GPO PRICE $

OTS PRICE(S) $

Hard copy (HC) 2.00

Microfiche (MF) .50

Address By
Dr. Harry J. Goett, Director
Goddard Space Flight Center
NASA, Greenbelt, Maryland

Centennial Convocation Luncheon
Morgan Hall
Worcester Polytechnic Institute
Scientific Exploration of Space and Its Challenges to Education
OCT - 8 1964

Mr. Alberti
Governor Peabody
President Storke, Distinguished Members of the Board of Trustees and the Faculty
Honored Guests
Ladies and Gentlemen

It is a pleasure to be asked to return to Worcester and to participate in the exercises commemorating the Founding of Worcester Polytechnic Institute one hundred years ago.

I only regret that Dr. Hugh L. Dryden, Deputy Administrator of the National Aeronautics and Space Administration was prevented from being with you for reasons of health. He had looked forward to participating and has asked me to extend his sincere regrets.

When I was invited to fill Dr. Dryden's engagement, I felt honored and a bit awed.

It is a privilege to be with you in these halls which sparked the mind of the father of the space age, Dr. Robert H. Goddard. Those of us engaged in the space program have a very special respect for Dr. Goddard. We see in him the embodiment of the curious and far-seeing scholar who best exemplified the theme of this convocation -- the partnership of engineering and science in progress. Two generations ago, well ahead of his time, he gave us the theory and tools with which to reach into the universe in our never ending quest for knowledge. Those who read his reports cannot help but being impressed by the fact that it was due to the unique combination of the scientist and an engineer in a single individual, that enabled Dr. Goddard to be as far ahead of his time as he was.

We are now on the threshold of the Space Age which will require the same combination of the vision and practical application which characterized Dr. Goddard's work. Just as some 500 years ago man ventured beyond the Mediterranean, leading to the discovery of the new world, so today, man is breaking his earth-bound shackles to venture into space. Aside from the technological advances to which we are witness today, we must expect possibly even greater changes to our political, social and educational concepts.

Those earlier explorations extended the horizons of the times in a literal sense, but even more important, they opened up new possibilities and concepts. They forced the people out of their established patterns of thought and produced an intellectual ferment and interest in new ideas necessary for the scientific revolution and for the political and social advances of the 18th Century. These explorations were the most important events of that time; now some 500 years later, the space program can potentially play that same role.

The challenge posed by the Space Age is therefore addressed not only to the scientist and the engineer who are directly engaged in its projects. More importantly, it is a challenge to our society and, in particular, to its educational processes. The physicist, the astronomer, the geodesist, the meteorologist, the geologist and the astrophysicist, all have new frontiers open to them. Their job as scientists is to bridge the gap between the known and the unknown. The question we must ask ourselves is whether they are being educated in such a manner as to prepare them to do this job in that new laboratory of space that has been opened up to them.

The job of the engineer, in contrast to the scientist, is to use the resources of nature for social ends -- to bridge the gap between the known and the desired. The laboratory of space has already opened up a new "known" to the engineer in the field of communications and meteorology. The experimental communication satellites - Syncom, Relay, Telstar and Echo - have answered many of the questions that used to exist relative to the use of satellites for communication. The job of the engineer now is to translate this knowledge into a system that will be better than the under ocean cables.

The experimental meteorological satellites - Tiros and Nimbus - have demonstrated the utility of cloud pictures taken from satellites as an additional operational tool for weather forecast. The job of the engineer is to translate this knowledge into a practical and economical operational system.

The second question we must ask is whether the engineer is being educated in such a manner as to enable him to exploit these new developments in space.

We have seen the changes made during the past thirty years to adapt engineering education first to the new field of aeronautical and guided-missile engineering, late to the use of radar, still later to the adaptation of nuclear energy to practical uses. Space exploration will continue this trend. I think that even closer collaboration than heretofore is going to be required between the scientist and the engineer. Also there is growing a need for closer interdisciplinary collaboration between scientific specialists in various fields. Have our universities who are now training these scientists and engineers reacted to this trend?

To seek a basis for an answer to the questions I have posed, I would like to digress and describe our space efforts from the viewpoint from which I see it. This viewpoint tends to emphasize, as you will see, the involvement of the various scientific disciplines and the close collaboration that is required with the engineer.

This first slide (slide #1) gives a somewhat kaleiodoscopic view of the variety of the projects involved. We have launched some 35 major U. S. satellites for various scientific communication and meteorological purposes. In this lower corner you can see the Syncom, Relay and Echo communications satellites. The upper corner are Tiros and Nimbus satellites which have served as experimental meteorological satellites. The group on the remainder of the slide are the scientific satellites with which we are literally exploring space. Quite appropriately many of them are named Explorers.

This next slide (slide #2) shows our map of space which is being explored by these satellites. This map might be compared with the maps of the world that were probably available to the early maritime explorers. Space is not an empty void but can be divided into various regions of distinctly different characteristics that are emphasised on this slide. First, there is the near earth region, the upper atmosphere and the ionosphere. Then, there is the region called the magnetosphere in which the magnetic field lines anchored in the earth extend out to space. They form a gigantic magnetic shield around the earth which makes this region quite different from that on out further. This region labled the "interplanetary medium" is essentially uninfluenced by the earth's magnetic field. Finally, there is the sun which might on our map be given the same prominence as was India on the map of the early explorers, since, as you will see, the sun is the basic cause of many of the variations observed in the other regions of space.

Just as the early explorers initially ventured out only a short distance from their home ports, our first ventures into space were in the near earth region. Satellites such as Tiros and Nimbus go up into orbits some 300 - 600 miles and look down on the earth as shown in this slide (slide #3). From a satellite such as this, we have obtained data on the upper atmosphere. This next slide (slide #4) is a striking example of result. On the lower portion, you can see a montage made up of some 64 successive pictures taken by Tiros. These pictures after rectification have been superimposed on the map in the upper portion of the slide. You can observe the huge cyclonic disturbance that has been mapped extending all the way from Wake Island in the Pacific to the Great Lakes. This was the first opportunity for meteorologists to observe weather patterns on such a massive global scale. Cloud pictures such as this are now being used daily by the operational meteorologists in their weather predictions. They are also serving a more basis research purpose in that they give an insight into the dynamics of the weather. We can look forward to much more accurate long range weather forecasting as our understanding of this phenomenon improves.

Another type of experimental information made available by Tiros to the upper altitude physicists is shown on the next slide, (slide #5). This is a plot of global temperature distribution obtained from infrared instrumentation on board Tiros. It is especially notable because it depicts the phenomena of stratospheric warming shown in this region here. This phenomena has been suspected to be the trigger to weather disturbances and to be traceable in some manner to solar activity. The data shown on this slide is now being studied by upper altitude physicists in an attempt to obtain a better understanding of this phenomenon, with the eventual hope of using observations such as this for long range weather prediction.

This next slide (slide #6) shows a picture that was made by Nimbus by infrared techniques. Here you see a strip approximately 1,500 miles extending all the way up from the Antarctic to close to the North Pole. These pictures are less than a month old but already they are under detailed scrutiny by meteorologists who consider them to be a gold mine of data. They give a global picture of the cloud patterns and enable an understanding of cause and effect in the movement of the weather, not heretofore obtainable in observations from the ground. Features observable include:

Antarctic ice shelf
Low pressure system generated at polar fronts
Location of jet streams
Intertropical convergence zone
Volcanoes
Ocean currents

To analyze this global picture some of the following disciplines are involved -- meteorologist, upper altitude physicist, geologist, and oceanographer.

