By setting up small artifical explosions, scientist may explore in great detail the depths below any specified area.

PLANNED ANTARCTIC STATIONS

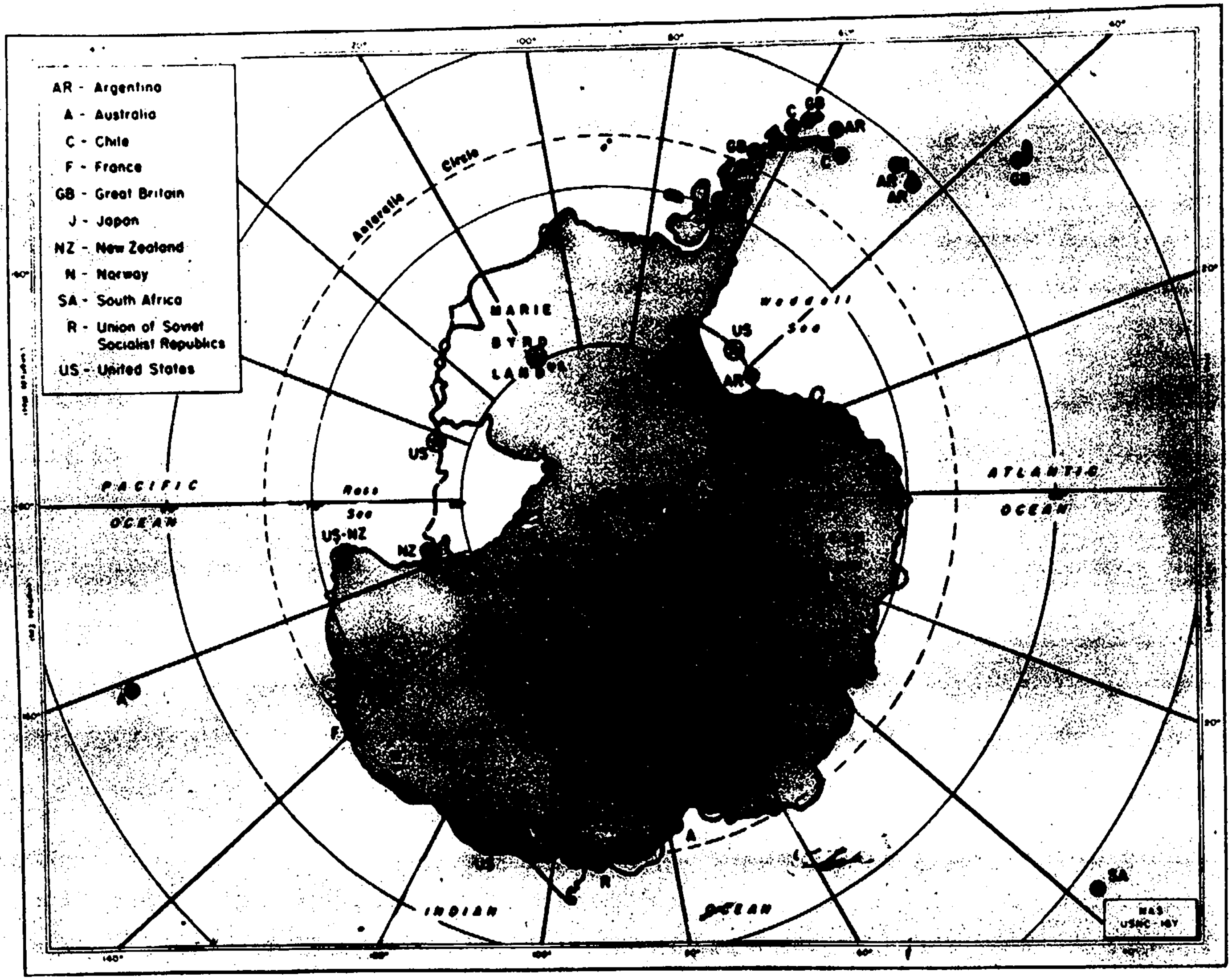
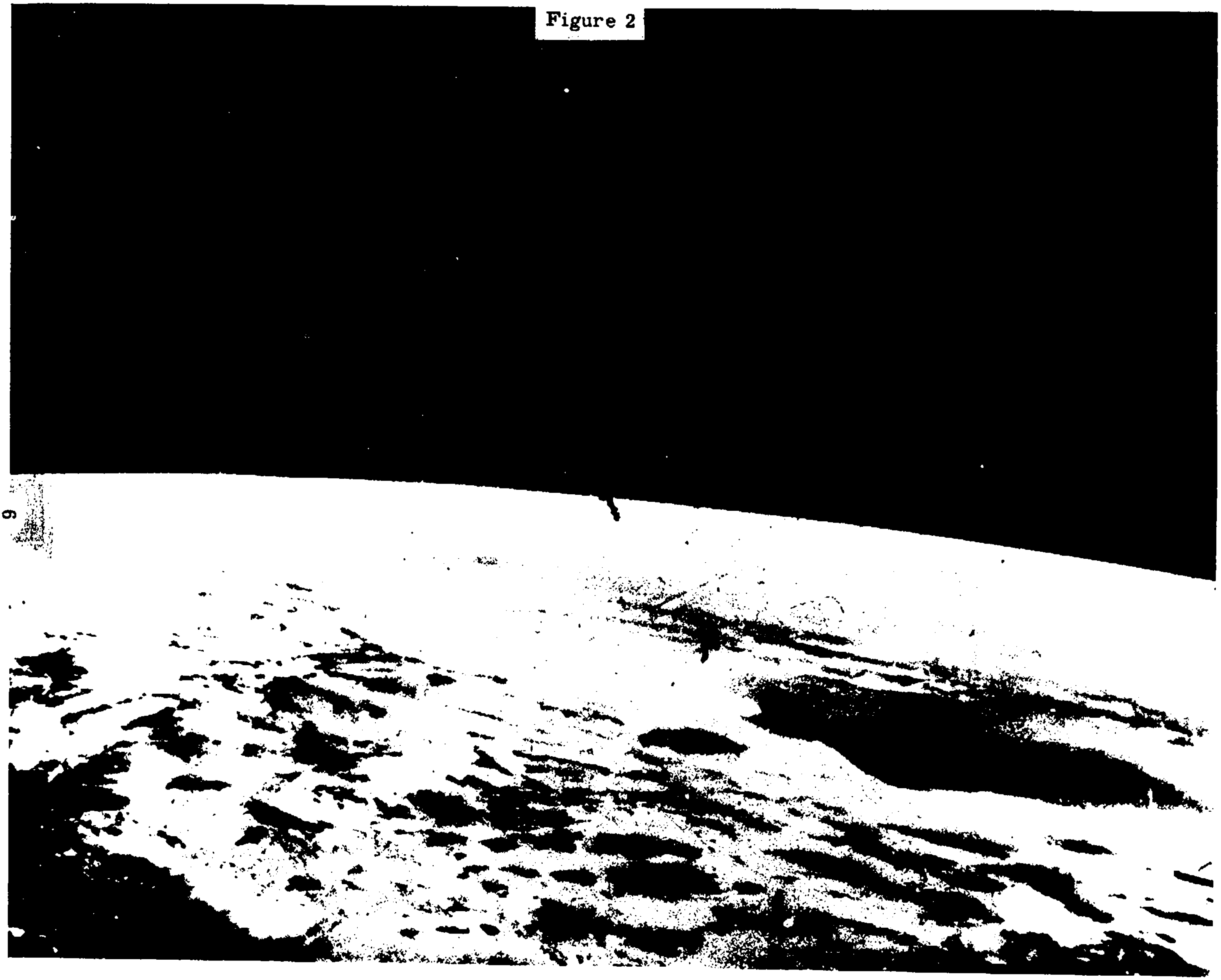


Figure 2



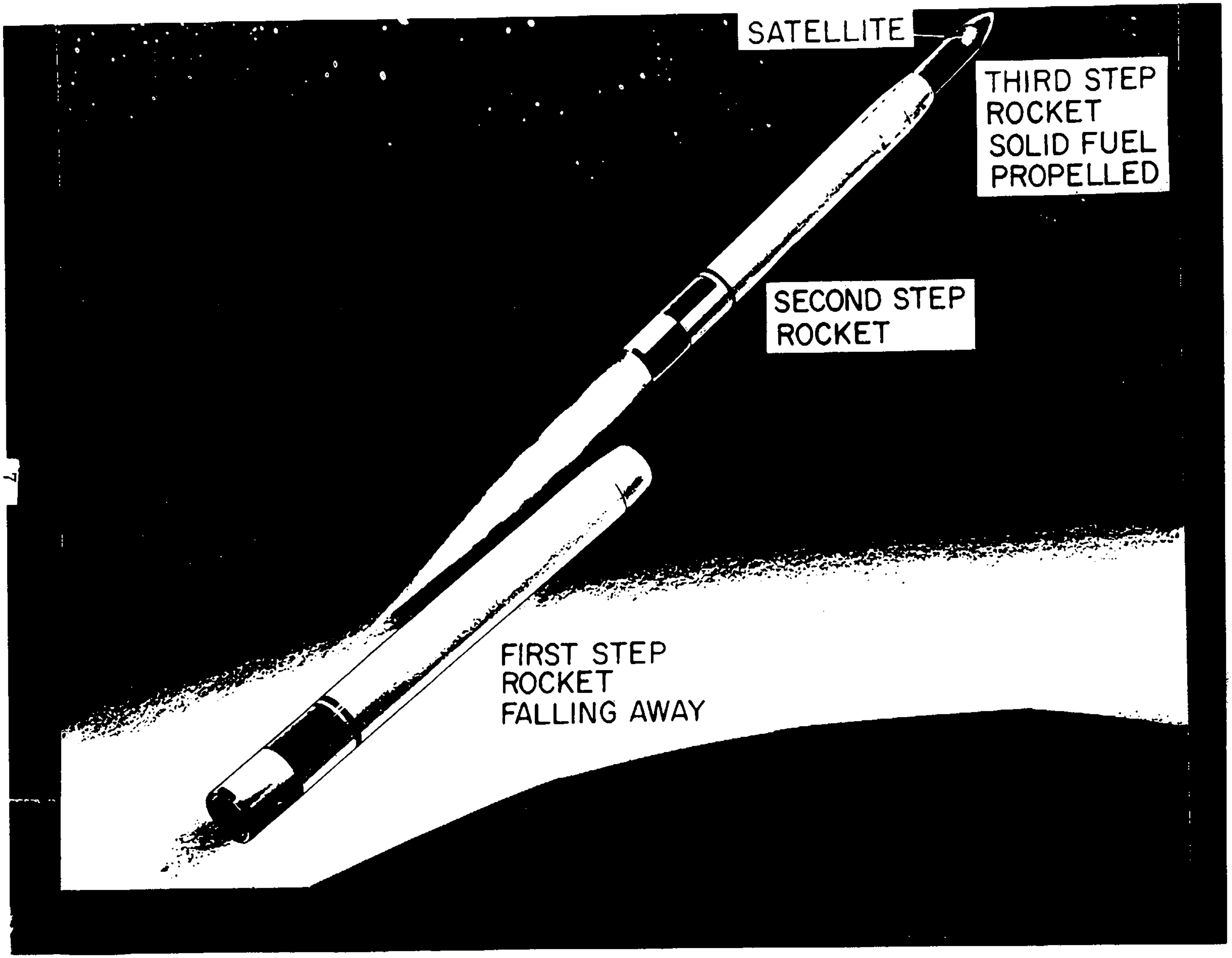
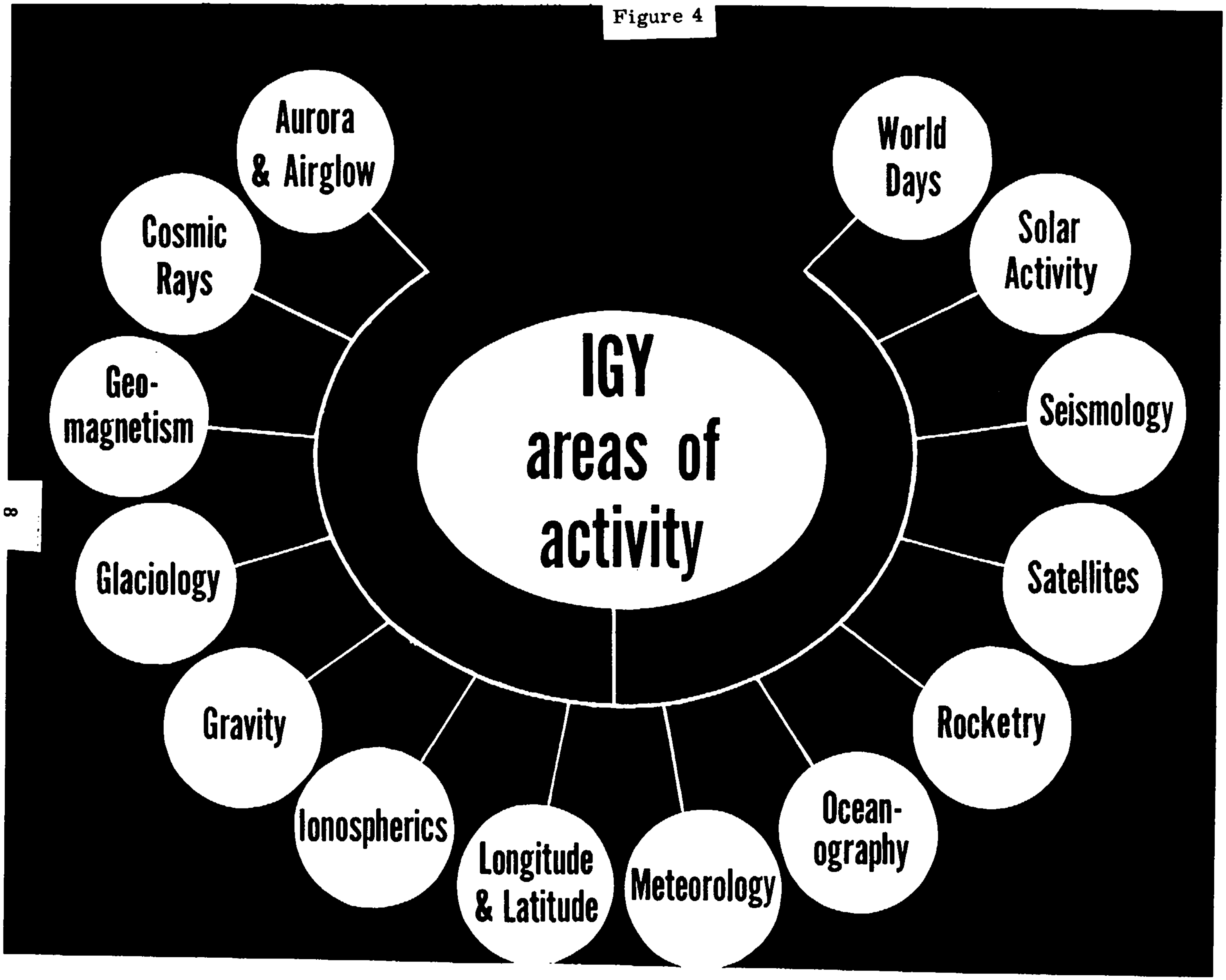

SATELLITE
THIRD STEP ROCKET SOLID FUEL PROPELLED
SECOND STEP ROCKET
FIRST STEP ROCKET FALLING AWAY

Figure 4


IGY areas of activity
Aurora & Airglow
Cosmic Rays
Geo-magnetism
Glaciology
Gravity
Ionospherics
Longitude & Latitude
Meteorology
Ocean-ography
Rocketry
Satellites
Seismology
Solar Activity
World Days

Thus, we have learned that the earth's crust is but a thin frosting covering the earth and floating on top of the 1800-mile thick mantle that surrounds the molten core below. This crust is only about 20 miles thick under the continents, and only about 4 miles thick under the oceans. The earth's interior can be studied, of course, in other ways, by measuring the force of the earth's gravity, which changes from place to place; by noting the type and the temperature of material thrown out of volcanoes; by measuring the distortions of the earth's magnetic field in different localities; and by examining the kinds of materials, of course, found every place over its surface.

As satellites fly around the earth, small changes in the earth's gravitational pull are reflected in corresponding changes in the orbit of the satellites. So studies of this orbit give further evidence of the character of the earth's figure and interior. Indeed, the Vanguard satelite, which is now flying 400 miles overhead, already provides us with he corrected figure for the flattening of the earth, which comes out to be 298.3.

The geophysicist, therefore, is a kind of detective who hunts for clues that nature provides and then studies them with every scientific method to learn what they can tell of regions of the earth that cannot be reached in any other way.

During the IGY, men have traveled everywhere over the oceans with special laboratory ships to study these huge areas that cover three-quarters of the earth's surface. During such surveys ocean depths are mapped, of course, with the radar-like fathometer, using sound pulses, and ocean currents are measured with floating buoys at different depths hat signal back the velocity and direction of these currents. These new uoys that float at various levels are very useful in measuring currents elow the surface. Indeed, a new current was discovered in the Pacific uring the IGY, running about four knots clear across the Pacific, from Tahiti nearly to South America only 300 feet below the surface. But he surface doesn't show any sign of the current unless you get down nderneath.

Sea water is sampled for temperature and salt and chemical contents hrough its whole thickness. The age of water is determined since its last mixing by the examining of radioactive elements or isotopes, and, through hese two methods, it is possible to determine where water originated nd how it travels. For example, the very saline water of the Mediteranean can be traced clear down at deep depths to the Southern Atlantic.

The geology of the ocean bottom is disclosed with explosive core-boring drills that cut through the ocean floor to bring back cross sections more than 70 feet long, and the exchange of gases and particles between the ocean and the overlying air, and the driving of ocean currents by the winds, of course, is measured.

Glaciers cover nearly one-tenth of the earth's surface, mostly, of course, over the Antarctic and Greenland--nine-tenths in the Antarctic and one-tenth in Greenland (figure 5, page 11). They contain the history of climate for the past thousands of years, a history that merely awaits reading by scientists by obtaining drill-cores through the glaciers. We are getting those drill-cores this year at Little America, running right through the Ross Ice Shelf. Interestingly enough, we find that about 400 years ago Mount Erebus had its last great eruption, and a thick layer of volcanic dust can be found at this level, which now gives us a datum over very large areas of the Antarctic. But, year by year, one can determine the amount of precipitation that has occurred by looking at these cores.

To read the story that the glaciers tell, glacial thickness, rates of flow, and rates of accumulation have been measured now at many places, so that the total amount of ice above sea level can be known, and the ice budget of the Antarctic Continent can be calculated. The rate of melting of the great glaciers is determined as we emerge from the last ice age, so that we may know how fast the seas will rise and the climates are changing (figure 6, page 12).

At Byrd Station near the South Pole, which rests on ice a mile above sea level, we have learned during the IGY that the ice is two miles thick and rests on the earth's crust more than a mile below the normal level of the sea (figure 7, page 13). The reason you can't see more of Byrd Station in the illustration, of course, is that it is now about 20 feet under the ice (figure 8, page 14). At the South Pole ice nearly two miles thick rests on land only a few hundred feet above sea level, but the land rises very sharply on either side of the Pole.