The next area of exploration has been the ionosphere -- the region of highly ionized particles that exists above what is conventionally considered the upper atmosphere. We have launched several satellites into elliptical orbits such that they traverse the altitudes from 200 to 800 miles. The region of space they explore is shown in relation to the space map previously shown is depicted on this slide (slide #7). As you can see, these satellites are still pretty close to the earth in terms of our total area of exploration. From such satellites (slide #8) we measured for the first time the temperature in this region and found that it fluctuated in a 27-day cycle corresponding to the time of rotation of the sun which shows clearly the close link between solar activity and events in our upper atmosphere. These satellites also discovered a helium layer which fluctuates and varies in thickness with solar conditions. Finally, there were measured flow of currents in the ionosphere and observations were made of the patterns of Whistlers into outer space.

Our exploration was next pushed out into the magnetosphere as shown on this slide (slide #9). Here, you can see the paths of successive satellites. This satellite was sent up to investigate the energetic particle population of the Van Allen radiation belts. This information is not only important in our understanding of sun-earth relationships but also is essential if we are to acquire the engineering information required for the design of communication and meteorological satellites. Their lifetime will be strongly dependent on the radiation environment found in this region.

Two other satellites were launched into the outer magnetosphere, and finally two were sent up in order to identify the conditions in the interplanetary medium. The last of these, called an Interplanetary Monitoring Probe (IMP), was launched only last week.

Here is a pictorial description (slide #10) of what this latter group of satellites found. As you can see, there is shown the orbit of the first IMP Satellite which carried it out to 122,000 miles. When it got out there, it found that there was a "solar wind" blowing. This wind sometimes is a gentle breeze and on other occasions grows into what might be termed a hurricane. Of course it is not a wind in the conventional sense but is a stream of energetic particles (electrons and protons of varying energy) that are ejected by the sun. During quiet sun conditions, there is this gentle breeze and during a solar flare, the number and intensity of these particles increase. It is through this solar wind that the sun has a profound effect as on what goes on in our upper atmosphere. The earth is like a rock in a stream with a bow wave in front of it formed by the shock front that marks the boundary of the solar wind and the magnetosphere. There is a wake behind the earth not shown. One of our orbits is shown here -- the satellite got in the moon's wake and we were able to observe the effect of the moon on this solar wind.

As you will observe, the sun has been the basic cause of all the phenomena that were observed by these various satellites. Therefore, the results obtained from the Orbiting Solar Observatory shown on this slide (slide #11), were of particular interest since they enabled us to observe what was going on in the sun and causing these variations. Man has been observing the sun for thousands of years. The existence of the early sun worshipers attests to the fact that the importance of the sun to terrestrial conditions has been appreicated for many centuries. However, during all this time, we have been looking at the sun as if through translucent blindfold. The earth's atmosphere and the magnetosphere filter out much of the solar radiation. Thus, earth based instruments have only been able to observe the sun in a relatively narrow visual band and at radio wave lengths. The Orbiting Solar Observatory was able for the first time to observe the sun in the shorter wave ultraviolet, gamma ray and Xray regions. New light has been shed on the relation between solar flares and the associated variation in the solar wind fluctuations observed from IMP.

This slide (slide #12) shows what has been deduced from these combined observations. When there is a solar flare there apparently is a huge magnetic bottle that is exploded from the sun. Contained within this bottle are energetic particles, electrons, protons traveling at varying speeds. Anything external to the bottle, such as galactic cosmic rays, can not penetrate within the bottle and bounce off as shown here. This magnetic bottle gradually expands and if headed toward the earth impinges on the earth's magnetosphere as shown here (slide #13) and distorts it. Many of the energetic particles bounce off the magnetic shield formed by the magnetosphere, others get injected into the magnetosphere and in due course, form the radiation belts or Van Allen Belt, as they are commonly called. These particles ride the magnetic lines which exist in the magnetosphere and in due course impinge on the upper atmosphere in the auroral regions and cause changes in temperature that I have previously referred to and in some manner influence our cyclic variations in climate. (Slide Off - Lights On).

My object in giving this broadbrush sketch of the information that has been brought back from space, has not been to convey any detailed understanding of the implications of these results. The point that I hope has been conveyed is that it has commanded the efforts of a broad spectrum of scientific disciplines. These include the solar physicist who is involved in the observation of the sun, the nuclear physicist who applies his techniques to the observation of the energetic population in the interplanetary space and the radiation belts; the magnetic field specialist who has been mapping the variation in the magnetic lines of the magnetosphere and studying the collision process with the solar wind; the ionospheric physicist who has been studying the electron distribution in the ionosphere and its variation with the solar cycle; the upper atmosphere physicists who have been trying to correlate his observed atmospheric temperature and composition variations with the events in the other regions; and, finally, the meteorologist who has been trying to put together the interelated effects of all these phenomena on the earth's weather. This interrelation between the various disciplines, I suggest, is a unique feature of space science which should be taken into account in the educational process. It is in distinct contrast to the trend toward specialization that has characterized the past thirty years. The aerodynamicist could concentrate on his wind tunnel with relatively little reference to other disciplines; the nuclear physicist could work with his reactor and the biologist to his microscope in the same relative isolation. Creativity could flourish because it was the era of the individual worker; there were less technical committees, budget reviews, administrators and the like, who could kill an idea while it was still in the formative stage.

The new era promised by the Spage Age perhaps connotes a return to what was once called natural philosophy. The unifying element of these developments of the space program is a general spirit of inquiry into the nature of the external physical world. It represents a re-direction of interest away from the increasingly narrow specialization which has characterized the physical sciences in the last decades.

The second distinguishing feature of research in space is the fact that scientists have only been able to make the observations that I have discussed by virtue of the hardware developed by the engineer. This is in distinct contrast to the biologist who could invest in a good microscope and do research comparable with the best.

The control equipment which enables the pointing of instruments with precise accuracy at the sun, the solar power supplies which supply the energy to run the experiments, the communication devices which bring back the information from outer space, all are developments which must come from engineers. In one sense, the normal situation has been reversed. Generally, the engineer exploits and puts to practical use the knowledge acquired by the scientist. But in space research, the scientist seems to be particularly dependent on the engineer to develop new devices and techniques. Engineering, in this context, has become a more creative and trail-blazing profession.