These are the wanigans that are used for carrying out the explosive soundings to measure the ice thickness (figure 9, page 15). Out of the measurements of the IGY in the Antarctic, we hope to be able to estimate more exactly how much ice lies on the Antarctic Continent and how much of the continent is depressed by this massive load, but we can now estimate that between 6 and 8 million cubic miles of ice rest on this continent.

Figure 6

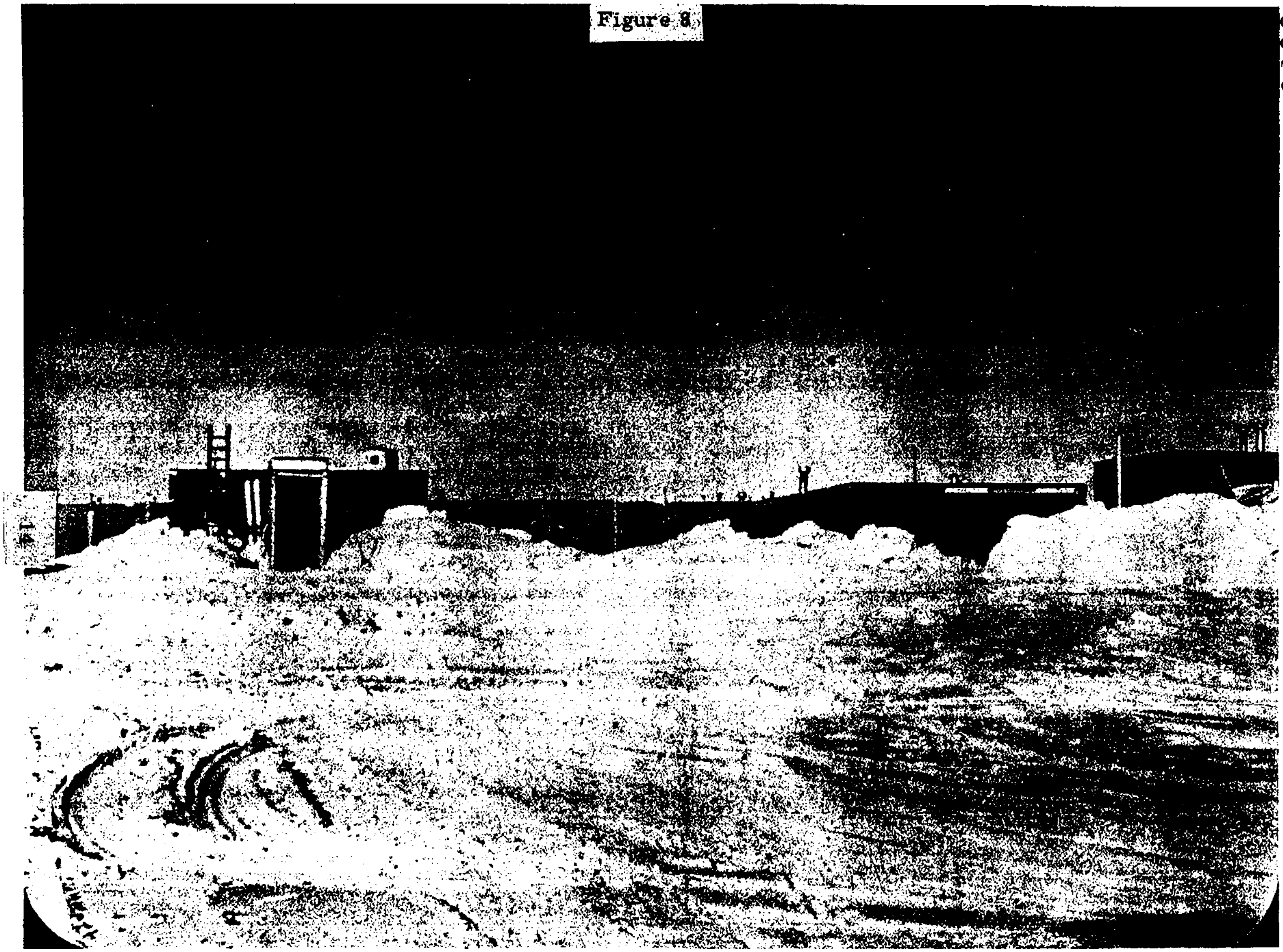
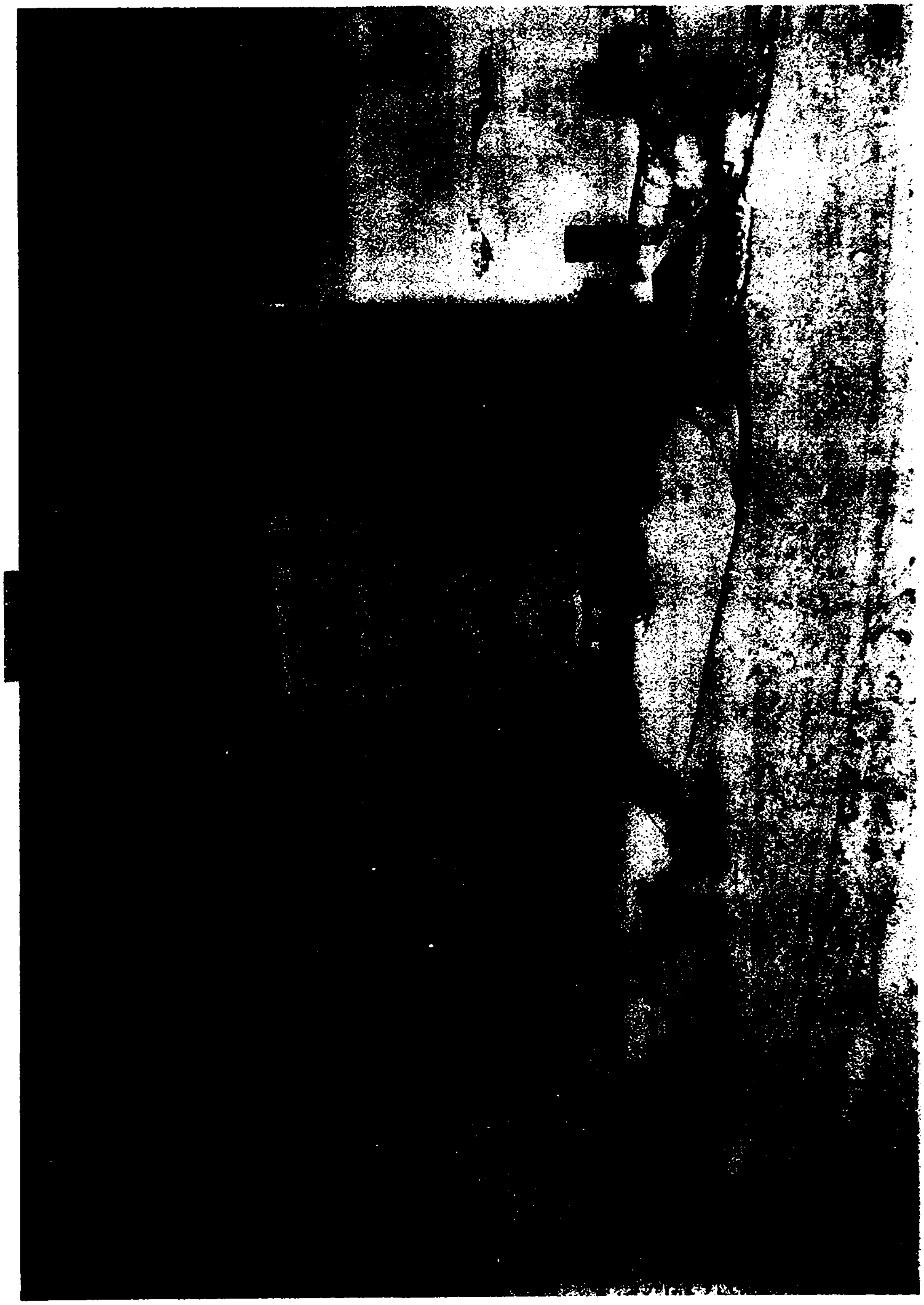


Figure 8



In studying the atmosphere, the geophysicist uses, of course, not only the ordinary weather instruments in his laboratory but also instru ments, that are called radiosondes, launched from towers such as thes in the cold polar regions (figure 10, page 17). These are sent aloft to altitudes of 100,000 feet to measure the wind, temperature, and humid at various levels of the atmosphere, and the information is sent back c tinuously by radio. During the IGY temperatures measured by United States scientists at the South Pole fell below -100° F. --about -103°-- and temperatures below -125° F. have been observed by scientists of t USSR at the Antarctic Vostok Station at about 11,000 feet (figure 11, pa 18). I should say that we are not quite sure about that -125°--their the mometer has a + 5° correction at that temperature; but it read only down to -130° and it ran off the scale.

In contrast, the extensive ice-free "dry-valley" area of more than 10,000 square miles, only 60 miles from our base near McMurdo Soun appears to have an unusually agreeable climate, ranging from + 70° F to -30° F. as a low, and of course these valleys are found with fine lak and rivers (figure 12, page 19). Strangely enough, scientists at the South Pole Station, which is more than two miles above sea level, have found that the air a few hundred feet above the surface is usually much warmer because of the exchange of warmer air from the equatorial regions, the surface losing heat by radiation.

A most unusual achievement during the IGY has been the completic of the first weather maps of the Antarctic Continent. With the extraor dinary communication network that ties the Antarctic stations together these weather maps have been produced four times each day at the Inte national Weather Central at Little America by meteorologists from Argentina, Australia, Chile, France, United States, and USSR. Recer ly I had the pleasure of listening to lectures one evening at Little America by each of these scientists on their work. Maps for much hig altitudes, of course, are drawn twice each day, each based on the radi sonde observations. We no longer think of the continent as uniformly icy cold, for we know its climatological structure, of which the differences from the coastline to the Pole are probably about the same as th differences between the climate at Miami, Florida, and the Canadian Arctic. Man now begins, you see, to piece together the weather pheno ena of planet Earth into a global pattern. Indeed, observations in the Antarctic during the IGY have been so important and successful that, a you probably know, the nations have decided to continue these observations indefinitely in the future.

Figure 10

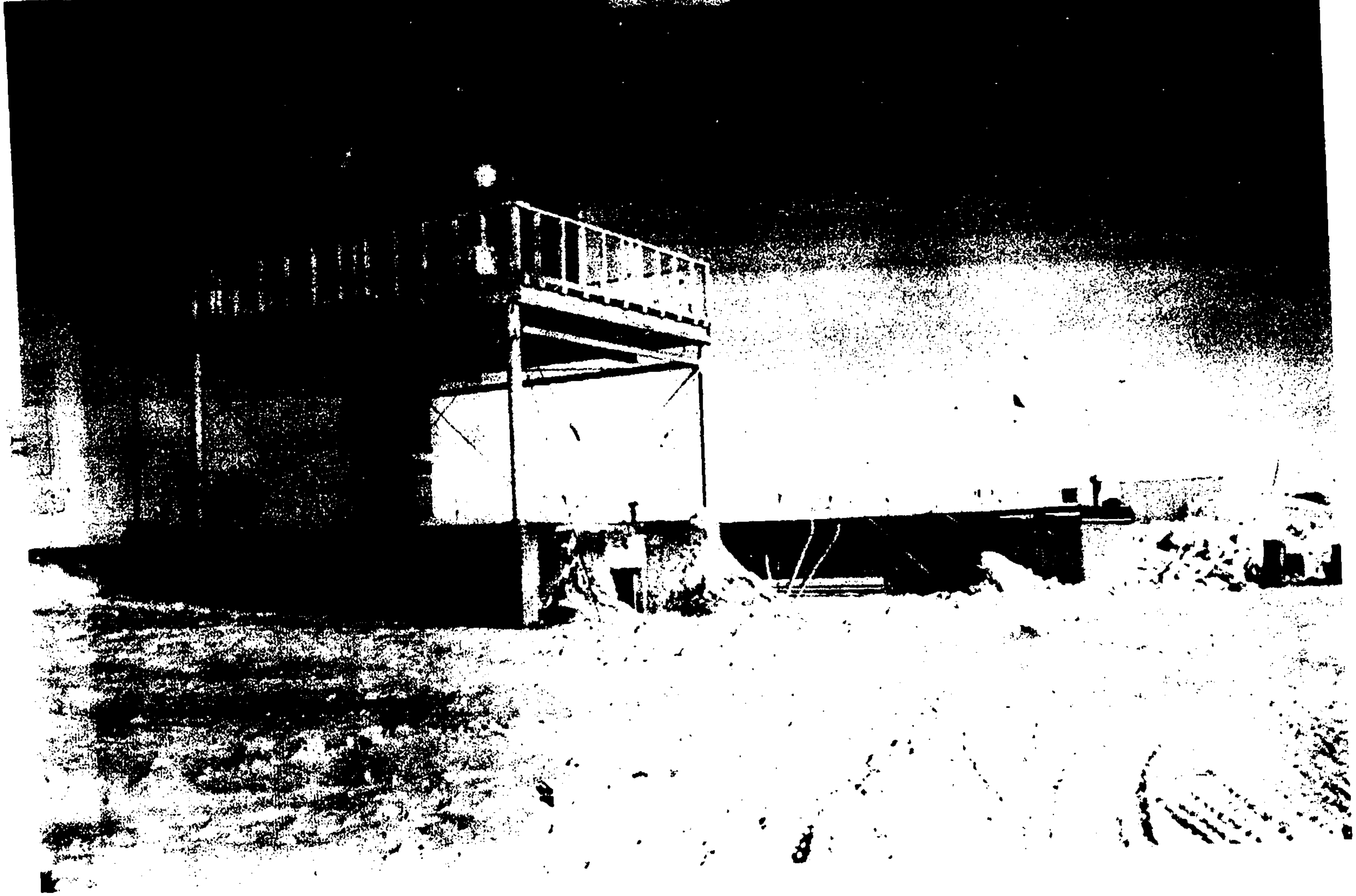
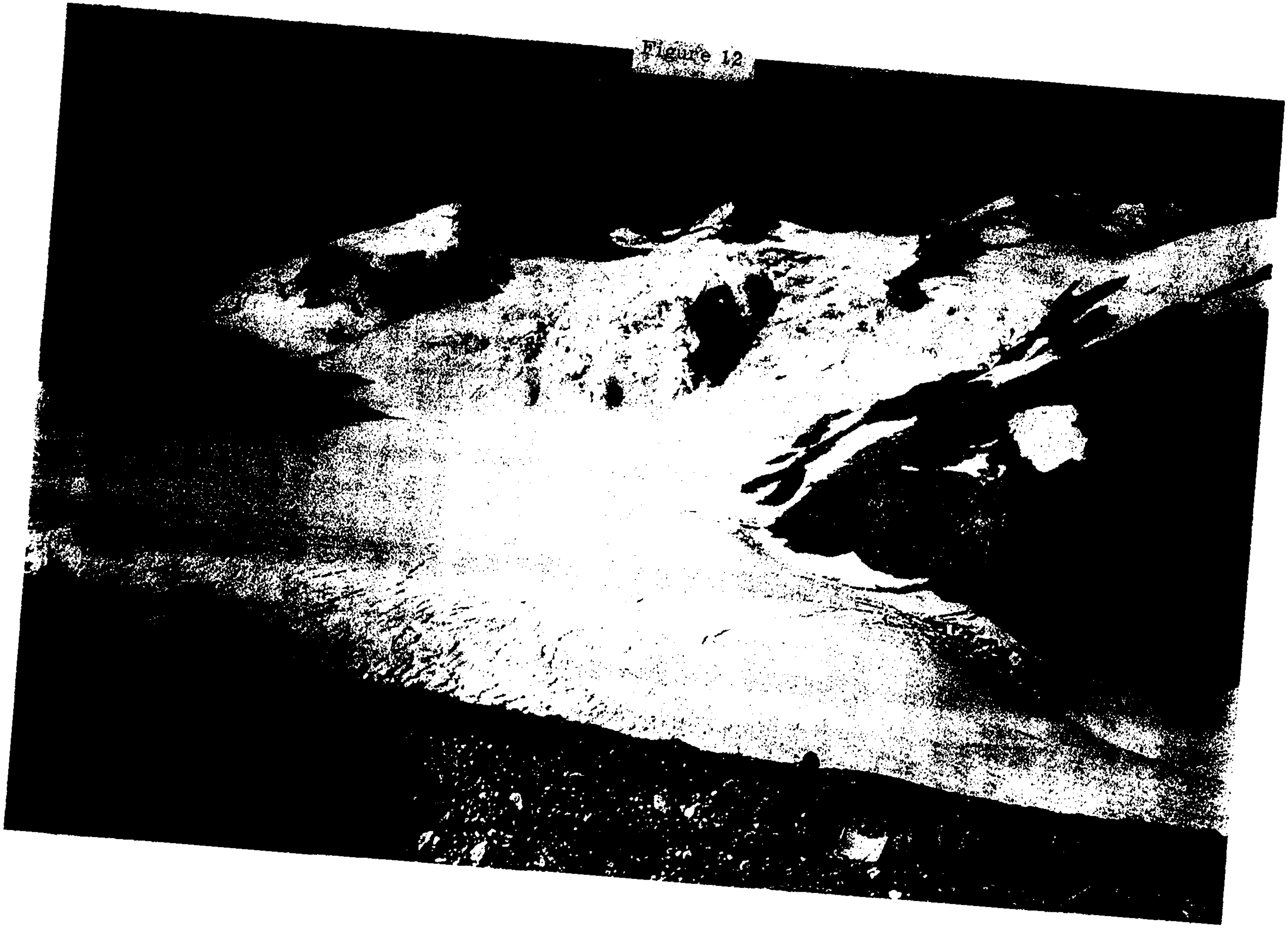