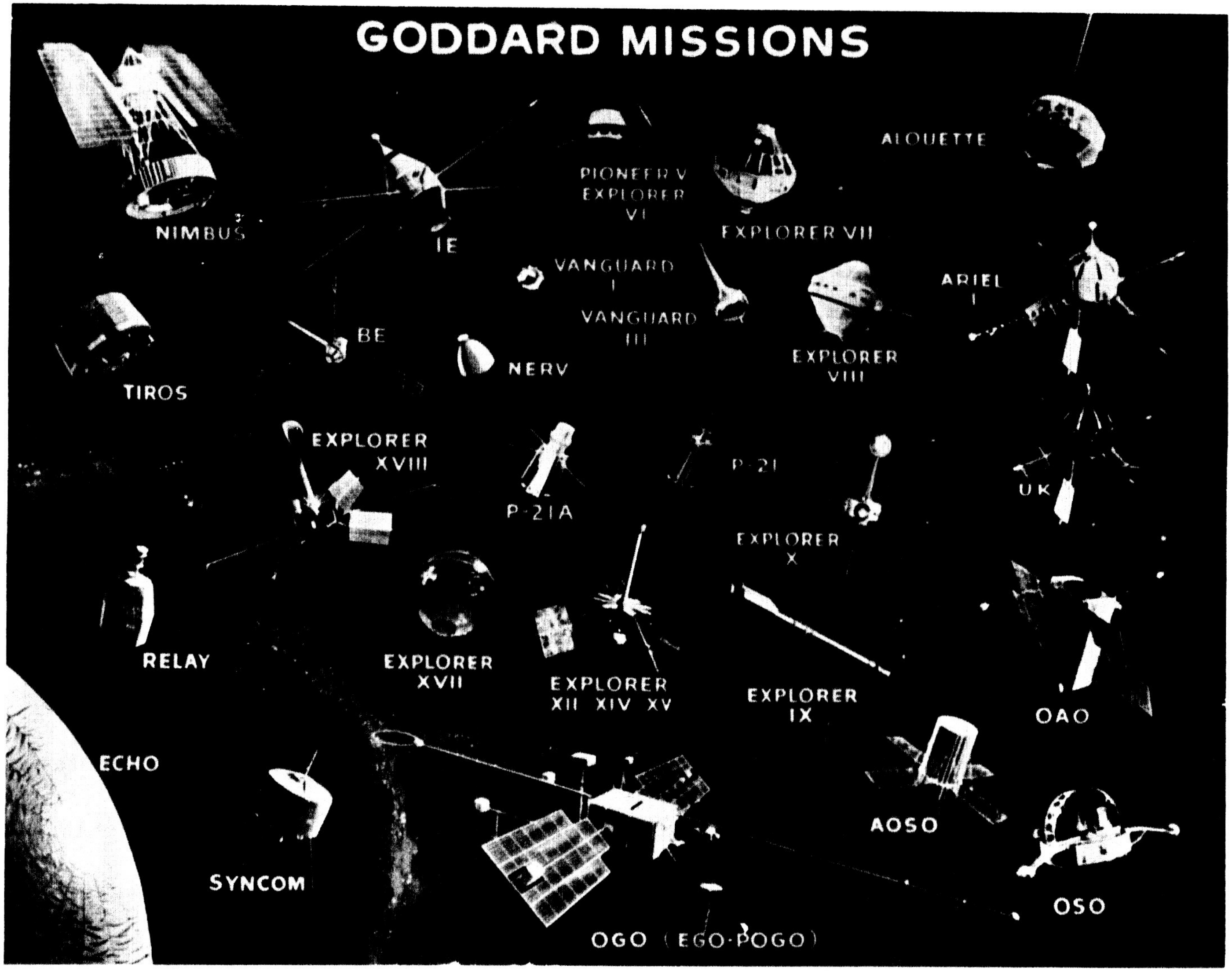
The third and possibly most imposing challenge of the space age is the potential feed-back of its developments into the civilian economy. In the long run, the justification of our space budget must stand on this "fall-out".

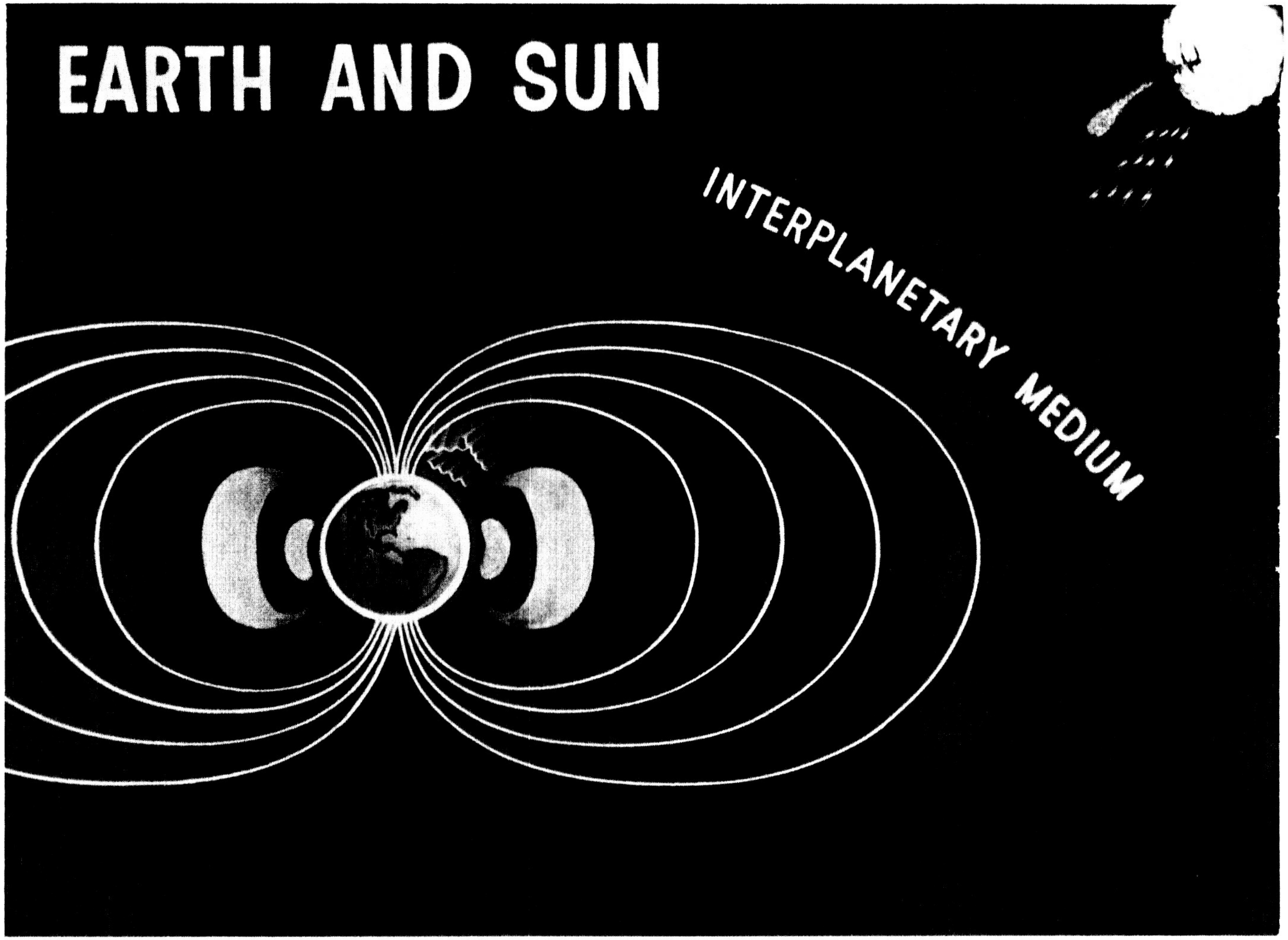
Everyone knows the drive for miniaturization of electronic components to reduce weight and size of space applications. We can foresee the pressure for electronic components to operate at very high temperature. There is a need for new developments for electronic apparatus to operate in the hard vacuum of space. New materials must be developed for the space environment. There are applications for cryogenics and new power sources. There is a special need for insuring long periods of unattended operation of mechanical equipment in space. Development is needed of methods of lubrication in high vacuum and the creation of new sensing and control devices. Means of medical research of man in space must be developed.

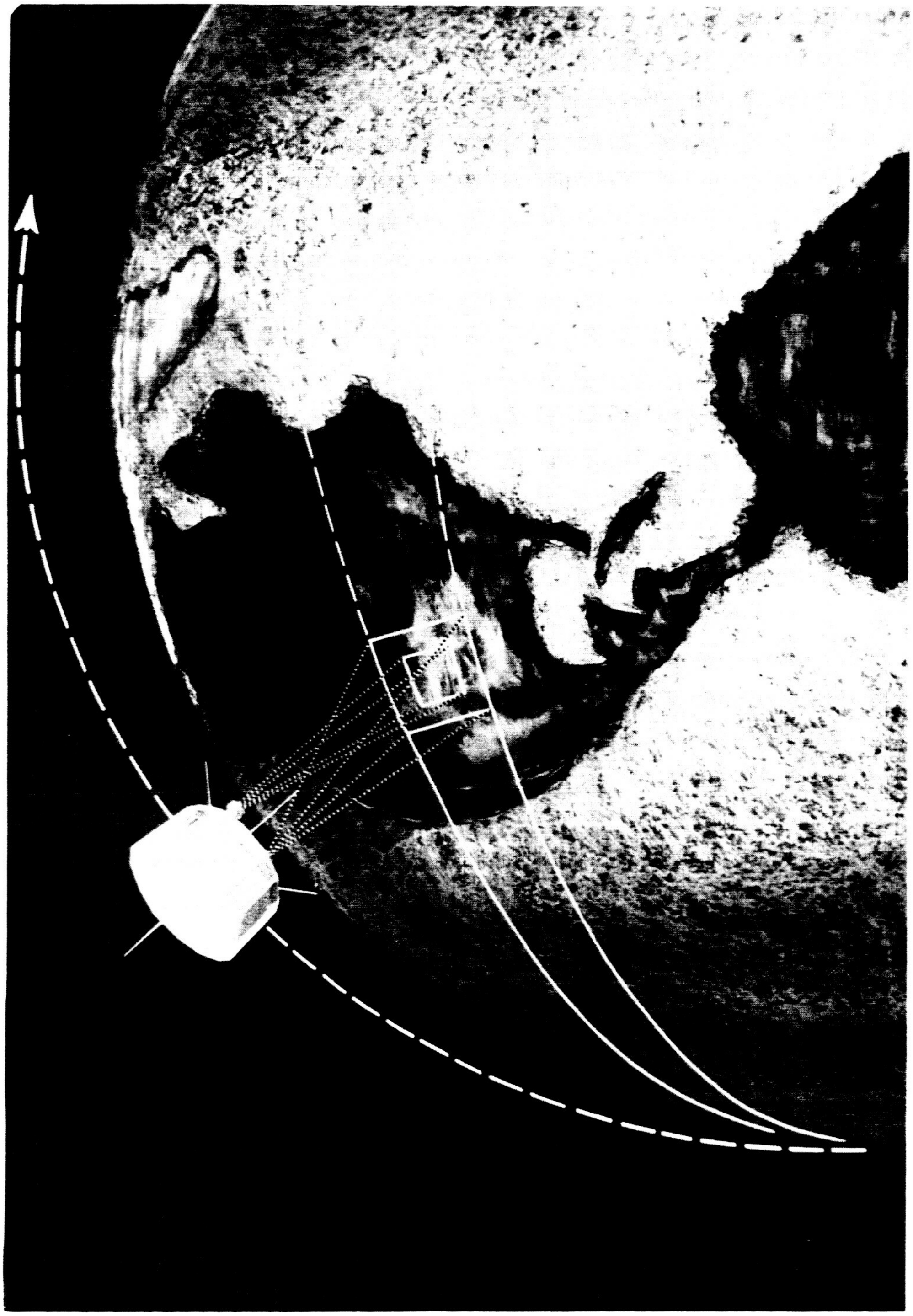
These are some of the most immediate returns of space exploration. In due course, they will surely be exploited by our civilian economy. But I submit that the engineering profession is confronted with a new challenge in its job of converting the known into the desired. These developments will not find their way into the civilian economy unless the engineer has the creative initiative necessary for their application.

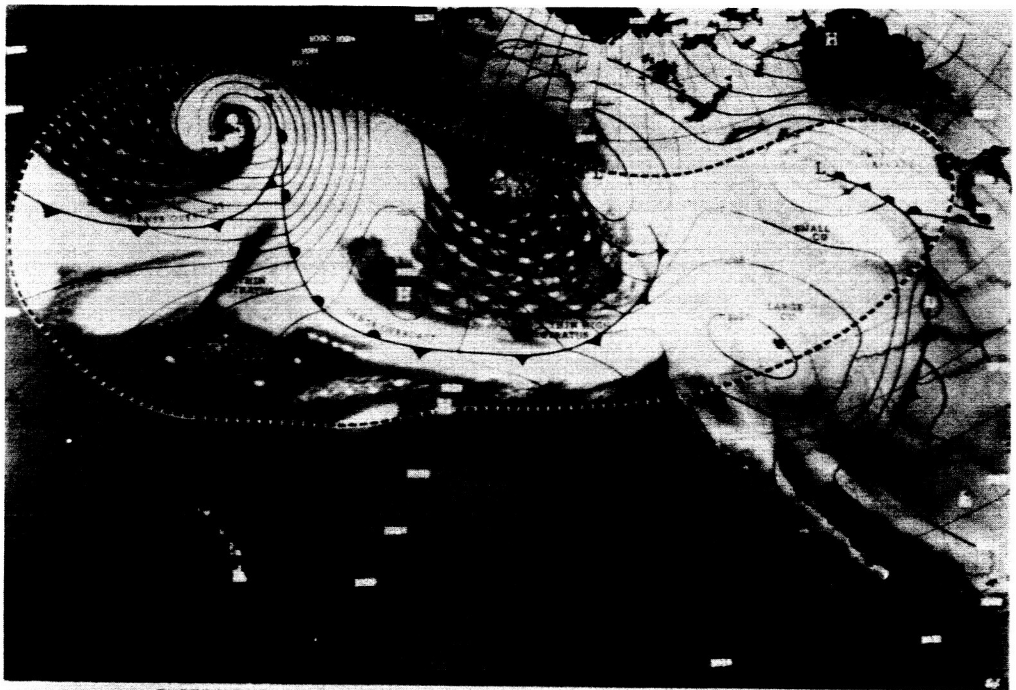
These three developments of the space age present a new challenge to our educational process. They are, in the first place, the interdisciplinary collaboration of various scientific specialists. Secondly, the leadership of the engineer in developing new techniques to enable the scientist to achieve his objectives in space. And thirdly, the creative thinking which is required to apply the new developments of space to our civilian economy.