Figure 11

Figure 12

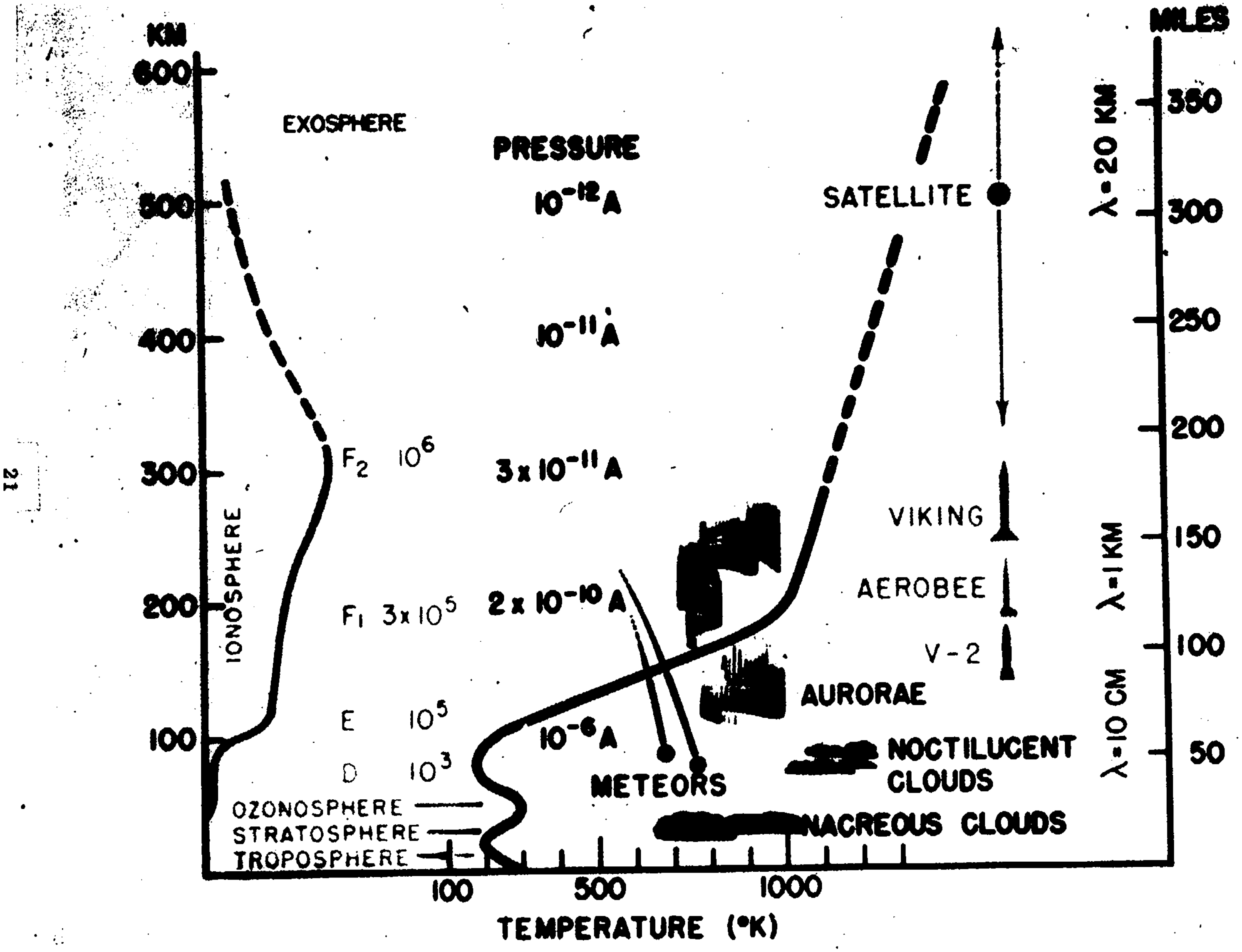


2/90

Turning to the atmosphere, its chemical makeup is, of course, of very great importance. Everyone knows that the earth's atmospher contains oxygen and nitrogen and water vapor, but it also has small amounts of many other elements, compounds, and particles. These have much influence on atmospheric pollution, cloud formation, rainfall, and other aspects of life. For instance, mankind is now engaged in the gigantic experiment of burning up most of the earth's coal and oil in about a century. This experiment can be done only once. The combustion products added to the atmosphere by our present industrie may have a very far-reaching effect on man's climate and his life in the future. Therefore, scientists must continue to observe this experiment very carefully by every scientific method.

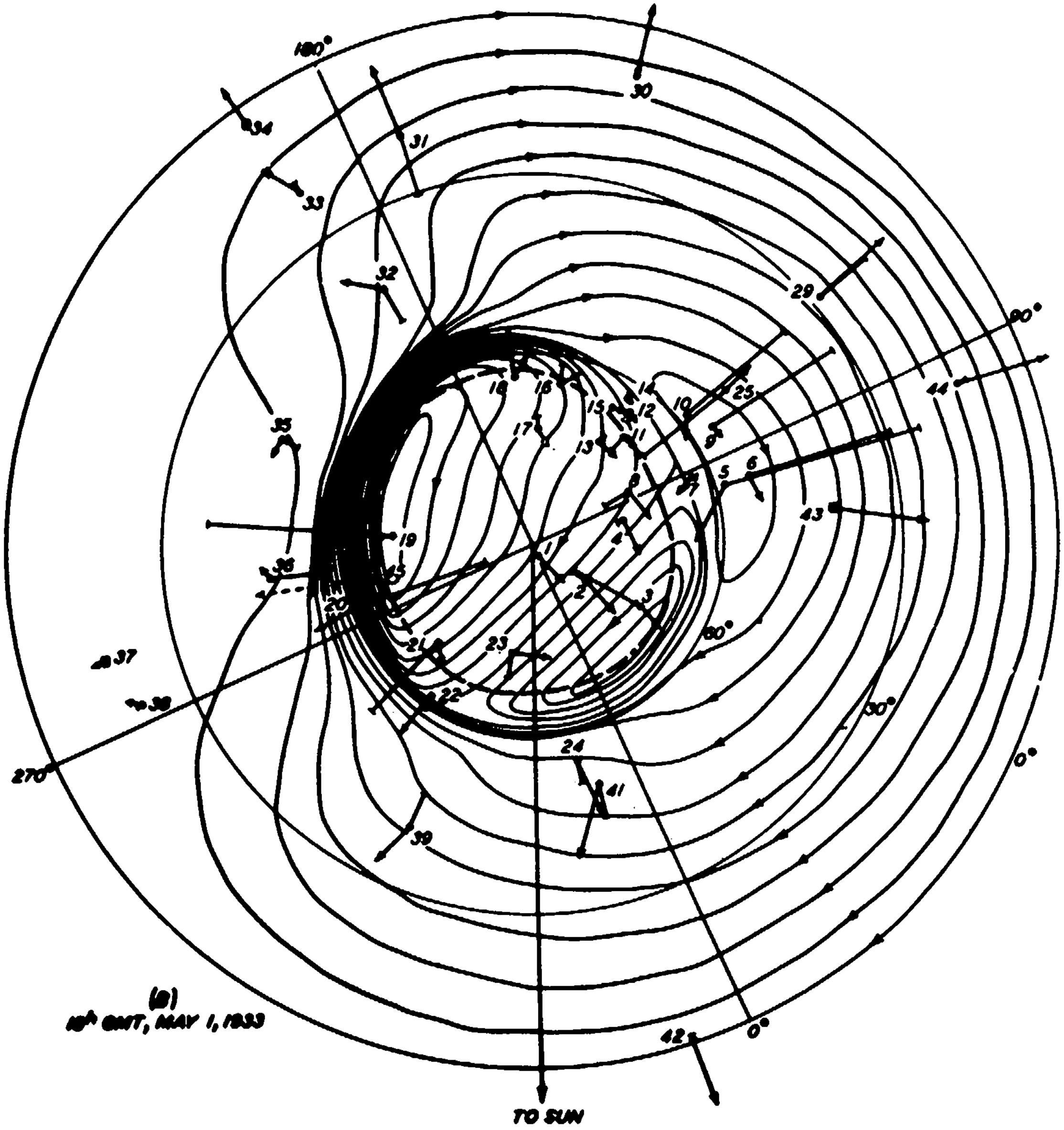
Above 50, to about 150, miles the outer atmosphere is called the ionosphere (figure 13, page 21). The very short rays of the sun, the X-rays, and the ultra-violet light can cause the atmosphere in these regions to be electrified, or ionized, into electrically charged atoms and electrons. The ionoshpere is of very special interest, of course, since it reflects radio waves. Because of this we can "bounce" short radio waves or scatter very short radio waves over long distances around the curvature of the earth. Large electrical currents, sometimes more than a million amperes, flow in the ionosphere (figure 14, page 22). These curved lines show the density of current. These currents, of course, disturb the earth's magnetic field. In a case lik this about 10 million amperes were flowing over one side of the polar cap. It is in this region that the strange glowing arcs and flashing lig known as the aurora occur (figure 15, page 23). You see here the reg of maximum auroral frequency. These auroras are caused by electri excitation of atoms and molecules in the very high atmosphere that th glow very much the same as the gas in a fluorescent lamp. For obse vations in the polar regions, houses like this are used for auroral observations (figure 16, page 24).

I might say that, during the IGY, we found for the first time that auroral arcs that appear in the Northern Hemisphere appear within a few seconds of the same time that similar arcs appear in the Southern Hemisphere.


KM
600
500
400
300
200
100
EXOSPHERE
PRESSURE
10^{-12} A
10^{-11} A
3×10^{-11} A
2×10^{-10} A
10^{-6} A
IONOSPHERE
F_2 10^6
F_1 3×10^5
E 10^5
D 10^3
OZONOSPHERE
STRATOSPHERE
TROPOSPHERE
METEORS
SATELLITE
VIKING
AEROBEE
V-2
AURORAE
NOCTILUCENT CLOUDS
NACREOUS CLOUDS
100
500
1000
TEMPERATURE (°K)
MILES
350
300
250
200
150
100
50
λ = 20 KM
λ = 1 KM
λ = 10 CM

5730

Figure 14



(B)
18h GMT, MAY 1, 1933

Figure 15

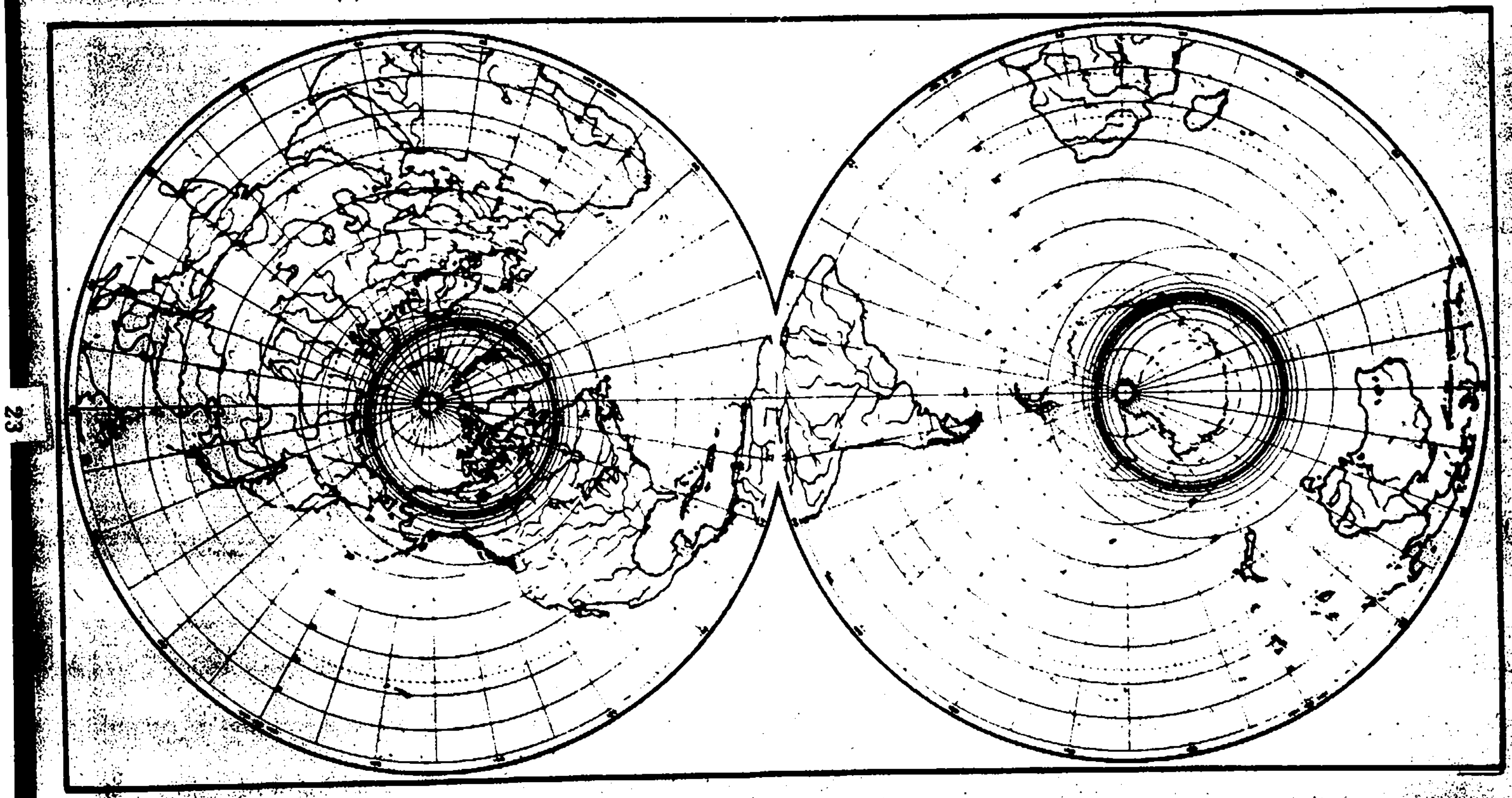
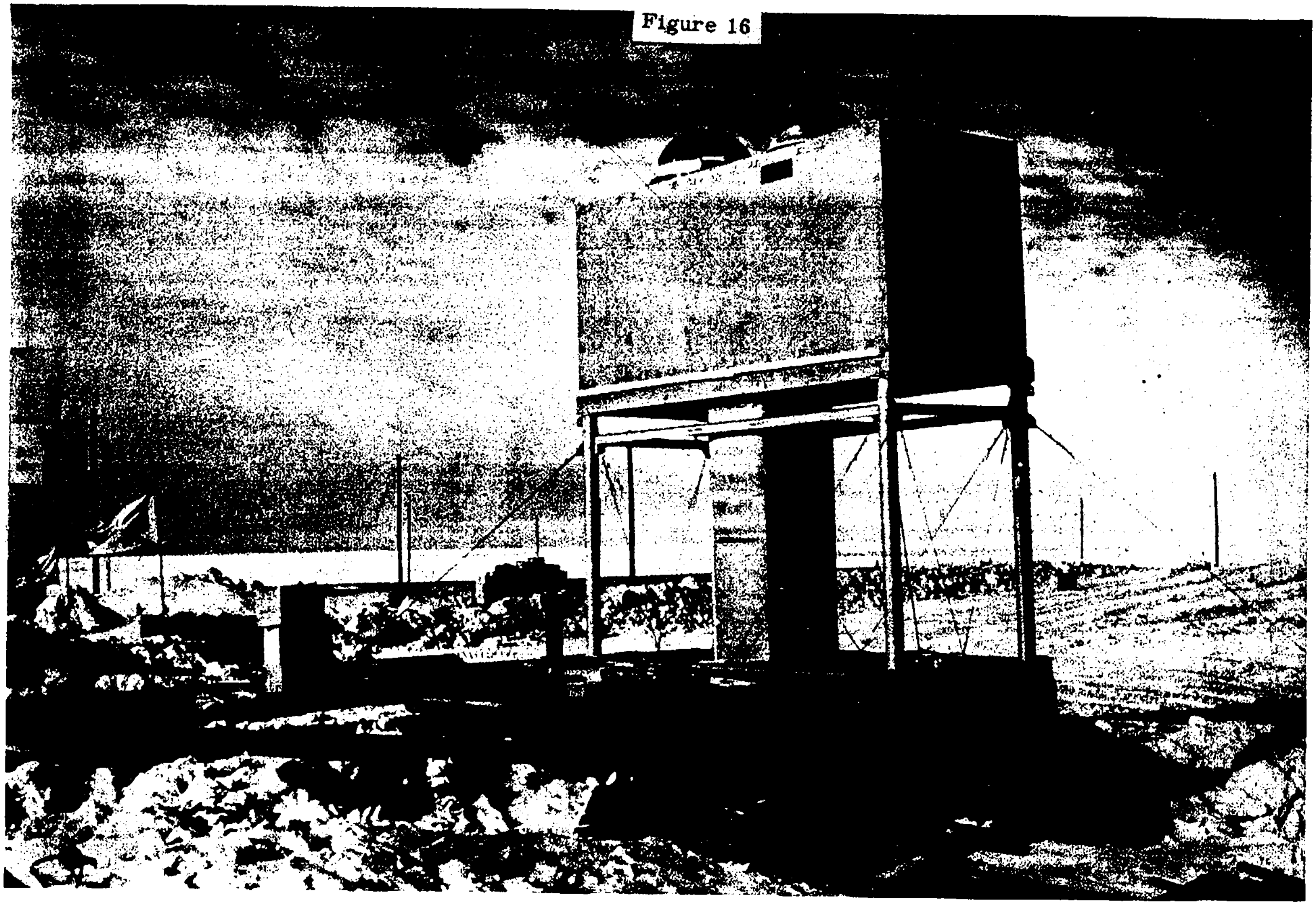


Figure 16



To study the ionosphere, scientists send radar pulses that are reflected from the ionized clouds. (In fact, as many of you know, radar was invented in 1925 for this purpose.) The radar pulses are sent on different radio frequencies to discover the amount and the kind of ionization present and the thickness and temperature of the atmosphere at these great heights. During the IGY the observations of the ionosphere at the South Pole showed that, while the sun was at the same altitude all day, there was nevertheless a noticeable diurnal variation in ion density with its maximum corresponding to noon at the longitude of San Francisco. This is a very puzzling matter which has to be investigated further, but it must have something to do with the movement of the ions horizontally under the control of the earth's magnetic field. The study of the fall of meteors by both visual and radar methods tells us much about the outer atmosphere. In addition, the sky gives off a faint light, called airglow, that changes from time to time and from place to place. The intensity and changes of airglow give us information about the kinds of atoms and molecules in the outer atmosphere. We find, for example, such things as nitrogen-oxide in considerable quantity.

To explore the atmosphere directly at great heights, geophysicists must use balloons and rockets equipped with scientific instruments and radio transmitters to telemeter the data back. During the IGY scientific rockets have risen, as you know, to heights of nearly 70,000 miles. Hundreds of rockets, usually sent to heights of 100 or 200 miles, were launched during the IGY by scientists of many nations in their study of the phenomena in the earth's outer atmosphere. Large numbers of small rockets, called "rockoons," have been launched from high altitude balloons to carry on research at high altitudes and at a relatively small cost. Following the high altitude atomic bomb explosions at Johnson Island last August, scientists from San Francisco to Tokyo observed a vast radio fadeout that lasted for several hours across the Pacific, blacking out communications almost completely. Simultaneously, an artificial aurora was observed at Apia in Samoa, showing that the electrically charged particles had followed the lines of the earth's magnetism up and across the equator and down into the opposite hemisphere. Such information of course is invaluable in understanding the theoretical behavior of our atmospheric environment and shows that there are very great uses for such explosions in science.

I might add that a few weeks after the bomb explosions at Johnson Island, the lithium line was observed at all of the Antarctic Stations. This gave information on the rate of the air transfer from the region of Hawaii down into the Antarctic, across the equator.

The happenings, of course, at the very farthest fringes of the outer atmosphere, known as the exosphere, are of unusual importance, for here we can learn just what kind of space it is through which the earth rotates and courses on its orbit. Scientists have learned that this space is not a vacuum but contains more than 1,000 particles in each cubic inch. In fact, the earth's orbit seems to pass right through the outer reaches of the sun's corona. This outer space can be studied by the observation of zodiacal light, which is sunlight reflected by particles in space. Cosmic rays reaching the earth carry telltale marks of the space through which they have traveled. The exosphere can also be explored by curious radio waves known as whistlers which seem to travel far into space along the earth's magnetic field and then back to the earth again, bouncing back and forth from one hemisphere to another.

During the IGY scientists have found that these outer reaches of the atmosphere behave like a "traveling wave tube amplifer" that amplifies the whistlers as they pass through the region and acquire energy from the incoming particle streams originating on the sun. Thus, the sun is the cathode that sends the particles of the radio tube, and the earth's magnetic field is the focusing element that makes this natural traveling wave tube amplifier work.

Probably the most publicized achievement of the IGY has been the launching of the instrumented earth satellites by the United States and the USSR. By the end of the IGY, more than a half-dozen satellites had circled the earth (figure 17, page 27). This IGY development is so important to science that I am going to spend just a little time emphasizing its power for science. Certainly, as a scientific tool, the space vehicle is a device of superb potentialities comparable to other great scientific instruments of the past, such as the telescope, the microscope, and the nuclear accelerator (figure 18, page 28). We have already emphasized that, under our almost insulating atmosphere, we can sense the nature of the universe only through one octave of light, a few octaves of radio waves, the interaction of a few very energetic particles on our atmosphere, and the examination of a few meteorities. The result is an almost monochromatic view of the atmosphere from the surface of the earth.

Figure 17

Another View of Soviet Satellite

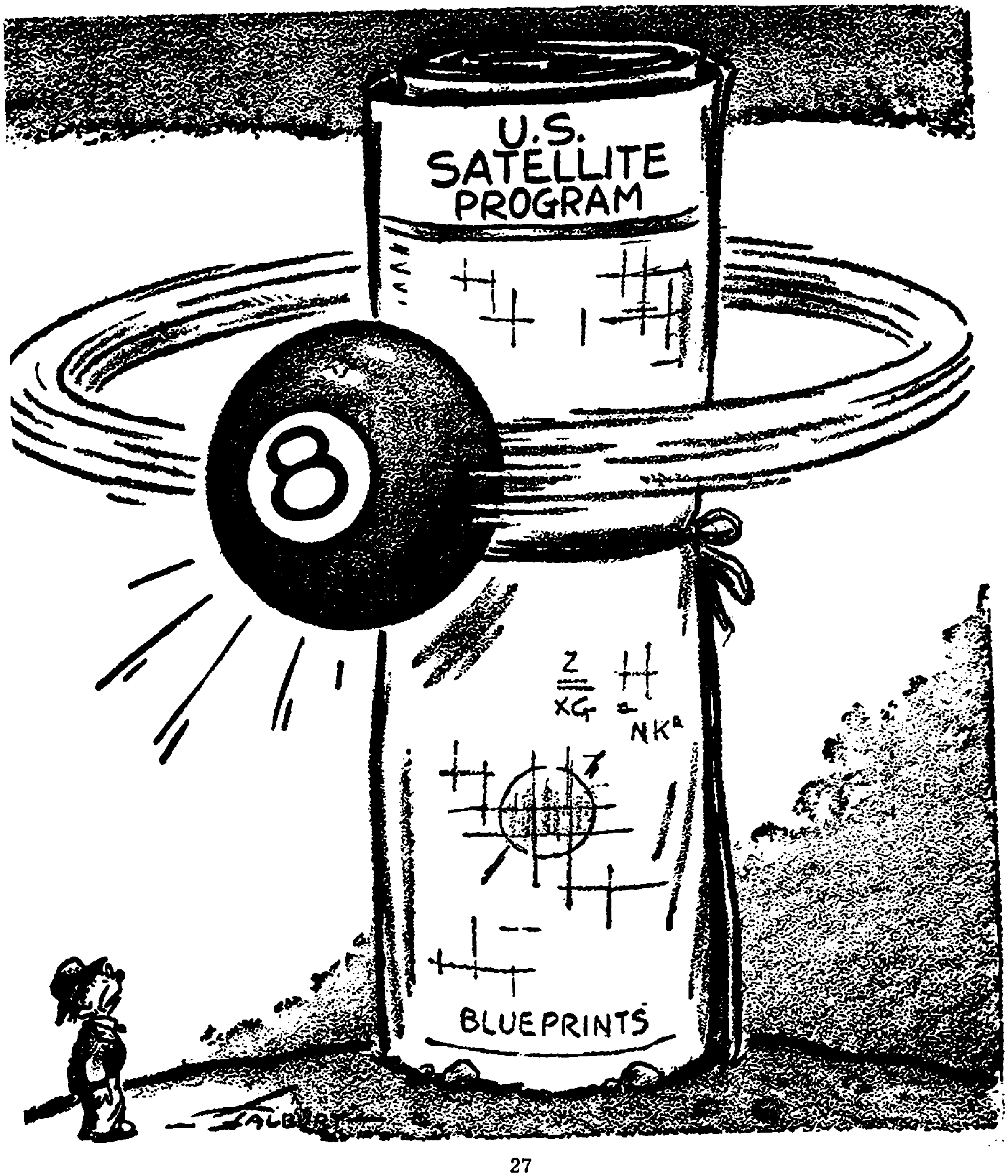
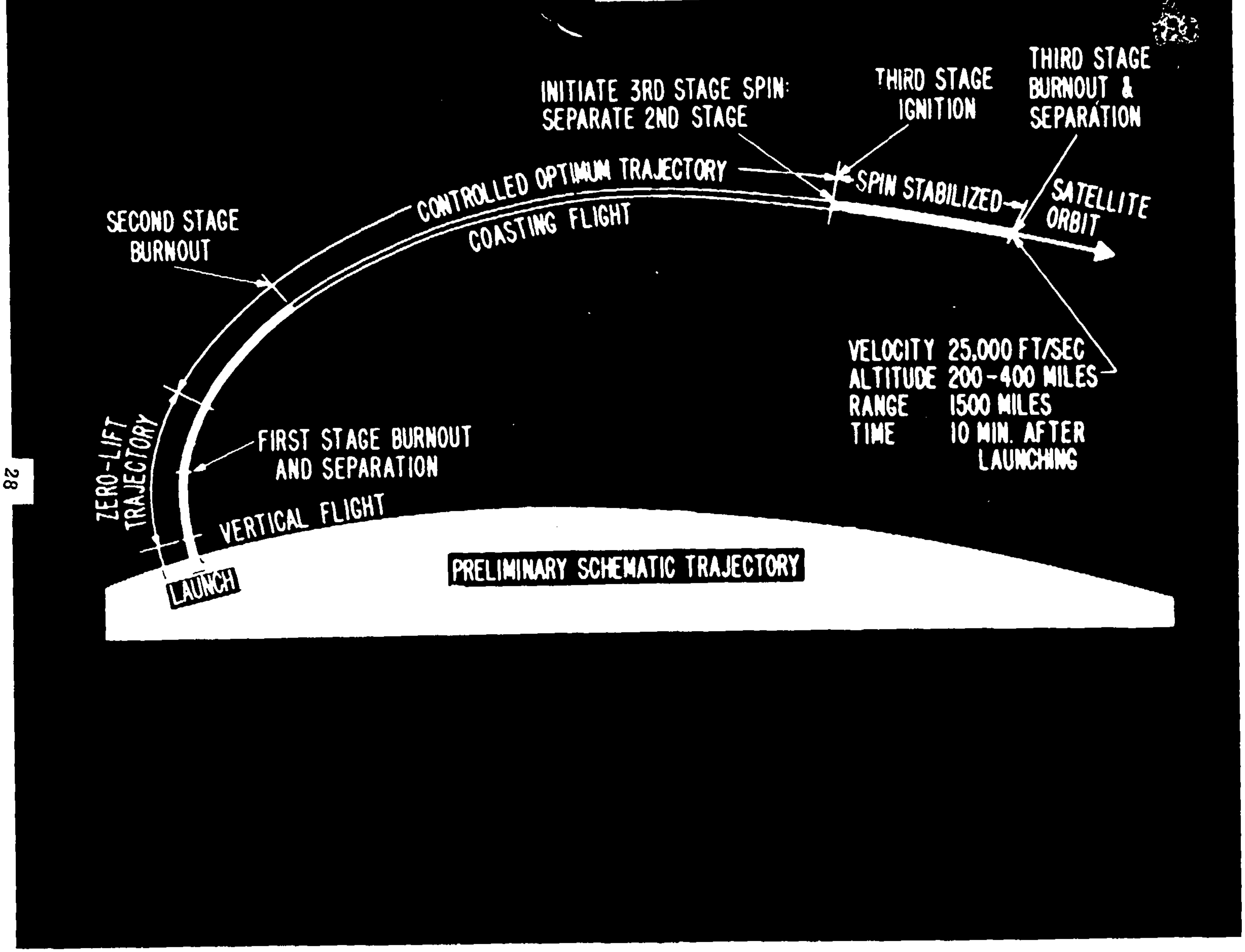


Figure 18


INITIATE 3RD STAGE SPIN:
SEPARATE 2ND STAGE
THIRD STAGE IGNITION
THIRD STAGE BURNOUT & SEPARATION
CONTROLLED OPTIMUM TRAJECTORY
SPIN STABILIZED
SATELLITE ORBIT
SECOND STAGE BURNOUT
COASTING FLIGHT
VELOCITY 25,000 FT/SEC
ALTITUDE 200-400 MILES
RANGE 1500 MILES
TIME 10 MIN. AFTER LAUNCHING
ZERO-LIFT TRAJECTORY
FIRST STAGE BURNOUT AND SEPARATION
VERTICAL FLIGHT
LAUNCH
PRELIMINARY SCHEMATIC TRAJECTORY

The simple satellite, as we now know it, extends our scientific apabilities far beyond this insulated view (figure 19, page 30). It pernits us to see the universe for the first time in its full range of color, n the special sense that the satellite broadens the range of our vision rom a narrow spectrum to the whole spectrum of nature--from the hortest to the longest wave lengths, from the lowest to the highest paricle energies.

To try to outline the full range of scientific experiments that can ow be foreseen in artificial satellites would take a very thick volume. might say that the Space Science Board of the National Academy is ow preparing such a volume. But I think it is useful to cite a few xamples of the real significance of even elementary space science.

We have said that the satellites can view the universe in the full ange of chromaticity. To the astrophysicist, of course, this means hat the word "color" just takes on new meaning. Through his access o the whole range of color of radiations and of spectral distributions ver this range, he can now look at the atoms through the entire spectral ange and study the origin, evolution, and destruction of matter in the niverse, which simply revolutionized our whole view of astrophysics. ventually, I suspect, an inhabited astrophysical observatory on the oon may become desirable and necessary to enjoy the full advantages hat space offers to astronomy.

Closely related to general astronomy are observations of our own un, our knowledge of the physics of the sun, and its changes as time asses. Above the atmosphere we can see the sun in its full glory, and e can enter the corona at will and even approach the sun's surface with atellites in the future (figure 20, page 31). But already our studies of he radiation distribution show very strong X-radiation from the sun tself, which permits us to acquire knowledge of the magnetized plasma nd its changes with time. This is the corona through the outer reaches f which the earth is now traveling.

Figure 19

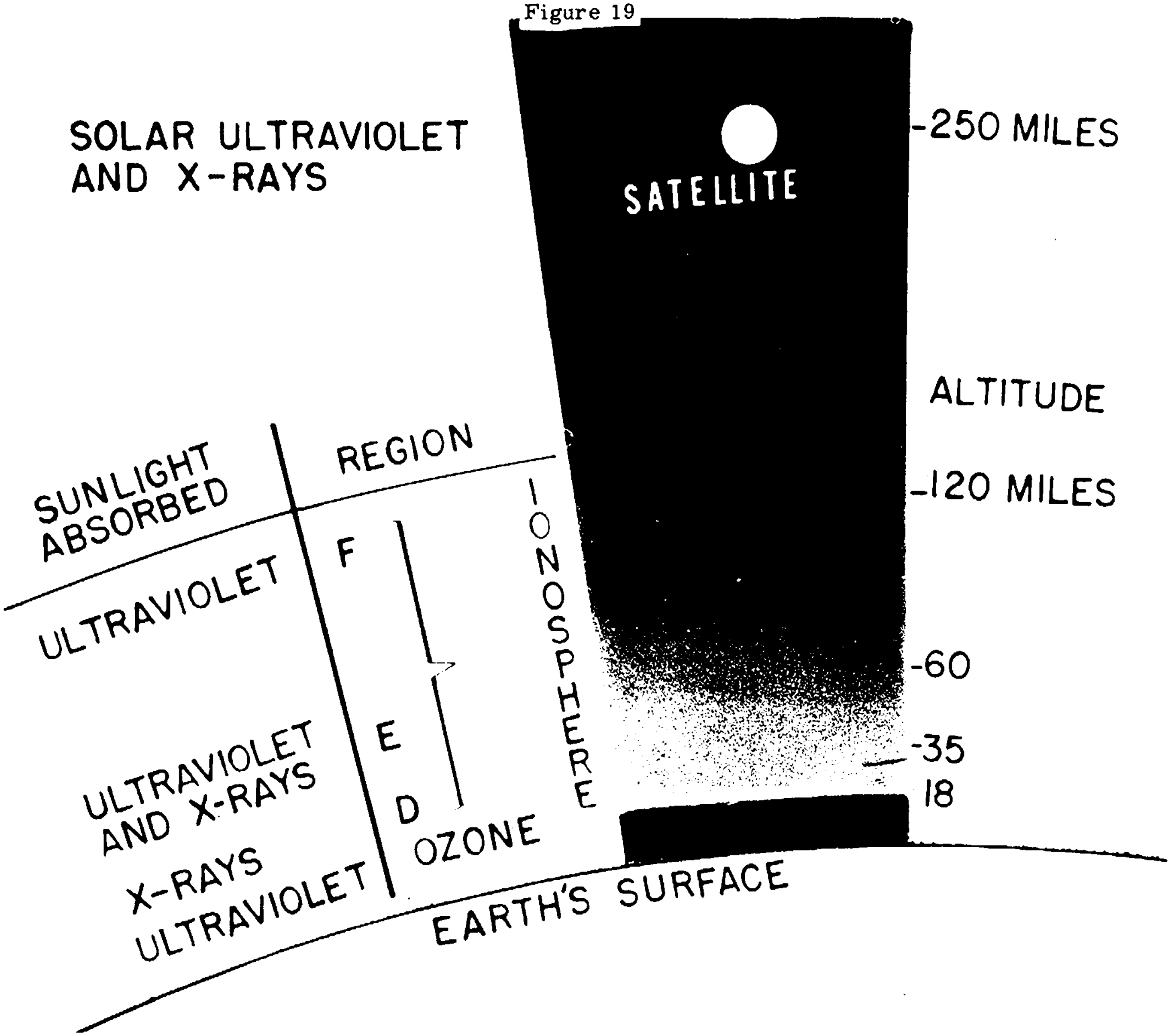
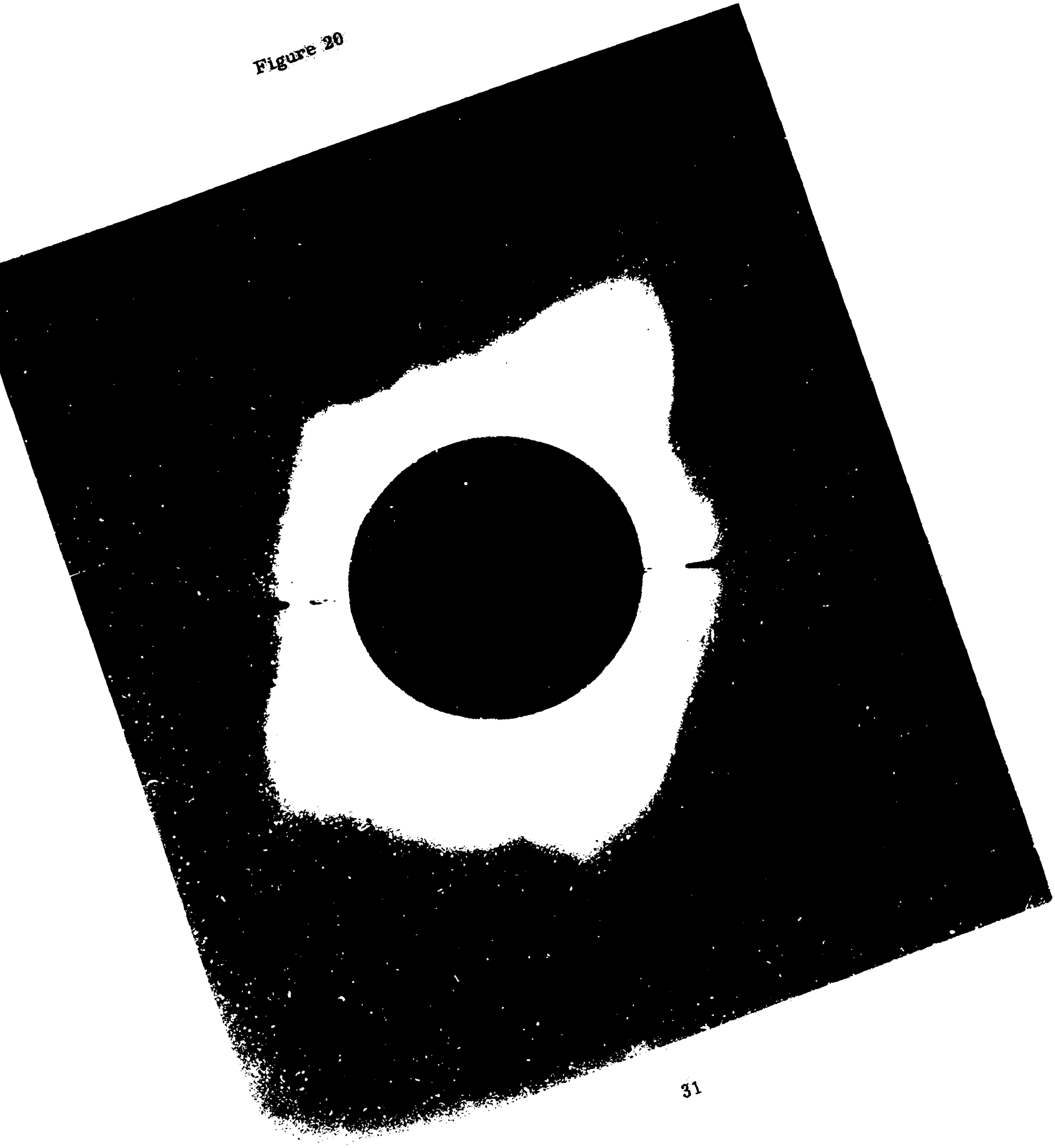

SOLAR ULTRAVIOLET AND X-RAYS
SATELLITE
-250 MILES
ALTITUDE
-120 MILES
-60
-35
18
SUNLIGHT ABSORBED
REGION
ULTRAVIOLET
F
ULTRAVIOLET AND X-RAYS
E
X-RAYS ULTRAVIOLET
D
IONOSPHERE
OZONE
EARTH'S SURFACE