If I were an educator, I would conclude this talk by suggesting some solutions. However, I claim no competence in the educational field; my job is to produce reliable satellites. There, I will terminate my discussion by suggesting a re-examination of the educational process and its curriculum by those competent in this field to see whether they think it has been properly adjusted to meet these new challenges of the space age.


GODDARD MISSIONS
NIMBUS
IE
PIONEER V
EXPLORER VI
EXPLORER VII
ALOUETTE
VANGUARD I
VANGUARD III
ARIEL I
TIROS
BE
NERV
EXPLORER VIII
EXPLORER XVIII
P-21A
P-21
UK
EXPLORER X
RELAY
EXPLORER XVII
EXPLORER XII XIV XV
EXPLORER IX
OAO
ECHO
AOSO
SYNCOM
OSO
OGO (EGO-POGO)


EARTH AND SUN
INTERPLANETARY MEDIUM

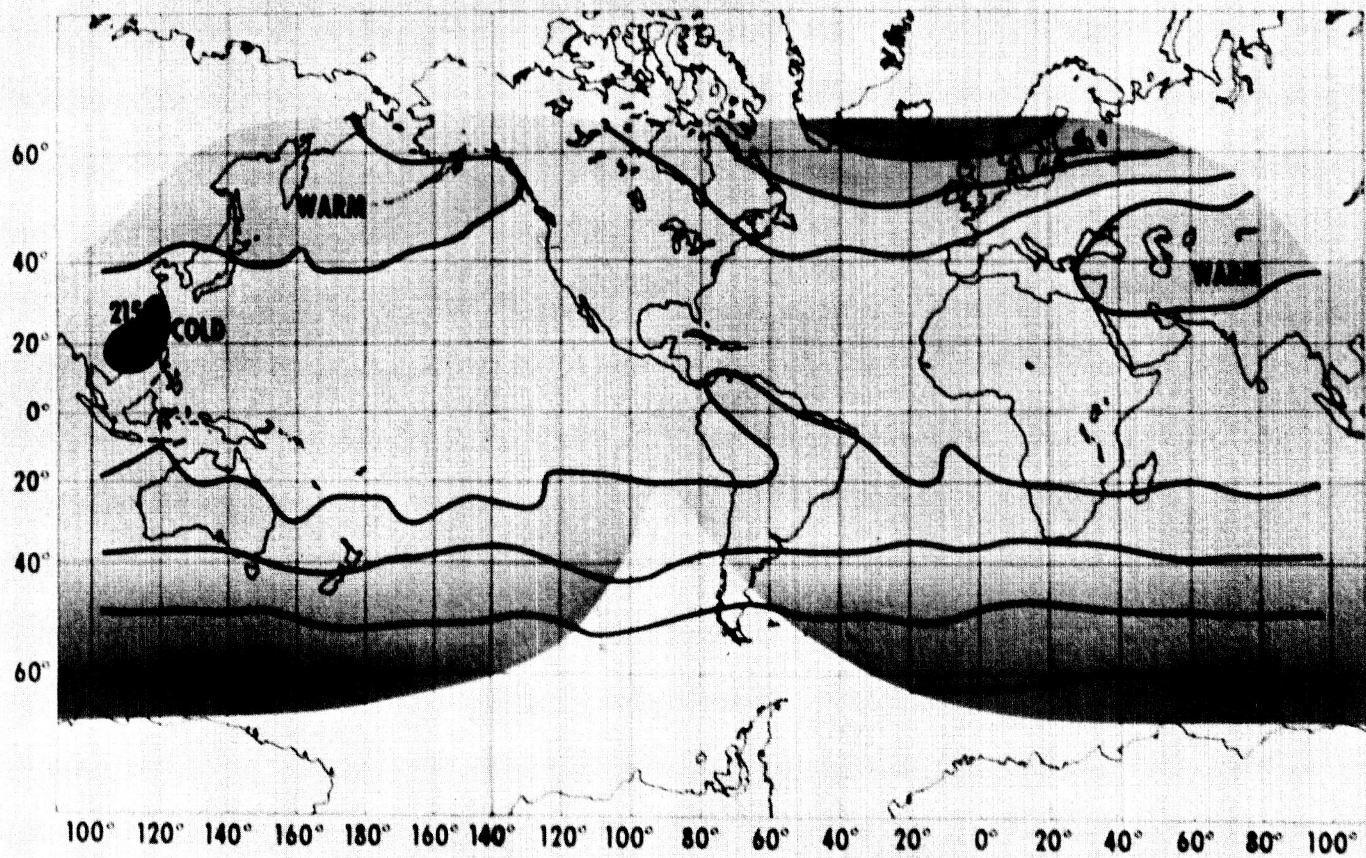


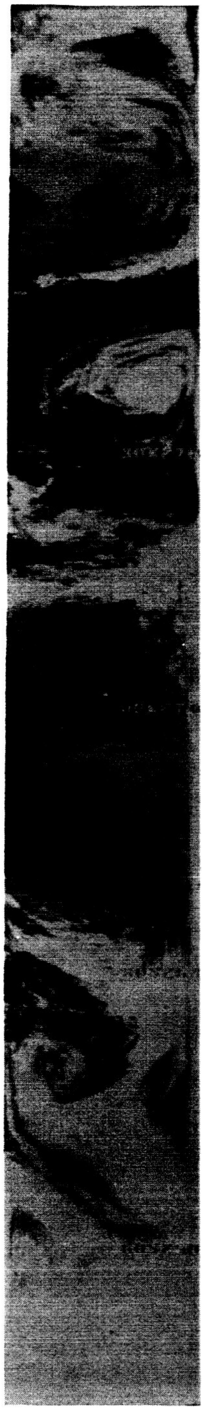


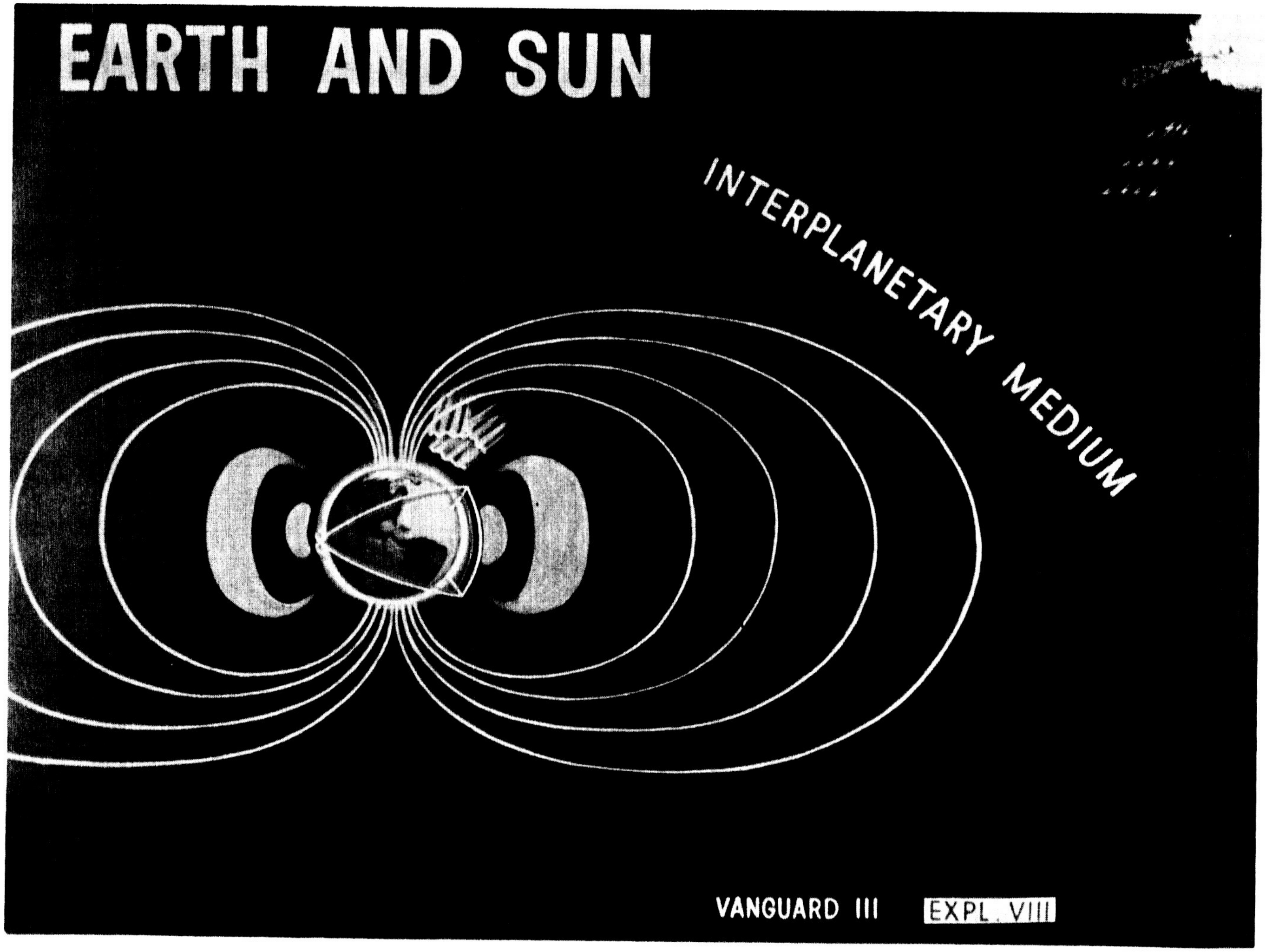
EXPERIMENTAL CLOUD DEPICTION CHART PREPARED FROM TIROS PICTURES SUPERIMPOSED ON NAWAC 0000Z MAP ANALYSIS OF MAY 20, 1960

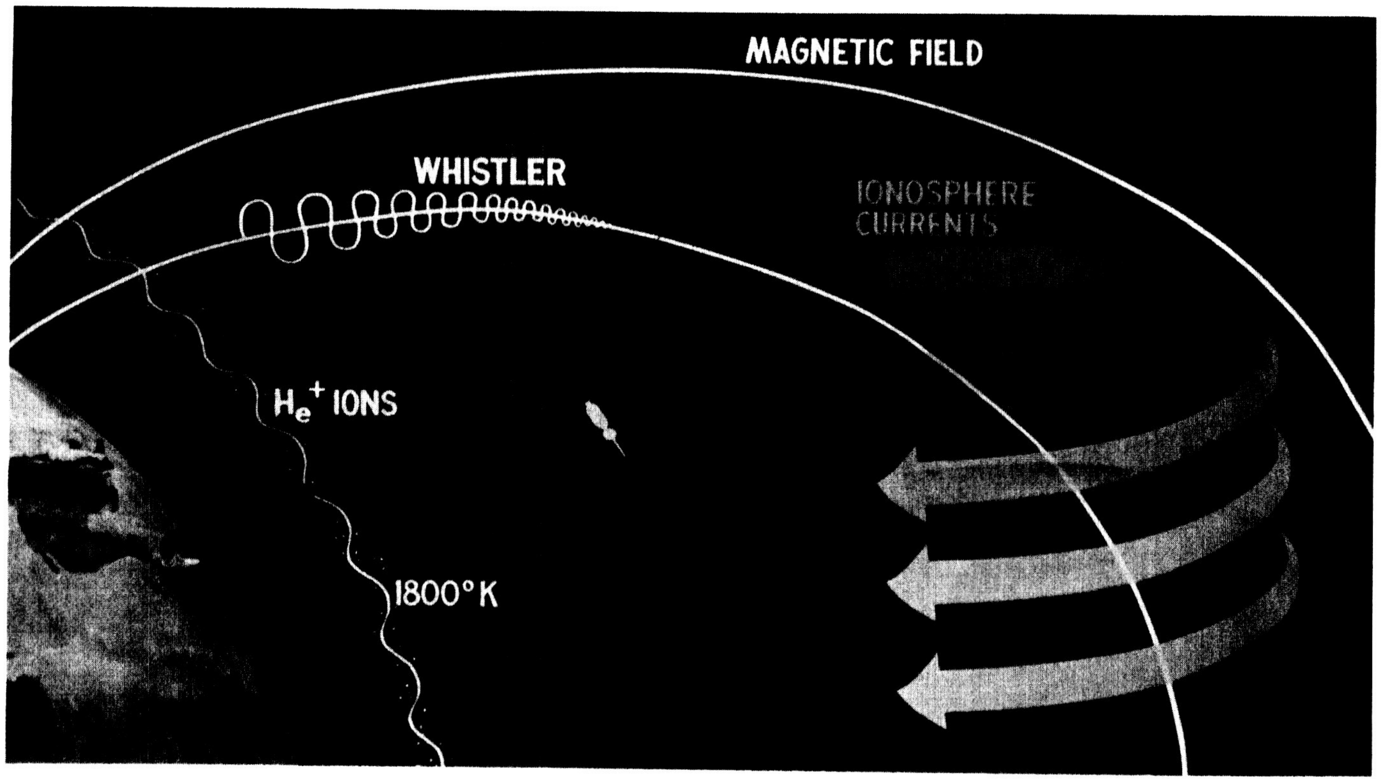
ACTUAL TIROS PHOTOGRAPHS TAKEN ON MAY 20, 1960