Figure 20

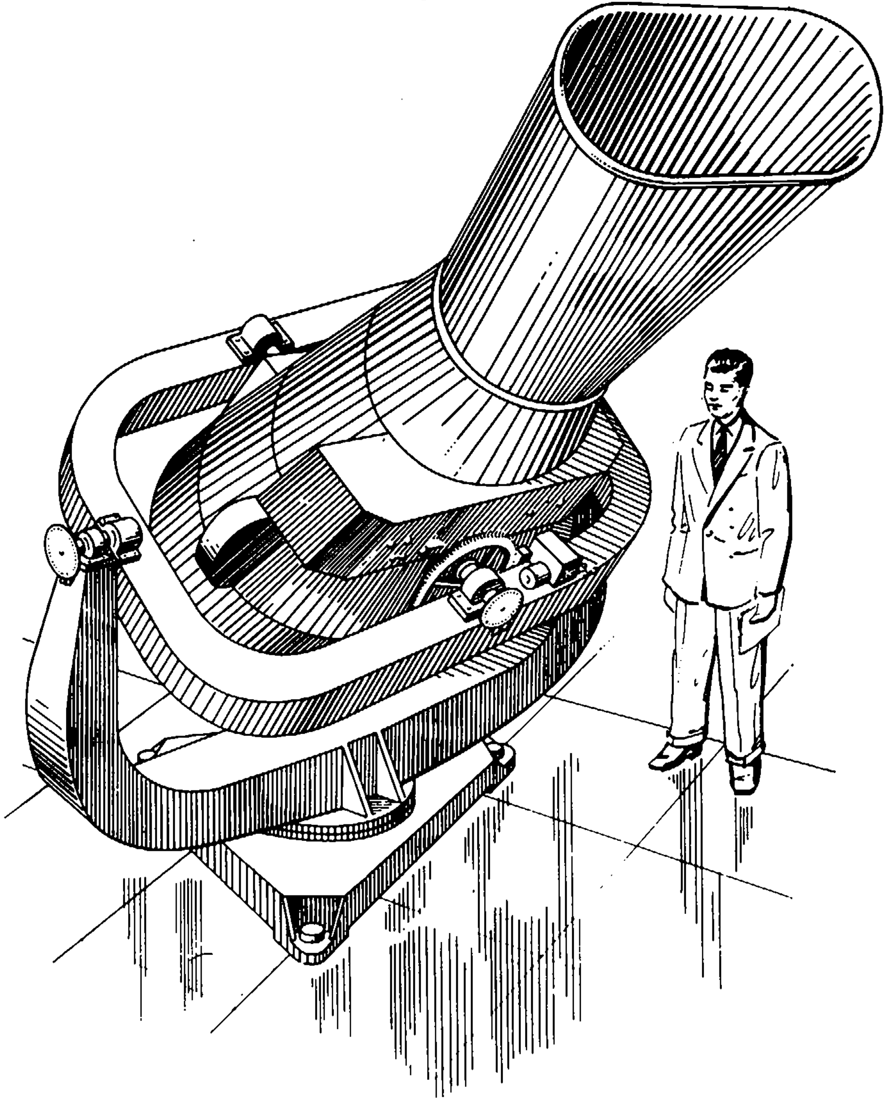


Turning to the earth itself, certainly much more accurate mapping with such cameras as this, the Baker-Nunn, on satellites is in sight, and we think that an ultimate precision of perhaps 10 feet will be possible, which will permit critical tests of such hypotheses as continental drift (figure 21, page 33). These Baker-Nunns are, of course, very precise when timed to about one-ten-thousandth of a second (figure 22, page 34). Already the major geodetic chains of the earth are being tied together. I might add that right at the moment the errors in the long-range landings of the Atlas are sufficiently small so that we are not quite sure whether the fault is of the rocket firings or of our lack of knowledge of the curvature and character of the earth itself. But perhaps the most important contribution, I think, that the satellite is bringing to the Earth sciences will be in the field of meteorology.

Turning to this field of meterology, we learned in high school that the earth's atmosphere can be regarded as the gas of a kind of heat engine (figure 23, page 35). The equatorial region is the fire-box that receives the net gain of energy from the sun and stores the energy largely in water vapor. Here you see the excess of energy received from the equatorial regions (figure 24, page 36). The polar regions are the condensers of this great heat engine, where the atmospheric gas suffers a net loss of energy by an excess of radiation of heat into space. Thus, the earth's atmosphere is perhaps the only great heat engine that uses a radiator as a condenser.

The circulation of the atmosphere that brings us our weather arises from the transfer of heat from the equatorial fire-box to the polar condenser. Unfortunately, the heat input and output of this engine are not constant. The input varies as the changing equatorial cloud-cover reflects more or less of incident heat from the sun back into space; the output depends on the reabsorption in the atmosphere of the heat radiate from the surface, as the gases within the atmosphere that reabsorb the radiated heat are redistributed. Furthermore, a small change in rate of overturn of the oceans by changing winds can change the supply of hea to or from the atmosphere, locally.

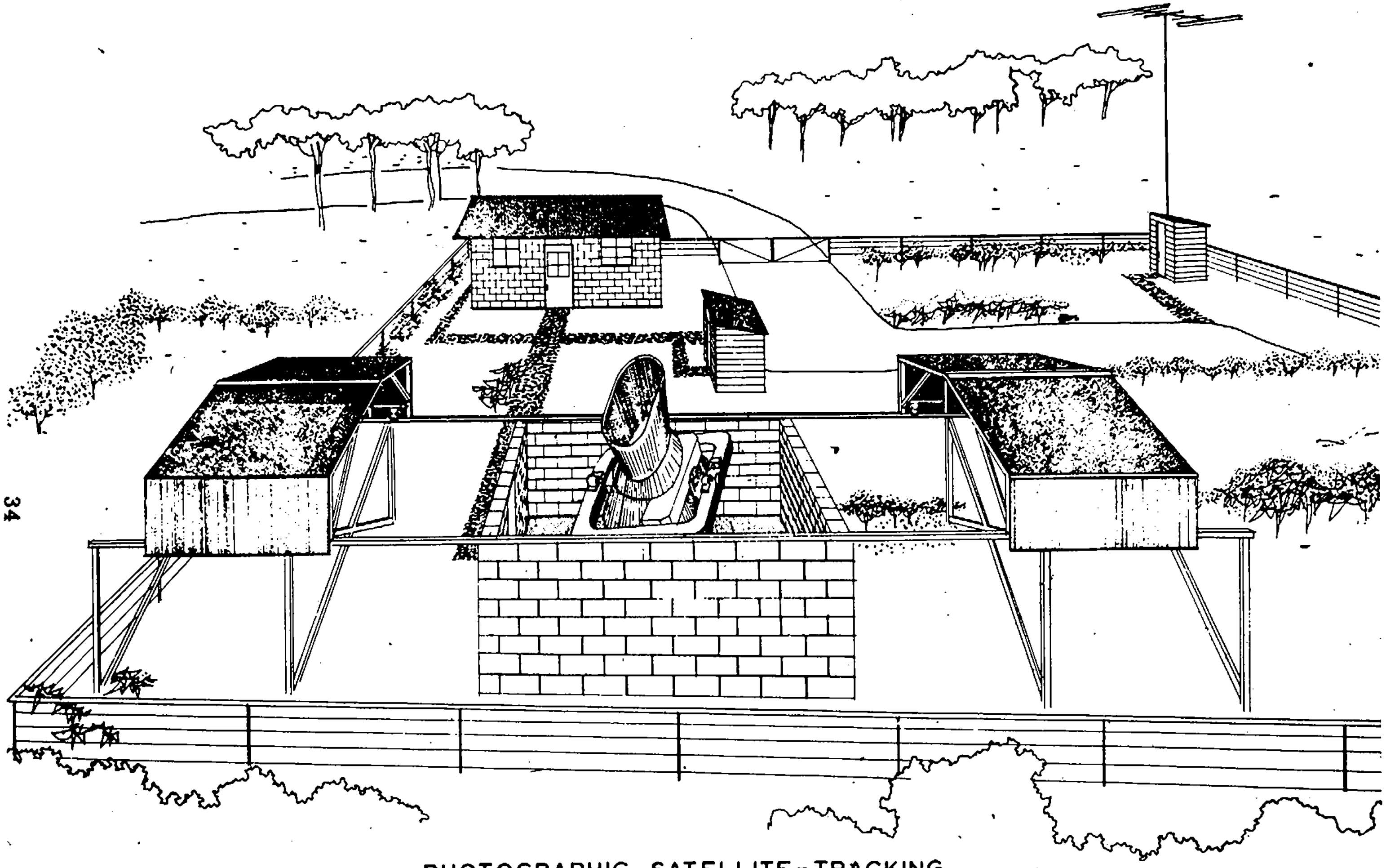
Figure 21



Perspective drawing of Baker-Nunn satellite tracking camera

IGY - Smithsonian Astrophysical Observatory

Figure 22



PHOTOGRAPHIC SATELLITE-TRACKING
STATION SHOWING CAMERA EXPOSED
INTERNATIONAL GEOPHYSICAL YEAR
SMITHSONIAN ASTROPHYSICAL OBSERVATORY

Figure 23

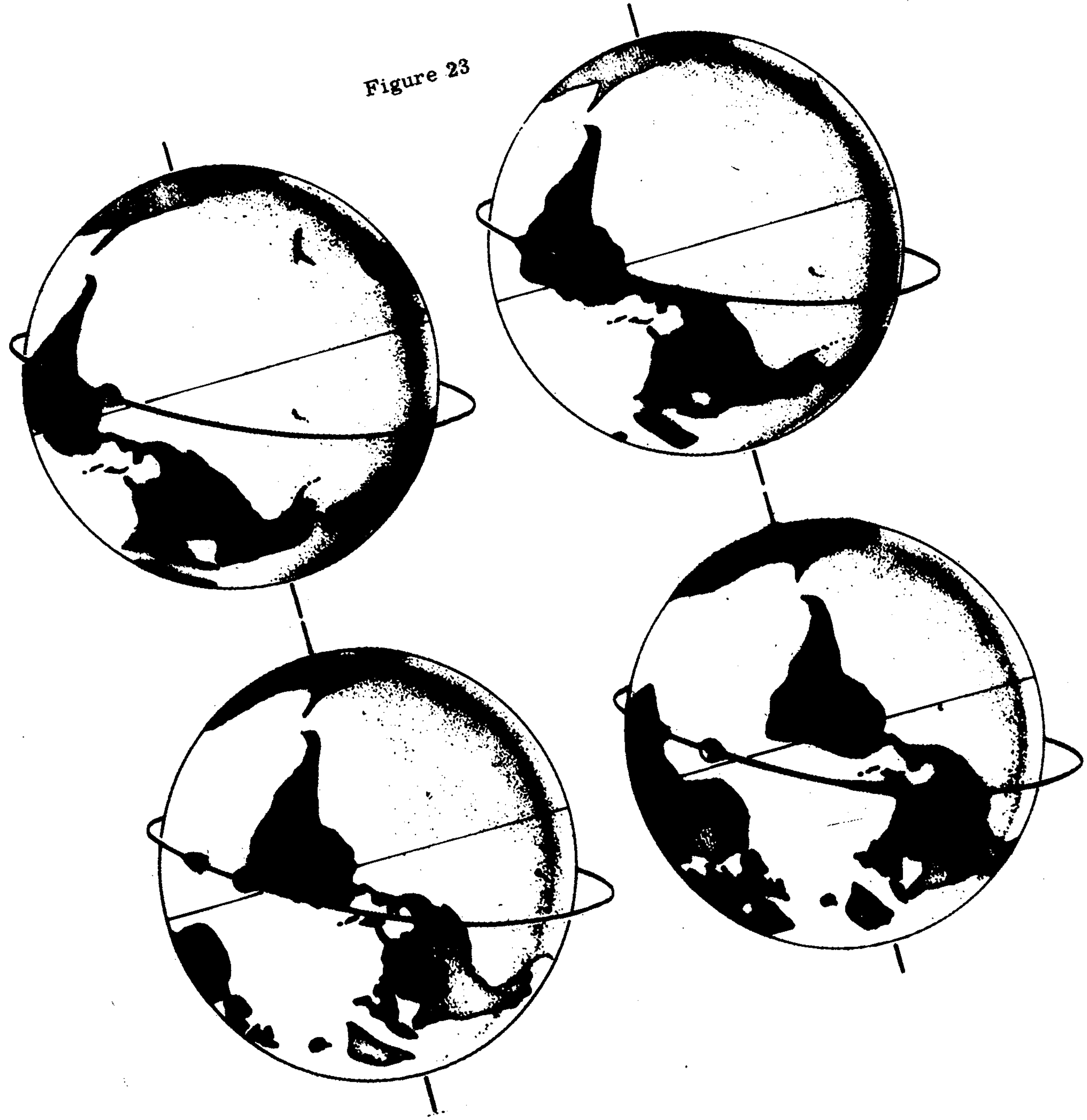
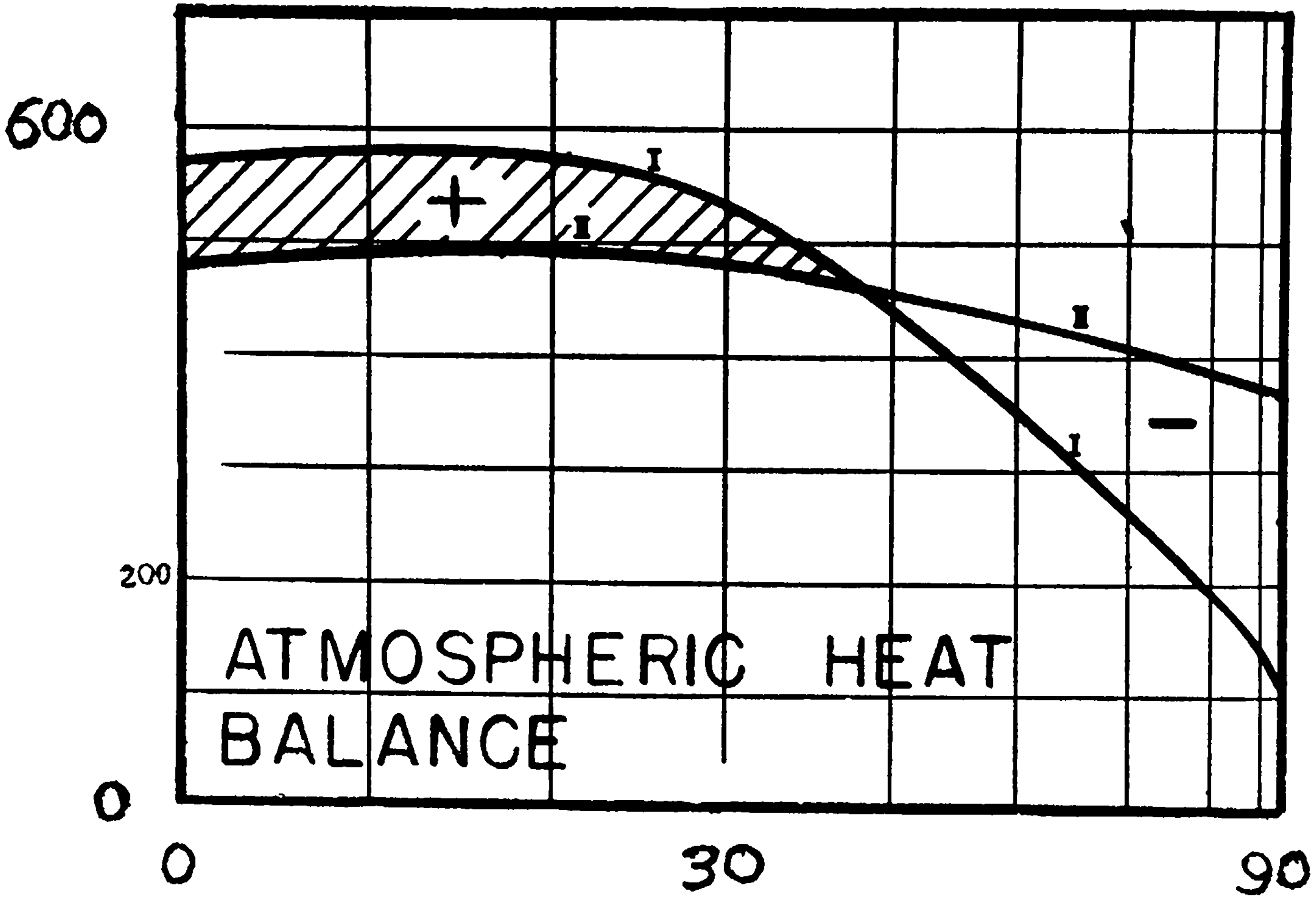


Figure 24



To complicate matters, the equatorial energy is collected by the trade winds and carried to the meteorological equator where it is piped up through the huge equatorial thunderstorm cells to the troposphere to be circulated poleward into the temperate zones. Perhaps 5,000 of these equatorial thunderstorm pipes normally occur each day. But occasionally such cells may fail to form locally, or conceivably may direct their energy into the wrong hemisphere to produce temporarily hemispheric unbalance of stored heat. All of these localized changes in input and output of this heat engine may upset the already doubtful stability of the atmospheric flow.

The circulation of heat from the equatorial regions toward the poles is not as simple as it would be through a series of pipes. Instead, the heat is conveyed through couplings between a series of vertical circulation cells successively in the equatorial regions, in the temperate zones, and in the polar regions. And of course these cells are bounded by the meteorological "fronts" with their associated west-east jet streams. Sometimes these cells do not transfer heat from one to another as expected, with a resultant delay in the heat transfer and consequent buildup of unusually hot and cold spots, or a rerouting of the ordinary flow patterns. The delay may extend for a considerable time, but, when the breakdown does occur, the effects on the weather may be catastrophic. Such gross effects cannot now be traced or understood until the whole earth is observed at very frequent intervals with appropriate measuring devices.

When we view meteorology in this way, it is not surprising that, through inability to make fundamental global measurements, our present methods of forecasting are far from perfect. By itself, the limited observation from a few poorly distributed points on the surface cannot possibily provide the basis for the continuing global description of atmospheric circulation and underlying heat balance and the exchange of heat that is the very basis of our weather and climatic change.

The satellite holds promise of revolutionizing our powers of observation in the field of meteorology. Among the early satellite experiments that would have been flown during the IGY, except for a few disasters, but will now be flown within a month or two, is the measure of the heat balance of the earth and the variation of that heat balance from place to place, namely, the map of the input and output energy to our atmospheric heat engine. Mapping of the hot and cold spots in the sense of excessive input to or output from atmospheric areas is certainly foreseeable now within a few months, in the earth satellite. Not far behind will come the experimental mapping of cloud and storm systems over the whole earth.

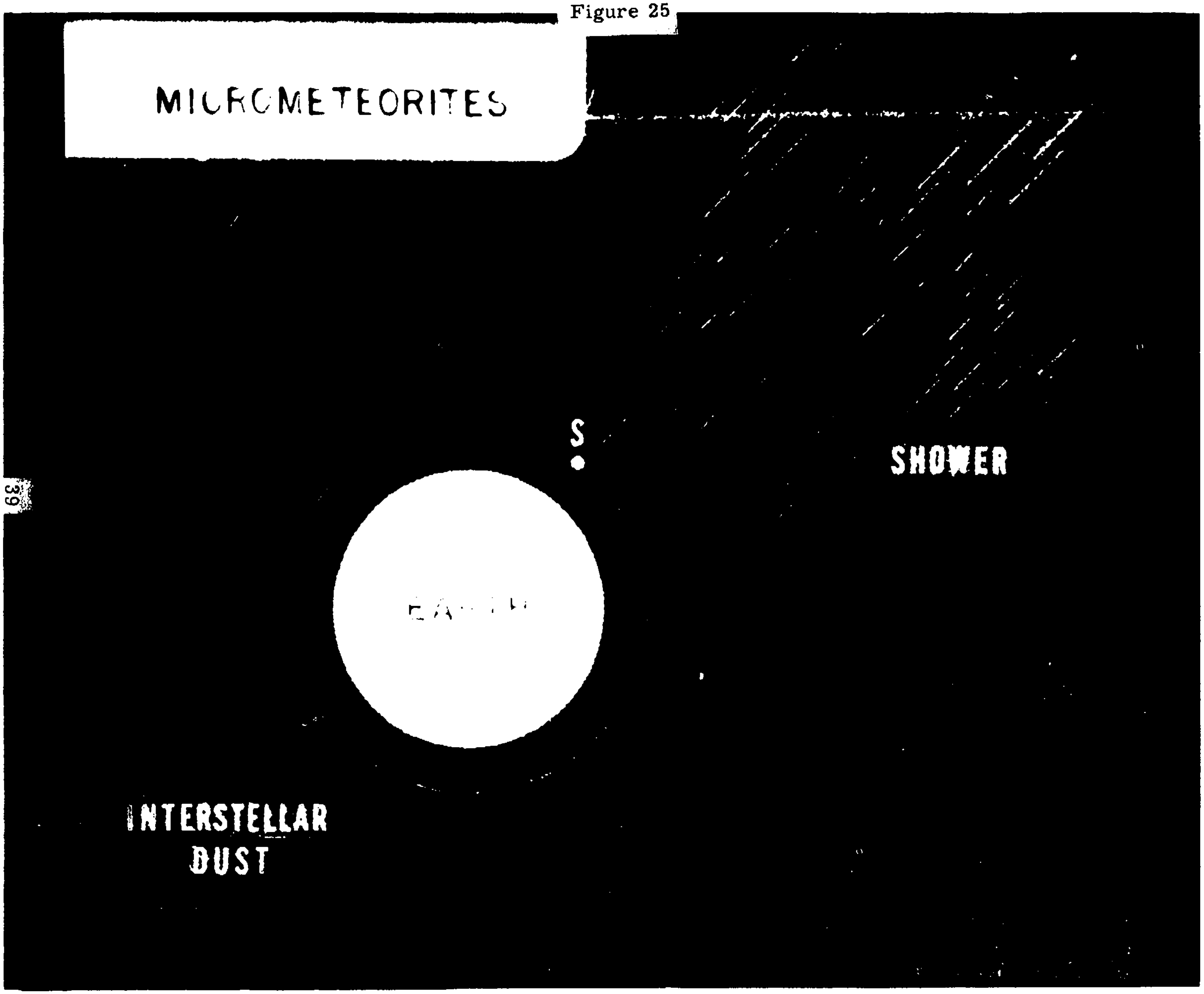
Some of you may have seen in the "New York Times" yesterday the magnificant map produced by the Navy with a single rocket. A similar apparatus, a bit more complex, will go into the satellites for mapping the cloud cover of the whole earth; and observing the signatures of the cloud tops one can identify these storm systems very well. So we are almost in reach, for the first time, of knowing how many storms exist on the earth, how they are moving, how they are forming relative to one another, and how they are disappearing. And of course one can observe the fronts by means of either the flash-frequency of lighting at night or by observations of radio static.

I could go on to many other powerful experiments that are critical to meteorology.

For instance, to what extent do meteoric dust particles of microscopic size vary in density as they are swept up from point to point by the earth as it courses along its orbit? Are such particles of meteoric dust of the kind and numbers that can influence rainfall, as Professor E. G. Bowen has suggested? (figure 25, p. 39.)

During the IGY a rather remarkable phenomenon has been observed in that ice crystal nuclei appear to be found every place over the earth on the same day. There are a few days during the year in which these will be found in Australia, in Hawaii, in Washington, and at other places. Their origin is not now known, although Bowen has suggested that they might be due to meteoric dust particles. Whether they cause rainfall or whether they are brought down from rainfall is not known, but it is known and has been known for a long time that rainfall tends to peak on these days. This new information is extremely important with respect to developing our theories of meteorology. I might say that one of these days happens to be in the vicinity of 18 March, the exact date depending on where leap year falls--a little before or a little after--which seems to be closely associated with the frequent heavy spring snowfalls. You remember the blizzard of 1888, and one can see that there has been a whole series of these events about this same date. These may be related, but we don't know yet. We are just beginning to get the clues through the position of the earth in its orbit and what it happens to be running into in those positions.

Figure 25



You might ask how this whole picture fits into the potentialities of weather control. We do not understand the atmosphere well enough at the moment to give an answer. But the satellite will help in improving our knowledge of the physics of the circulation and the formation of instabilities. If it turns out that the atmosphere is unstable--that is that small phenomena regenerate into large-scale storms--then one suspects that weather control or weather modification on a large scale would be possible at some time in the future by getting control of the triggering mechanisms.

If, on the other hand, the global circulation is really stable and small disturbances are quickly damped out, then large-scale weather control might be difficult or impossible; but in that case we should achieve near 100 percent prediction, even on a long climatic scale. Haphazard experiments with cloud seeding, of course, are of doubtful value at this time, but a full-scale attack on the physics of global meteorology is certain to give us a major payoff in one direction or another.

In the field of pure physics is a whole range of experiments that the satellite can do. One might mention the positive test of the general theory of relativity through the measurement of what we call the gravitational red-shift.

You might be surprised to know that, while the special theory of relativity is fully established--in fact our cosmotron at Brookhaven wouldn't work from day to day if it weren't for Einstein's special theory--the general theory of relativity is not at all well established and is considered by many to rest on very "rocky" ground. It is possible to test this theory by putting an atomic clock keeping time to one part in 10^{12}--that's one part in a million million--in a satellite which is flying in a lower gravitational field high above the earth, and another atomic clock on the ground, and to compare these two. This experiment will certainly be done in the next year or two to make a form test of the general theory of relativity.

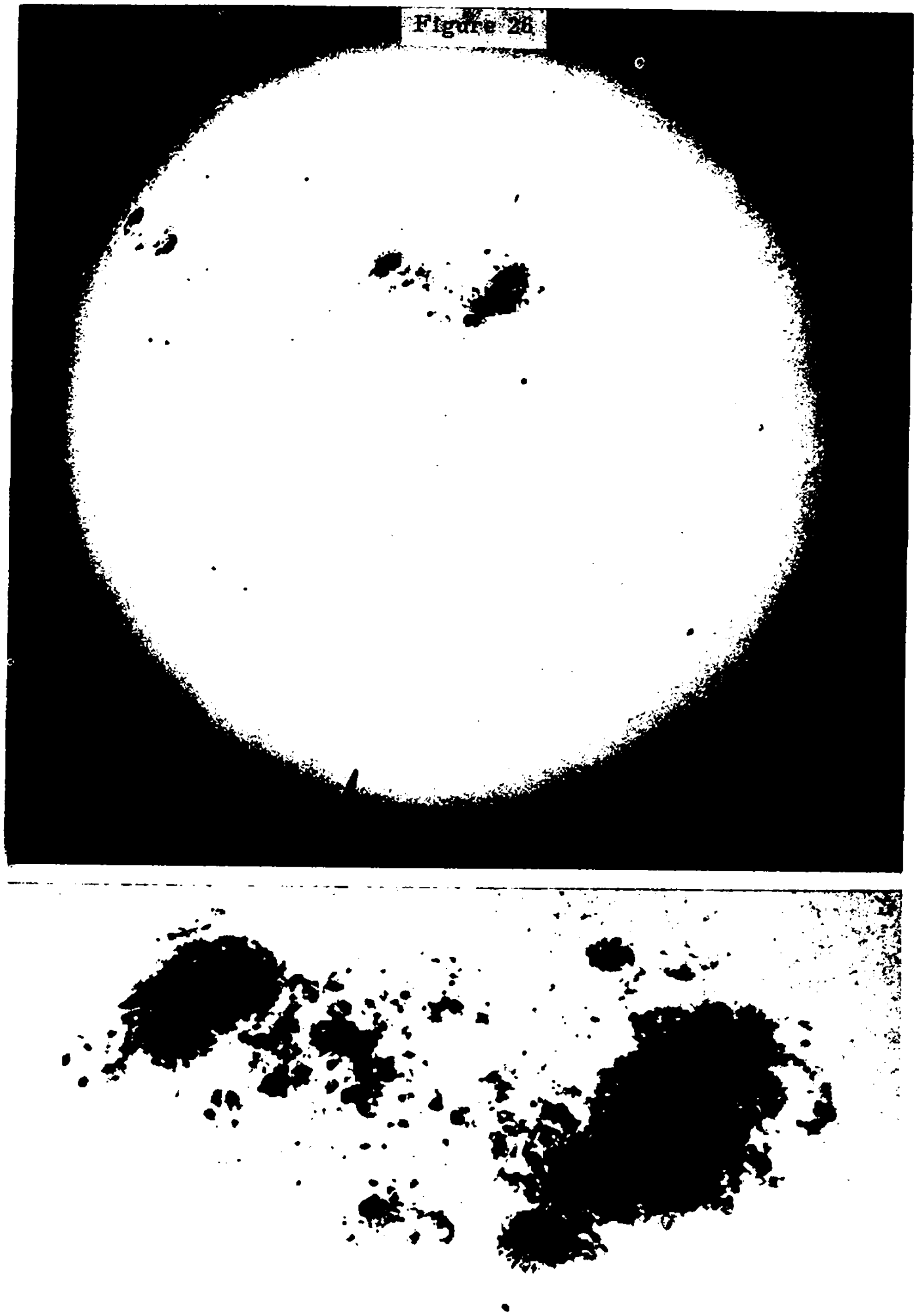
Likewise, the sampling of meteoric dust in space will add to our knowledge of the universe, its mass, and the processes of formation of matter. The interaction of cosmic rays with the particles of space can give us intimate knowledge of the age of such material.

I could go on to describe satellite experiments involving primary cosmic ray particles themselves, zodical light, character of the ionosphere, propagation of the whistlers, and a hundred other studies in physics. Already, during the IGY, Van Allen has discovered the curious "radiation belt" of high energy particles extending above some 700 miles over the surface in a band around the earth between the two auroral zones, but not above the poles themselves. This belt seems to arise from the upward-flying debris of cosmic ray collisions, technically called cosmic ray albedo, which is trapped by the earth's magnetic field because the particles are charged. The data from the Pioneer I rocket, which are just now being announced, suggest that two such belts may exist, one encircling the other. The discovery of this Van Allen region, of course, suggests a whole host of experiments related to geomagnetism, the aurora, and particle streams from the sun and from space that certainly will greatly illuminate our knowledge of the earth's environment.

While the studies of the IGY have been, of course, designed to tell us about the earth, we can't ignore our sun, the source of our light and energy (figure 26, page 42). The sun becomes unusually spotty and stormy and explosive every 11 years, and its spots and eruptions have important effects on our earth. They are the baby elephant in my original story. Following the great explosions on the sun's surface, radio blackouts occur and the intensity of cosmic rays sometimes increases greatly (figure 27, page 43). After a day or two the slower debris of the eruption reaches the earth, causing great polar radio blackouts, geomagnetic disturbances, auroras, and other visable results (figure 28, page 44). The nature of these events, of course, is not yet fully understood. Therefore, during the IGY, men and instruments have been watching the sun constantly at more than 20 stations around the earth, as well as having augmented observations of the satellites and rockets.

These particle streams may behave something like this, but we are not yet quite sure. This is a hypothesis (figure 29, page 45).

Figure 26



The Sunspot of April 7, 1947

Figure 27

Figure 28

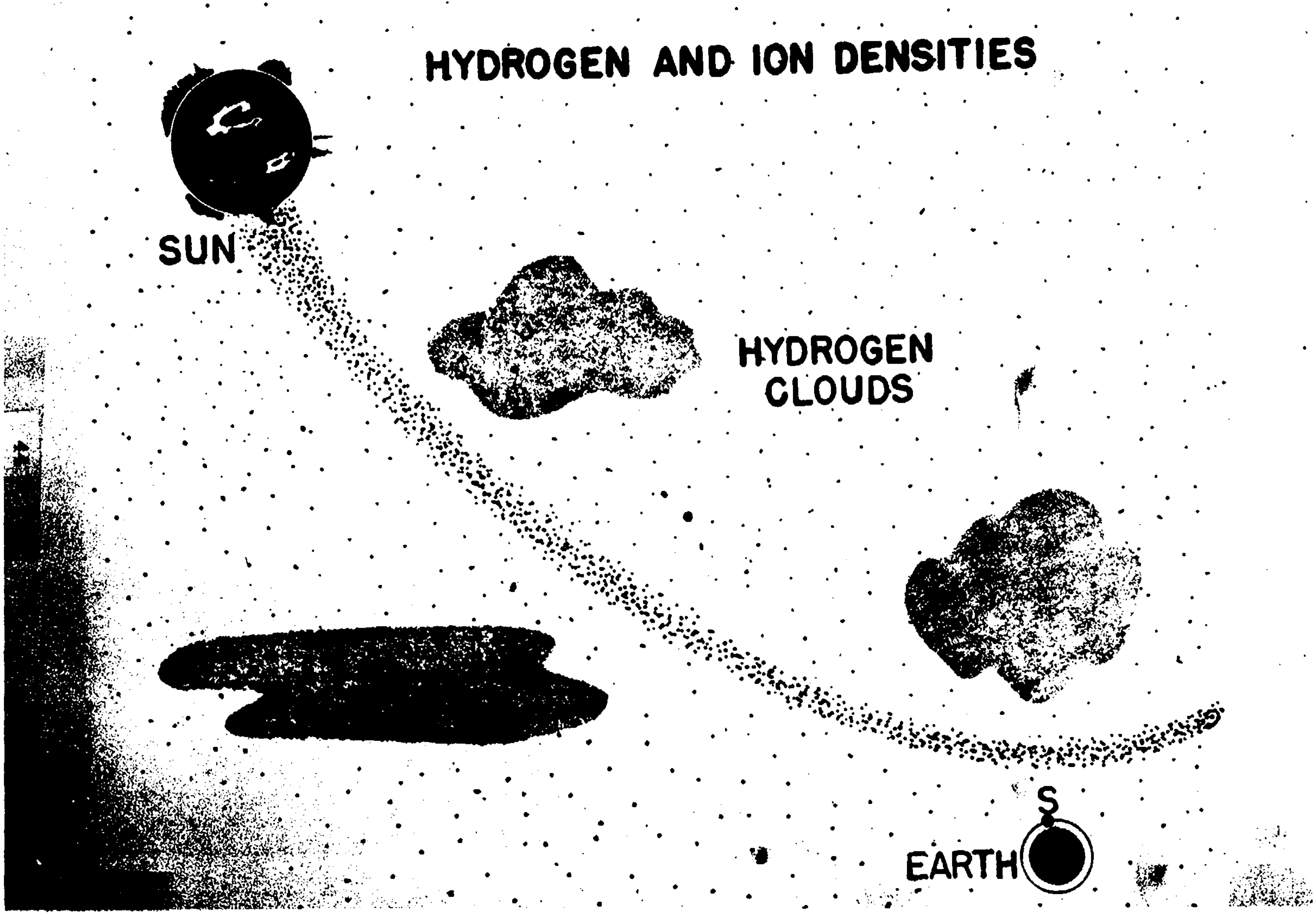
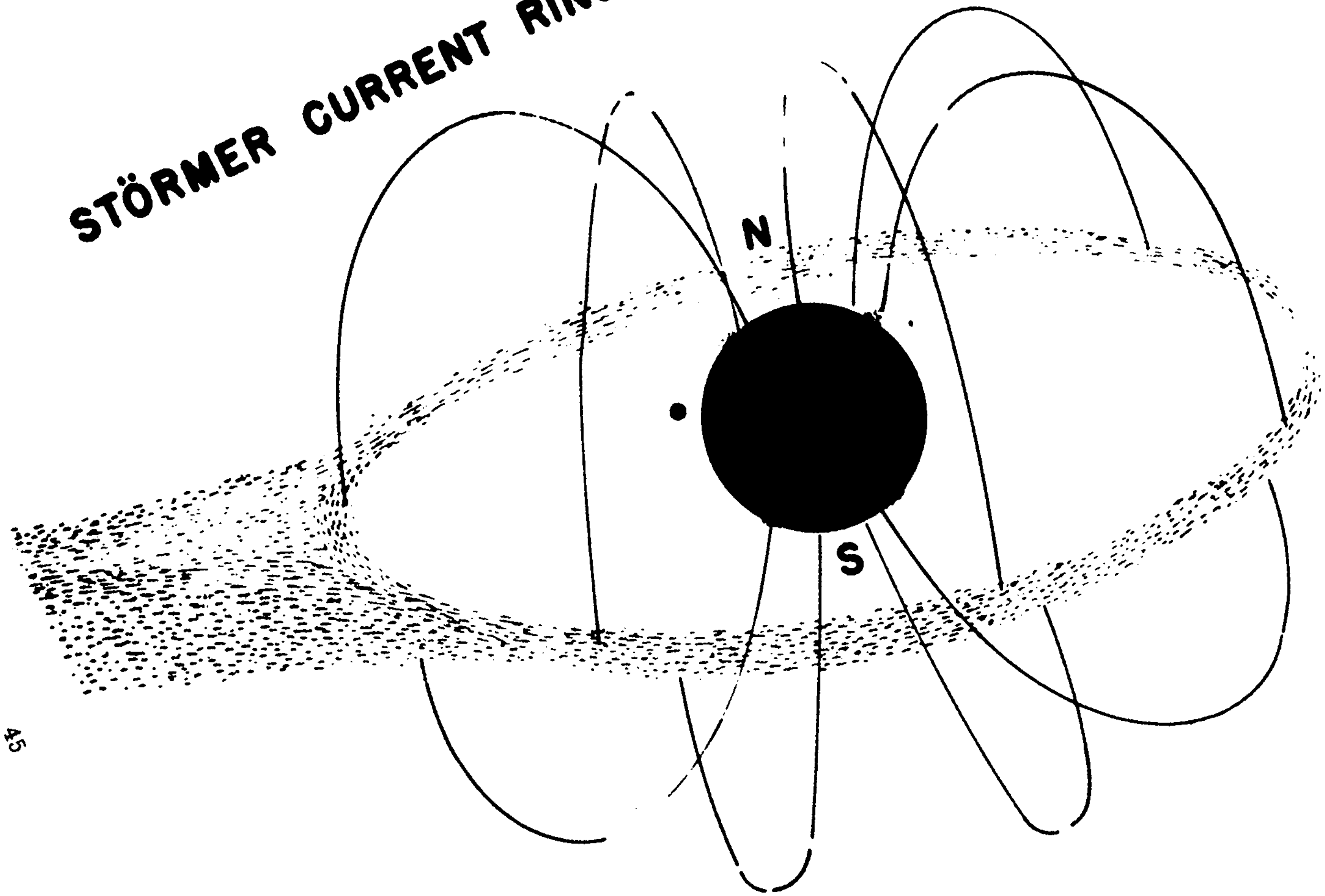


Figure 29

STÖRMER CURRENT RINGS



The interval of the IGY during 1957-1958 was deliberately selected because the sun would reach its 11-year maximum of solar storminess during that time. The present sunspot cycle certainly exceeded expectations. There's a very interesting story about it. Some people predicted that there would be a very low sunspot cycle. In January 1957 the sunspot number, however, which is a measurement of the storminess on the sun, had reached a count of 169.6. This alltime high exceeded the previous high of about 160 which was reached in 1778--about the time of the American Revolution--since sunspot activity was first estimated in 1755. By June of 1957, at the opening of the IGY, the count had reached the unheard of value of 205.6, far exceeding anything that could have been predicted, and it has remained at very high values, above 200, well through 1958. It is still up in the 180's.