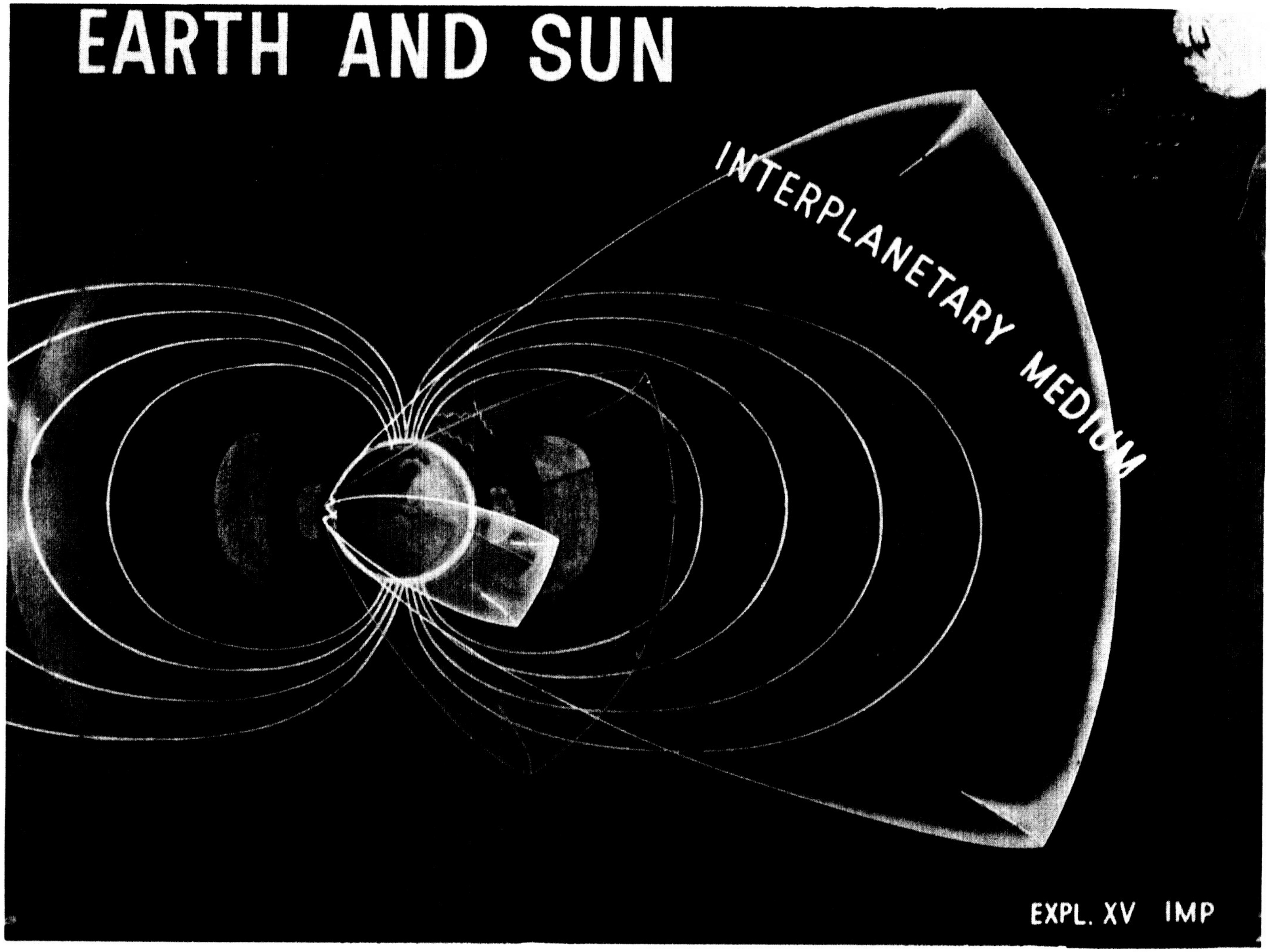
TIROS VII, 15 μ T_{BB} (°K)
NADIR ANGLE 0-40°
22-29 JANUARY 1964