Complicated observations that can be made only rarely, of course, must be made simultaneously over the earth, if we are to describe the phenomena that occur, but these observations may be so complex that they can't be made continuously (figure 30, page 47). Therefore, during the IGY, the scientists of the earth agreed to make the more complex observations on a calendar of two, three, or four regular world days each month, which you see circled on this calendar.

Moreover, special observations were made when worldwide geophysical disturbances were predicted. To make these predictions, solar observers sent reports of solar activity to three centers, at Washington, Paris, and Tokyo. After combining the data, the facts were sent to the Central Radio Propagation Laboratory of the National Bureau of Standards in Washington, where the complete story on solar activity was evaluated. This IGY plan was so successful that scientists are continuing it permanently. When active regions appear on the sun, the Washington Warning Center sends out an international alert on the worldwide IGY communications network, which is called AGIWARN, to warn geophysical observers that the sun may erupt (figure 31, page 48). If the activity is sustained or increases as it moves toward the sun's central meridian the Warning Center announces what is called a Special World Day, so that observers can be on the job to make the most complex observations when the eruption occurs, and will be ready to follow its development and its reaction over the earth (figure 32, page 49).

INT
GEOPH
CA

JUNE 1957

SUN.	MON.	TUE.	WED.	THU.	FRI.	SAT.
						1
2	3	4	5	[illegible]	[illegible]	8
9	10	11	12	13	[illegible]	15
16	17	18	19	[illegible]	21	22
23	24	25	26	27	[illegible]	[illegible]
30						

JULY 195[illegible]

SUN.	MON.	TUE.	WED.	THU.	FRI.	SAT.
	1	2	3	4	[illegible]	[illegible]
[illegible]	8	9	10	11	[illegible]	[illegible]
[illegible]	15	16	17	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	24	[illegible]	[illegible]	[illegible]
[illegible]	29	30	31			

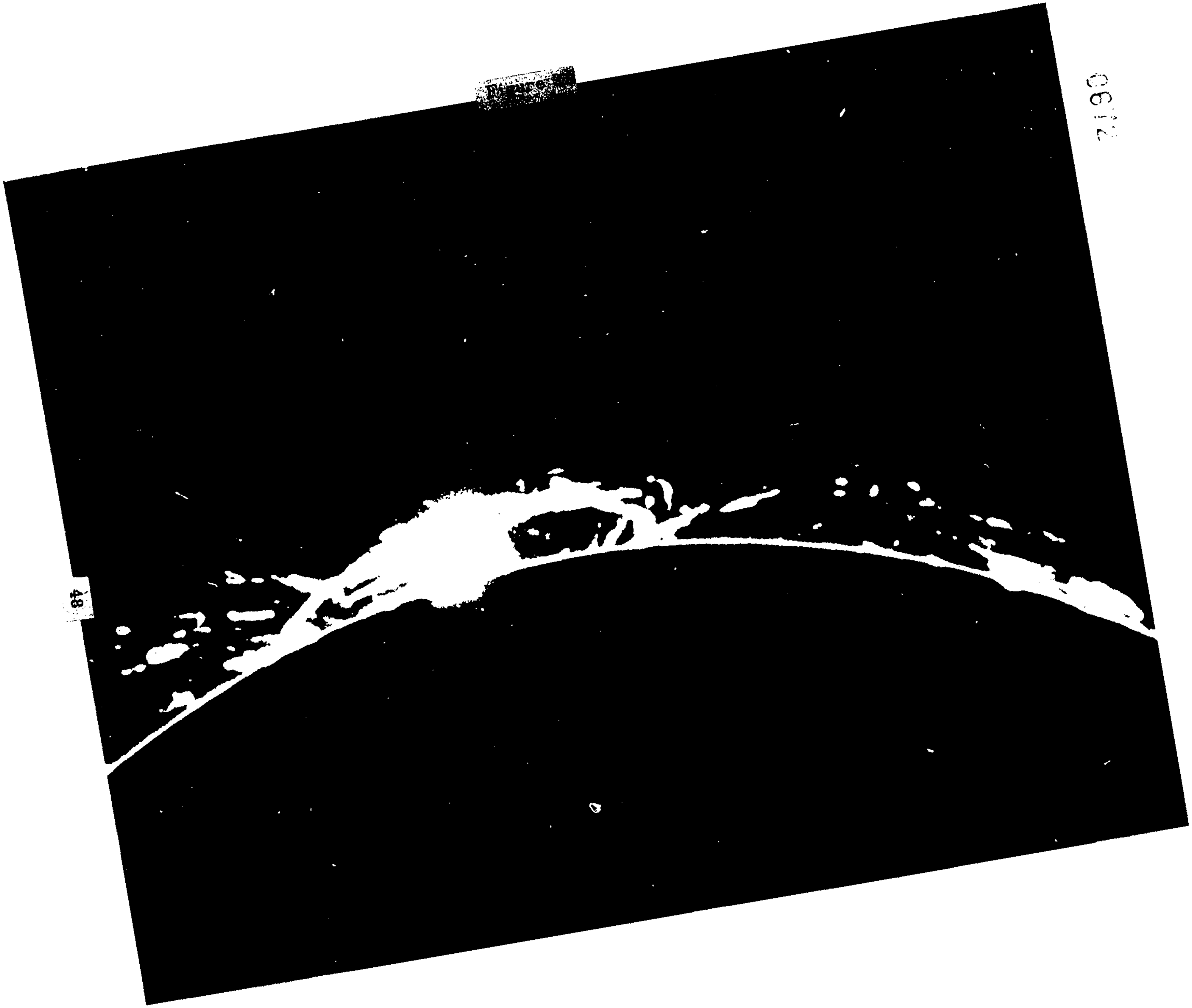
OCTOBER 1957

SUN.	MON.	TUE.	WED.	THU.	FRI.	SAT.
		1	2	3	[illegible]	[illegible]
6	7	8	9	10	[illegible]	[illegible]
13	14	15	16	17	[illegible]	[illegible]
20	21	22	23	24	[illegible]	[illegible]
27	28	29	30	31		

JANUARY 1958

SUN.	MON.	TUE.	WED.	THU.	FRI.	SAT.
			1	2	3	4
[illegible]	[illegible]	[illegible]	8	9	10	11
[illegible]	[illegible]	[illegible]	15	16	17	18
[illegible]	[illegible]	[illegible]	22	23	24	25
[illegible]	[illegible]	[illegible]	29	30	31	

World Meteorol[illegible]



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This International Geophysical Year has been so successful in an era when international disagreements and tensions were the rule that I think we should spend a moment on its origins and on the principles of management. By the early years of the 20th century, progress in science and particularly in astronomical observation, in international radio research, and in geodetic measurement and geophysical observation, had made imperative a more formal international instrument for scientific collaboration and planning. Moreover, the growth of research in localities, such as North America, that were widely separated from the origins of contemporary science in Western Europe multiplied the need for prompt agreement on nomenclature and standards to encourage a quick and healthy review and discussion of scientific discovery. It is significant that the corrective action to meet this situation occurred at the initiative of scientists themselves acting through their national academies and research councils and without any formal action on the part of governments.

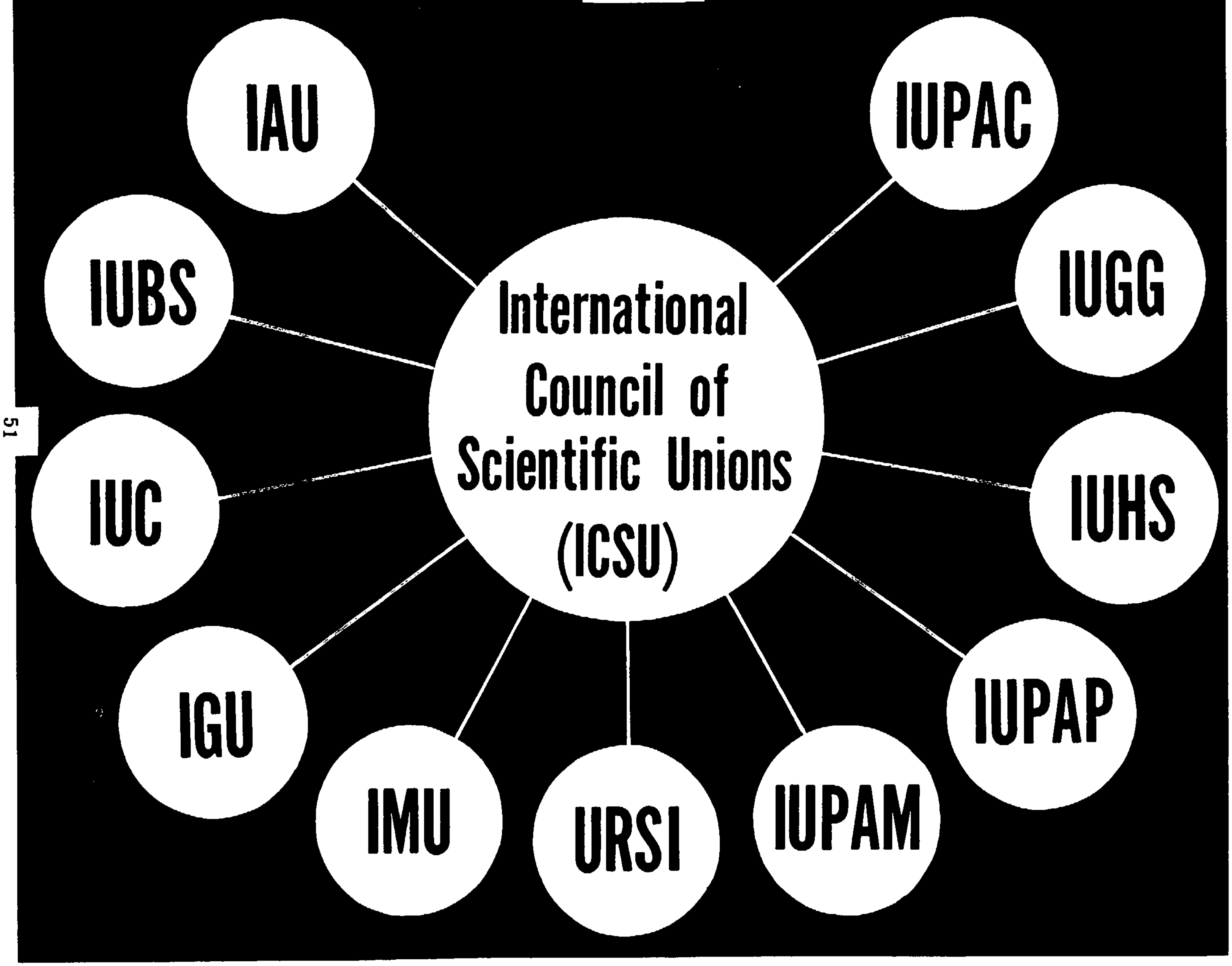
In 1918, the academies and research councils of many nations joined to create the International Research Council (figure 33, page 51). Under the sponsorship of this Council, the first international scientific unions were formed to deal with international problems in specific fields of science. In the ensuing years, more unions were recognized, as the need arose, until now 13 scientific unions are affiliated with the central international body. I think perhaps there are only 11 in this picture, but there have been two more added recently.

Just two other events in this history of the growth of international scientific activity are worthy of notice. The original International Research Council of 1918, through the failure to recognize Germany, had failed to understand the essential source of vitality of the principle of political nondiscrimination which, of course, must underly international scientific collaboration. So that consequently, the International Research Council was replaced in 1932 by the International Council of Scientific Unions (ICSU), which has recognized the overriding importance of principles of political nondiscrimination.

In concluding my mention of the ICSU and the scientific unions, I would just reiterate two points:

First, that the international activity among scientists is very young, having risen only in the present century.

Figure 33

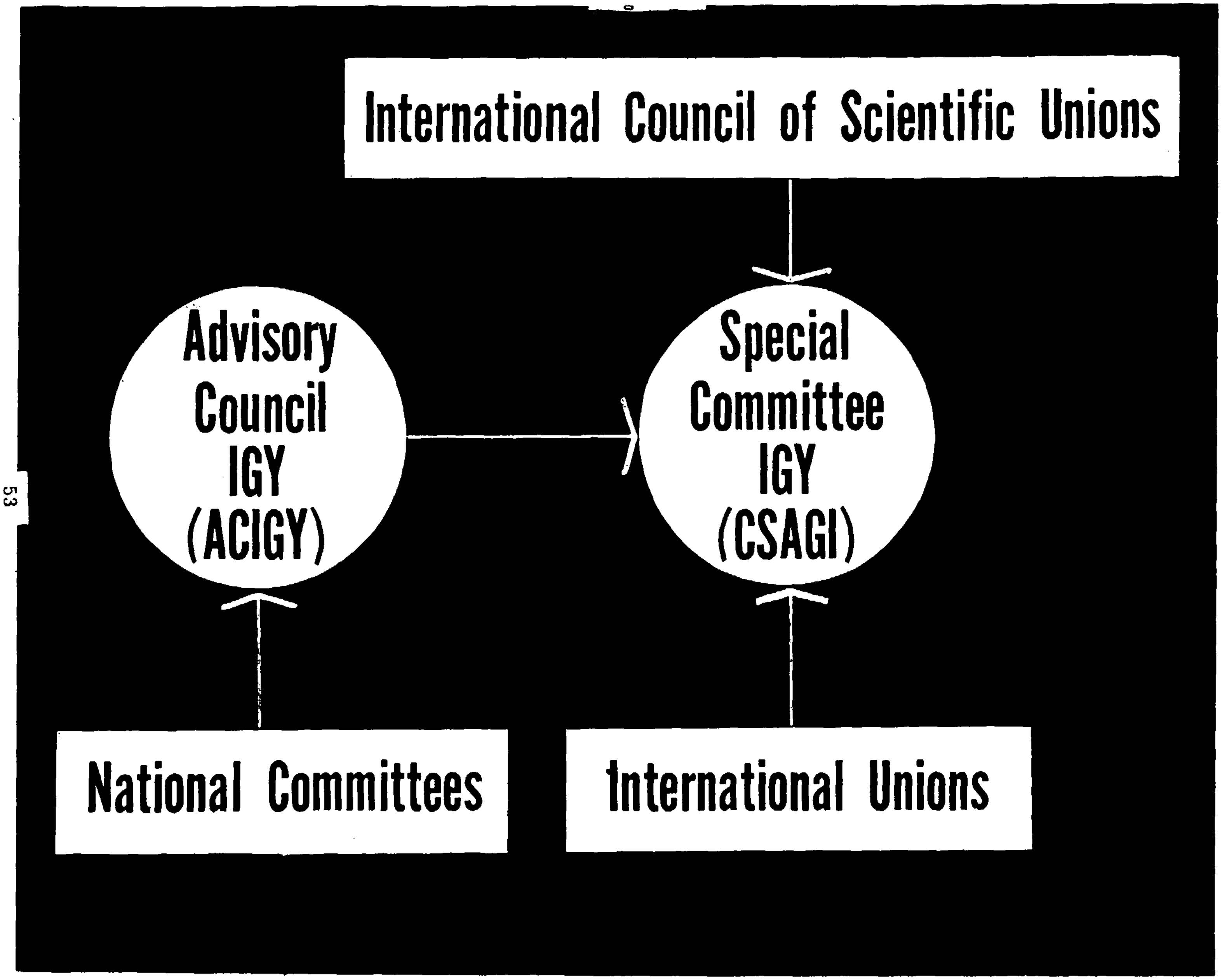

IAU
IUPAC
IUBS
IUGG
International Council of Scientific Unions (ICSU)
IUC
IUHS
IGU
IUPAP
IMU
URSI
IUPAM

Second, that the first genuine and lasting international collaboration in sceince has been generated and managed by the scientists themselves, acting through their national academies and research councils. There has grown, during the intervening 40 years, an international recognition and encouragement of the privilege and responsibilities of scientists to sojourn and to plan their activities formally in their own international groups, without political interference. While, of course, scientists acting in the international sphere consult their governments intimately, through their academies, concerning any international commitments they may make, their actions are much less restricted than if they were formal governmental bodies; for their agreements do not require the face-saving formulas that politicians sometimes believe necessary during intergovernmental negotiations at the political level.

By 1950 a worldwide effort was both necessary and feasible to describe geophysical events that encompassed all, or a great part, of the earth. This simultaneous worldwide effort of nations seemed the only way to make this significant advance in knowledge that was required. Consequently, the IGY was organized under a special committee formed by the International Council of Scientific Unions and was known as the Special Committee of the International Geophysical Year (figure 34, page 53). This committee was initially financed by grants from UNESCO. It had an advisory council of the nations that were interested, representing the national committees, and, of course, it included membership from the international unions.

It was in 1952 that the special committee asked each nation to organize a national committee to advise how its national committee could contribute to the achievement of specified IGY objectives (figure 35, page 54). Here is an example of the organization of the United States national committee under our National Academy of Sciences.

Sixty-six nations responded and the committee planned a comprehensive worldwide program of geophysical measurements that was carried out during 1957-1958. Of the great nations, only Communist China had a government so backward that it permitted its political jargon to stand in the way of its active participation. Parenthetically, it is reported that the scientists of Red China carried out their part of the program anyway. Indeed we know this, because we found some of their data at the International Data Center at Moscow. The plans were integerated by a series of meetings in Brussels in 1953, Rome in 1954, and Barcelona in 1956 to carry out every detail of the world program and to negotiate for whatever extension of the national programs was needed where serious or obvious gaps existed.



International Council of Scientific Unions

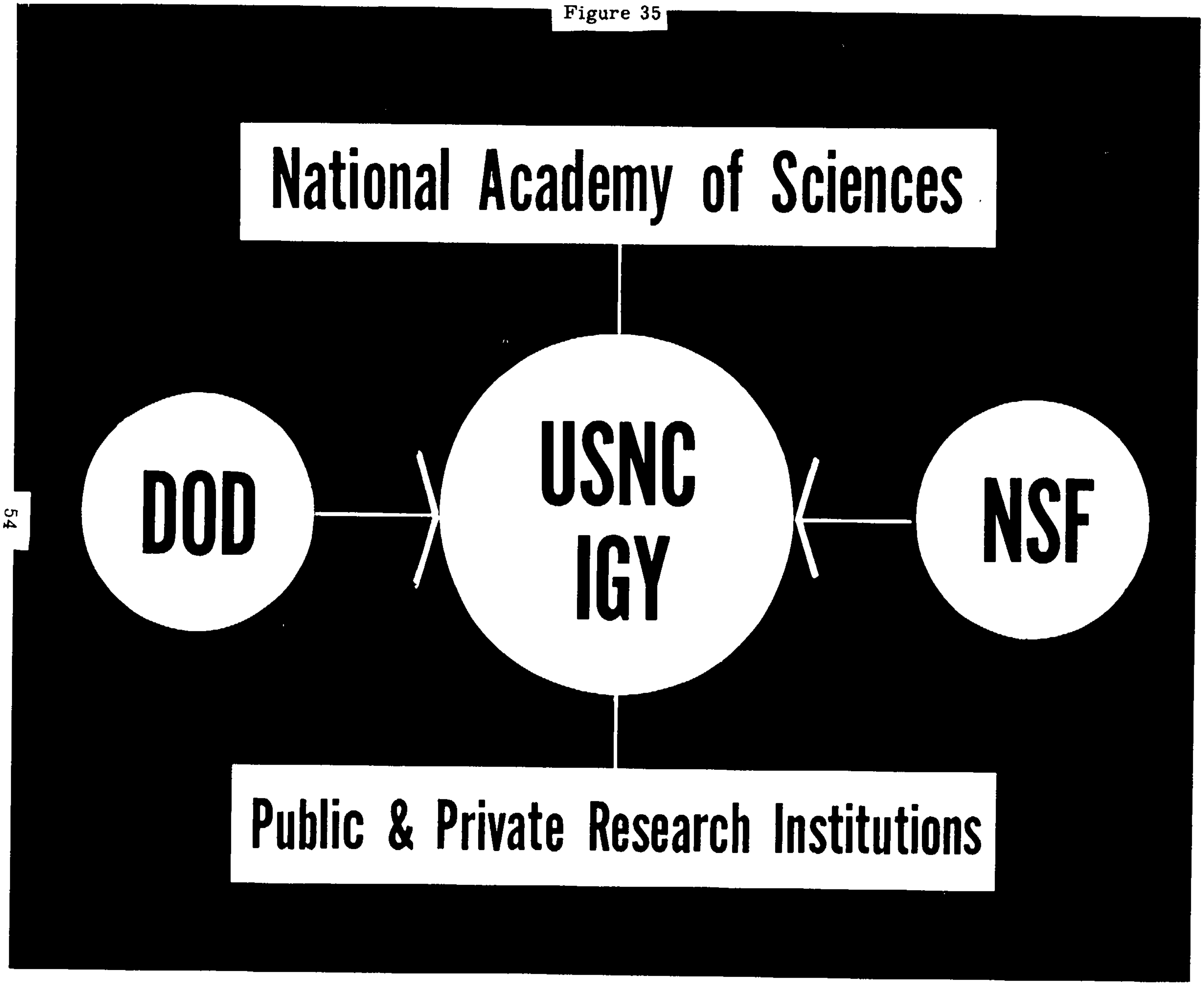
Advisory Council IGY (ACIGY)

Special Committee IGY (CSAGI)

National Committees

International Unions

Figure 35


National Academy of Sciences
DOD
USNC
IGY
NSF
Public & Private Research Institutions

There are several points about the organization and management of the IGY program that are worthy of notice:

1. The organization of the research is through national machinery. Consequently, the governments of the world respond favorably to requests by their own national committees for support of specific measures within their capabilities that are planned and endorsed by the world's leaders in science.

2. The planning function of the special committee is international and must be financed from international funds. Consequently, UNESCO properly played a leading role. The amount of such administrative funds is small (perhaps a few hundred thousand dollars) compared to the huge research funds of perhaps hundreds of millions that were catalyzed by this international planning.

3. The method is successful in catalyzing extensive research. The specification of particular international objectives tends to inspire the desire for participation on the part of every national group (except the Chinese politicians) since it satisfies a sense of national aspiration.

4. Research can be stimulated that would not otherwise be possible. I cite as an example of this power of cooperative planning the scientific exploration of the Antarctic Continent. The unknown "seventh" continent is being explored by means of every available scientific tool in cooperation among nations in spite of their previous vicious political claims.

5. The special committee is entirely nonpolitical. It states objectives and plans requirements and arranges for the interchange of data. (Incidentally, much of the Russian data, which were previously withheld, are now available as a consequence of this.) It makes no recommendations for the work by one nation in the territory of another. It encourages bilateral negotiations where cooperation between specific nations is advantageous. Above all, it welcomes participation by all national groups. (Our own Government was worried on this last one because of Communist China, but it has gotten over this worry).

6. The method captures the imaginations of the world's best research scientists. The planning by scientists of many nations toward a common objective inspires enthusiasm for otherwise unrealizable goals.

In conclusion I should mention that other special committees are now under consideration or are already at work to follow the IGY. For instance, collaboration in the Antarctic will continue after the IGY under the new Special Committee on Antarctic Research, called SCAR. The Special Committee on Oceanic Research is planning an international analysis of the Indian Ocean, using more than 20 vessels of many countries in 1961 and 1962, to be followed by similar studies of other oceans. The International Council of Scientific Unions has just established a Special Committee on Space Research to continue international planning for space science after the IGY, and all launching and tracking nations have joined this committee, including the USSR.

So the new patterns for international collaboration are being constructed and tested. Some, of course, will enjoy success, and others may fail. But at least men are rising to the challenge to provide the opportunity to acquire the benefits that international collaboration and science can provide.

We must remember that the whole purpose of the IGY and of the studies that will follow has been to understand this unusual Planet Earth with its special conditions that make life both possible and abundant. For it is necessary that we completely understand this extraordinary planet that is our home. We must be prepared to adjust our living to its changes and to turn to our advantage the boundless opportunities that it offers.

Thank you very much.

CAPTAIN FIKE: Dr. Berkner is ready for your questions.

QUESTION: Dr. Berkner, I would like to follow up a little bit on the point you made about getting information from the Soviets on their satellites. Initially, under the IGY, did you have an agreement as to the kind of information that would be obtained? If so, did the Russians come through on it?

DR. BERKNER: Yes. The fact is that we did have an agreement on what information should be announced, and, as usual, if you examine the records carefully, you find that the Soviets lived up exactly to the letter of the agreement. There was a good deal of misunderstanding on the part of many of our newspapers because much of the Soviet material, which was published in the Russian language, wasn't translated until too late. The second difficulty--and I think this was important--clearly hinged around the fact that, even after we knew they were going to launch we wouldn't believe it! It was just as rough as this!

I will give you a specific example. We had a conference on rockets and satellites in the National Academy of Sciences, starting on the first of October and going through the fourth. On Monday, the first, General Boganrobov, whom you see quoted frequently in the papers, and who is one of their leading academicians and rocket experts, got up on the platform in the Academy and made the statement, in front of a large audience, officially. He said, "We are on the eve of launching our first satellite." This was Monday, October first. Previous to that, as it turns out, there had been published, about two weeks before, a fairly good account in one of the scientific journals just how they were going to do this.

If you go on through the subsequent history you will find that the requirement was that they announce within an hour of launching the fact that a satellite had been launched. This they did, regularly. It is required that certain data be transmitted and they have transmitted these data, really pretty well. Careful examination of the record shows that they indeed lived up to the limits of their agreement, but I will further say that they didn't go any further.

QUESTION: There have been a number of suggestions for the role of the United Nations in carrying on space exploration by a UN Space Agency or even a UN Space Force. Although the United States entered a suggested plan, it seemed to be quite a limited one, and the general attitude of the United States seems to be rather limited in terms of what role the United Nations will play in the immediate future as far as space exploration is concerned. Could you give us your views, sir, on the role of the UN and on perhaps what attitude the United States should take toward such a UN program?

DR. BERKNER: Yes. I delivered a whole lecture on 12 January on this subject lasting about 50 minutes in New York before the American Geographical Society, so you have asked me to summarize a most complex situation very quickly. Let me say it this way: There are two aspects of satellite operations that require careful study. The first aspect is regulation and control; that is: To what extent does one establish regulatory procedures with respect to satellites or space vehicles? The second aspect is operations.

Now, when the State Department first laid its resolution on the table, it appeared, from Mr. Dulles' statement, that the view was that regulation and control and operation should be bunched together and put in the UN. There was a series of objections to this procedure and after very careful study in our Government, I think the original interpretation of

Mr. Dulles' proposal was modified substantially. In the final resolution, which we supported before the UN, it was recognized that at least regulation and control should go in UN or in some other international agency, but that under the resolution, operations might be delegated to other groups who would operate in accordance with the regulation and control exercized by the UN.

How far regulation and control are going to go, one doesn't know. It is perfectly clear, as I described this morning, that there is immense scientific importance in satellites. It is equally clear that we are on the verge of setting up a huge communications industry using satellites, which in a few years will be worth probably several billion dollars. Where we have a billion dollars, we are going to have some problems. It is also clear that satellites are of immense military value--contrary to a lot of other pronouncements. Whenever one nation can use a tool in a way which is inimical to the interests of another nation, that tool is certainly of military significance, and satellites can certainly be used this way. They can be used for reconnaissance; they can be used for intelligence, especially communications intelligence; they can be used to broadcast signals into areas into which other people don't want signals broadcast; they can be used in any number of military ways. Rand even points out that you can store your nuclear stockpile in them and drop it out at the appropriate moment. And this is quite feasible.

So it is perfectly clear that satellites have military implications. Now, some of these military implications may be very desirable. For example, reconnaissance, if accepted internationally, might be just the thing that was necessary to prevent the outbreak of an aggression.

Just how control and regulation will go in the future no one knows. It is quite clear that one could easily get into a satellite war. I will only say this in conclusion: If regulation and control are not established very soon, then I do hope that our military forces quite quickly acquire the means of disabling or destroying enemy satellites. One must remember and it can be put like this, that the hovering satellite, launched eastward at an altitude of 22, 000 miles, which hovers overhead along a meridian, could easily be a Soviet satellite hovering over the United States. And 1984 can come very quickly with "Big Brother looking at us."

QUESTION: Sir, it has been said in the past that the heat budget of the earth is rather intimately connected with the carbon dioxide content of the atmosphere. You mentioned that within a century we are doing our best to burn all of the hydrocarbons available to us. I wonder what the connection might be between this process of burning hydrocarbons and the climate of the earth.

DR. BERKNER: We think there is probably an intimate connection. Until the IGY it was generally thought that the interchange of carbon dioxide between the air and the ocean was a very quick interchange and that the half-life of carbon dioxide in the ocean or in the air was of the order of a few days, so that there was an equilibrium condition between the carbon dioxide in the air and the carbon dioxide in the ocean.

This turns out to be wrong and we have now found, during IGY, that the half-life of carbon dioxide in the air is probably about seven years. This is a very important observation, for the following reason: Because the half-life of carbon dioxide in the atmosphere is long, it means that carbon dioxide can build up in the atmosphere steadily.

Measurements during the IGY of carbon dioxide in wood grown in 1900, as compared to wood grown in 1950, showed that the carbon dioxide in the atmosphere had increased from 2 to 5 percent over the intervening 50 years. One can extrapolate this situation very readily and, I believe show that in another 50 years the carbon dioxide in the atmosphere will have increased 35 percent. This is a very large amount, and it is important for the following reason: that carbon dioxide is a molecule that is a dipole that absorbs heat infrared radiated from the earth's surface. If you increase the amount of carbon dioxide in the atmosphere it will absorb the heat that is normally radiated into space and radiate it back to earth. This is a kind of greenhouse effect, the same thing happens in the glass over a greenhouse.

So we might anticipate that, with increasing carbon dioxide in the atmosphere, the earth will get much warmer. We know the earth is indeed getting warmer. The temperature, for example, at such places as Spitzbergen in the observed time has risen on an average of 12°. At Little America, during the 50 years of observation from Amundsen down to the present time, the increase has been of the order of 4° or 5°. The glaciers are retreating almost everywhere, and, in, the dry valley areas that I described there is a poor little old iceberg sitting out in the middle of one of the dry valleys. Obviously the valley must have been cleared in relatively recent time, and this last iceberg has 10 or 15 more years to go and it will be gone, too.

So the implication is that the burning of the fuel will increase the carbon dioxide, warm the earth, and melt the glaciers. As you know, the oceans are probably rising. We don't have the final data from the IGY, but there is every indication that they are rising more rapidly than before.

QUESTION: Dr. Berkner, I have read that some of the data that the Soviets furnished under the IGY were not of a quality comparable to our own. If this is true, could you discuss what this means so far as the quality and competence of the Soviet scientists are concerned?

DR. BERKNER: I don't believe I would concur with this point. I think the data that they gave us were really of good quality. Soviet scientists have a great deal of pride and they won't release their data at all unless they feel they are pretty good. On the other hand, I point out that, while the Soviets could have spotted this Van Allen radiation zone, maybe they didn't release their data very quickly. Van Allen got the jump on them in the later observation.

So I can only summarize my attitude toward Soviet scientists by saying that I found that over the eight years of negotiations with them that their quality is really very good. One interesting aspect of this negotiation has been the fact that, in negotiating with their scientists, we are negotiating with a different group of people than if we were negotiating with their politicians. The politicians are rough, tough, and generally ignorant as hell. They are people who have shot their way to the top. You might call them the Batista type. On the other hand, their scientists on the whole are extremely intelligent people. The thing that is so noticeable in negotiating with Russian scientists is, first, of course, the politicians have their finger on them all the time. This is very apparent. On the other hand, the politicians in Russia have to use the Russian intellectual to get on with their job, and, therefore, the Russian politicans are in a dilemma. The more they use the intellectuals in Russia, the more the intellectuals rise in power, and the more the evolution goes on in the Soviet Union. If they try to avoid this rise in power they lose in the other direction by not having the skills that the intellectuals can provide.

In eight years I have seen an enormous evolution go on in the Soviet Union in the freedom with which we get their information and in the ease with which the negotiations are carried out. Inevitably, the rise of the intellectual class in the Soviet Union is causing a very rapid evolution in their whole system and is weakening the power of their gangster government leaders.

QUESTION: Dr. Berkner, in a recent issue of "The Atlantic" there was a very interesting article entitled "Will the Ice Age Return?" This concerns the shelf under the North Atlantic and states in effect that, when the warm Atlantic water melts the icecap we will have the beginning of the next ice age. Did this receive any attention in general under the IGY, and are there any other opinions on this?

DR. BERKNER: Yes. Wasn't that in "Harper's" instead of "The Atlantic?"

STUDENT: I guess it was.

DR. BERKNER: That is Maurice Ewing's hypothesis. As a matter of fact it is a very good one and it's very well respected. It looks to the fact that there have been four ice ages in the last million years, each separated by about 250,000 years, it seemed, with wide spaces between them. They seemed to come up very rapidly and to disappear very rapidly. For example, we now think that the last glacier, the Wisconsin, that reached the area just north of Washington and extended across where my home is in New York, disappeared in only about 3,000 years. This is a very interesting observation, because we calculated, during my recent trip to the Antarctic, what the total heat deficiency was in the ice of the Antarctic. It turns out that the heat deficiency could not be made up by all the heat in the ocean. In other words, if you took all the heat in the ocean and applied it to melting the ice in the Antarctic Continent, there wouldn't be enough.

This very interesting calculation that comes out of the IGY, shows that an ice age cannot be a completely closed system with heat being transferred from ice to water and vice versa. Of course you can explain it by saying. "Well, the albedo of the earth changes for 10,000 years about 1 percent or a few tenths of 1 percent, or something like this, so that you are receiving less heat for many thousands of years because the earth is more cloudy and it gets colder. Then, when it accumulates the ice in great sheets, it becomes less cloudy and the ice starts to melt."

This does not deny the Ewing theory, because the Ewing hypothesis, as I recall it, would really be a part of all this. In the lowering and raising of the oceans the effect of the submerged ridge running between Greenland and Iceland and to the Faroes prevents movement of water from the Atlantic into the polar regions when the water is low. The Ewing hypothesis is that this dam completely separates the water of the Arctic Ocean and the water in the Atlantic at the maximum of an ice age because the oceans are lowered about 200 to 400 feet, whereas, when ice disappears the water can exchange freely and the Arctic Ocean melts, causing a complete change in climate.

So I think we are getting very close to the time when perhaps we will be able to explain the ice ages. But we must remember one thing: There were four ages in the Pleistocene, one after the other, about 250,000 years apart. But, before that, there wasn't a single ice age in the earth until you go back to the Permian, which is 250 million years ago. So there must be external influences involved.

QUESTION: This goes back to previous to 1947. If you recall, in the old Research and Development Board there was a paper on what was called The Earth Satellite Vehicle. My question is this: If that project had been given funds and support at that time, how soon could we have launched the satellite?

DR. BERKNER: Well, I am not going to say how soon we could have launched it, but I'm damn sure we wouldn't have had so much trouble. I remember these papers at that time very well. You will recall that we got going on the rocket business in 1950 and then all our money was pulled away in 1952 and our people all dispersed. We got going again, and again our money was pulled away in 1954 and all our people dispersed. It was toward the end of 1955 that we really finally got to stay in this business.

You must remember the following facts: The Germans got going on rockets in 1928; the Russians in 1934; we, on small rockets, in 1942, but never continuously until 1955. So we have lost a lot by our failure to continuously support our rocket activity. And I can think of one or two things that we are not continuously supporting now. I'm not going to mention them here, but they are going to cause us the same kind of trouble in about 1962 or 1963.

CAPTAIN FIKE: Dr. Berkner, on behalf of both Colleges, I wish to thank you for a very stimulating and comprehensive presentation and for your very frank answers to our questions on a subject area that I am sure is almost mystical to most of us nonscientists. Thank you very much.

DR. BERKNER: Captain, I can only end with a little story that Van Bush always tells when a program goes on very long. One is never sure in talking about these scientific matters how long he should do it. The story is about the fellow who got on the platform and couldn't stop talking. This was at a dinner meeting. The chairman finally saw people going to sleep and a few in the back sneaking out, so he rapped his gavel on the table lightly, but the speaker kept right on going. Finally the chairman took his gavel and banged the table really hard. This didn't stop the speaker, but the head of the gavel went spinning out in the audience and hit a poor fellow on top of the head. He just disappeared under the table and passed out. This didn't stop the speaker; he went right on talking. Finally, the poor chairman just sat back. His gavel was gone and he had no control over the situation. Then a pair of hands appeared over the edge of the table, and finally the fellow pulled himself up until his chin was just over the top, and he shouted in a loud voice, "Hit me again, I can still hear him!"

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