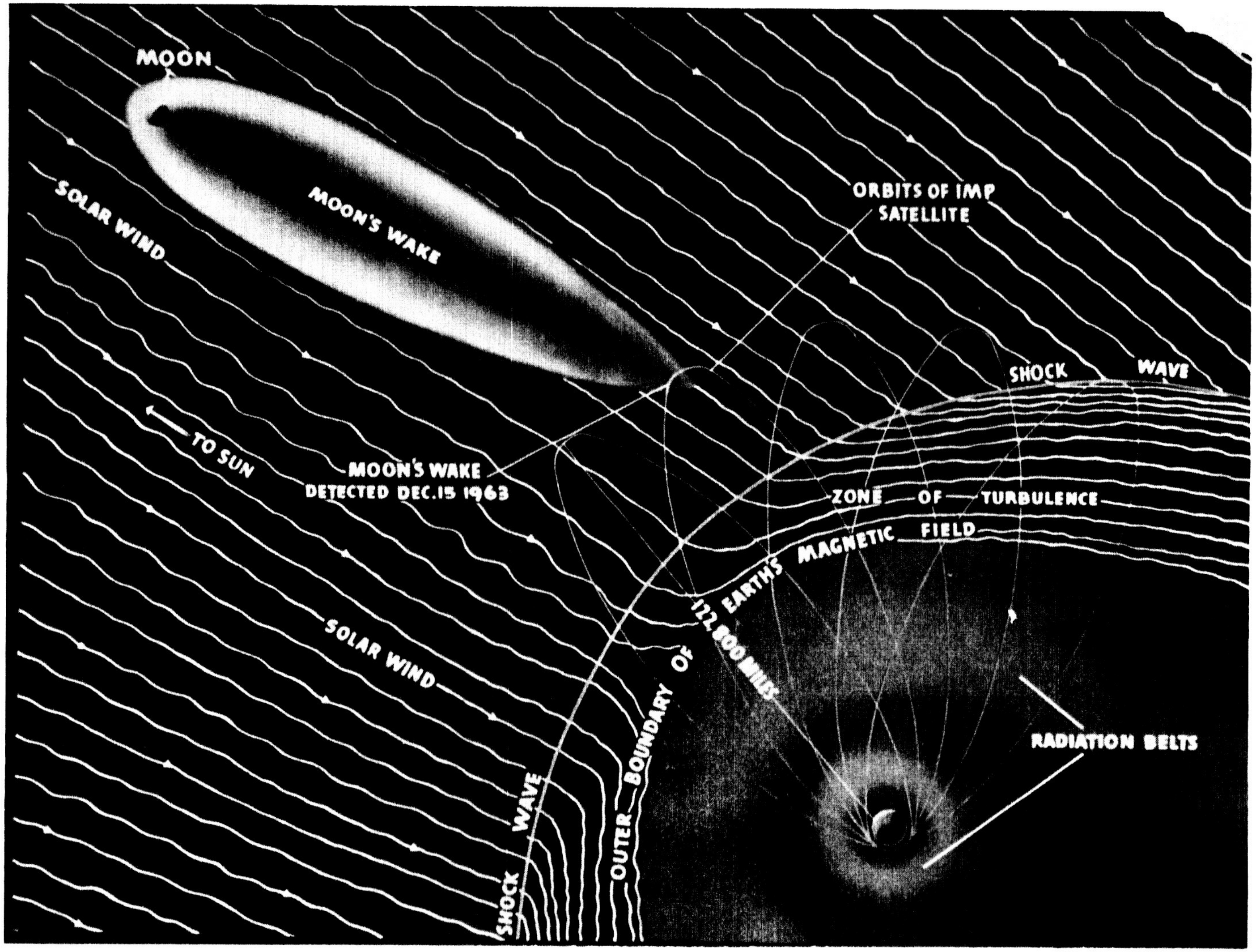


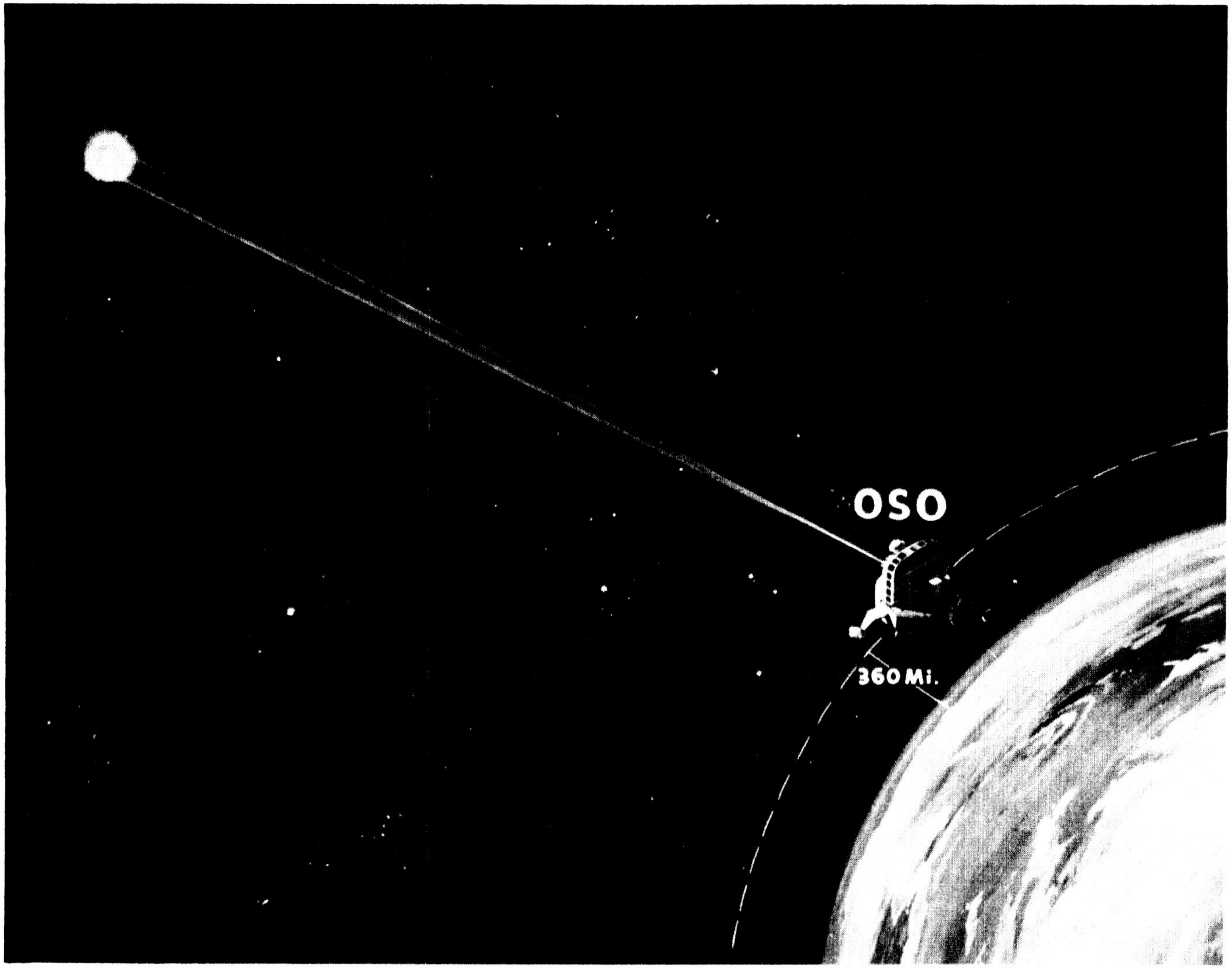


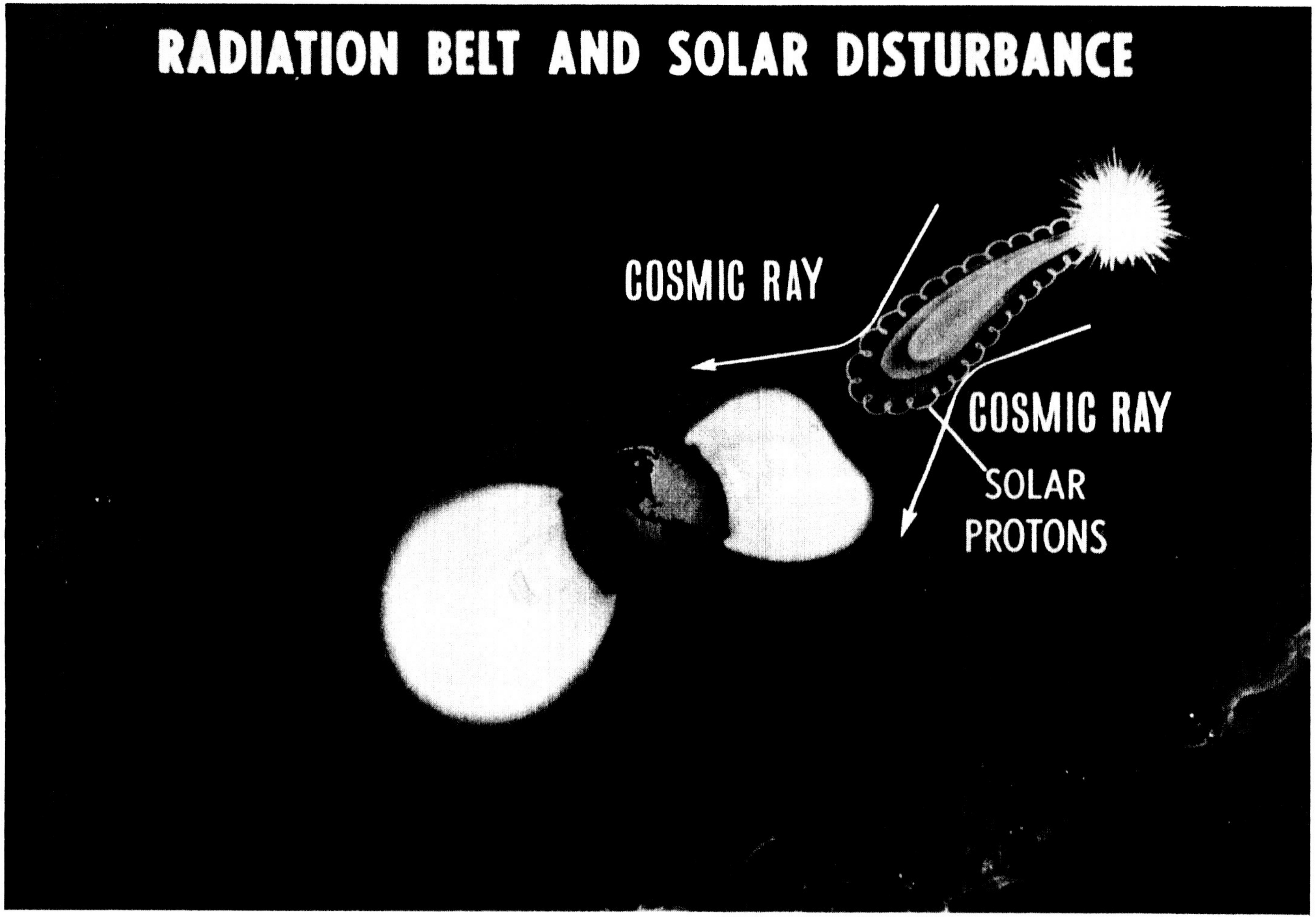

EARTH AND SUN
INTERPLANETARY MEDIUM
VANGUARD III
EXPL. VIII

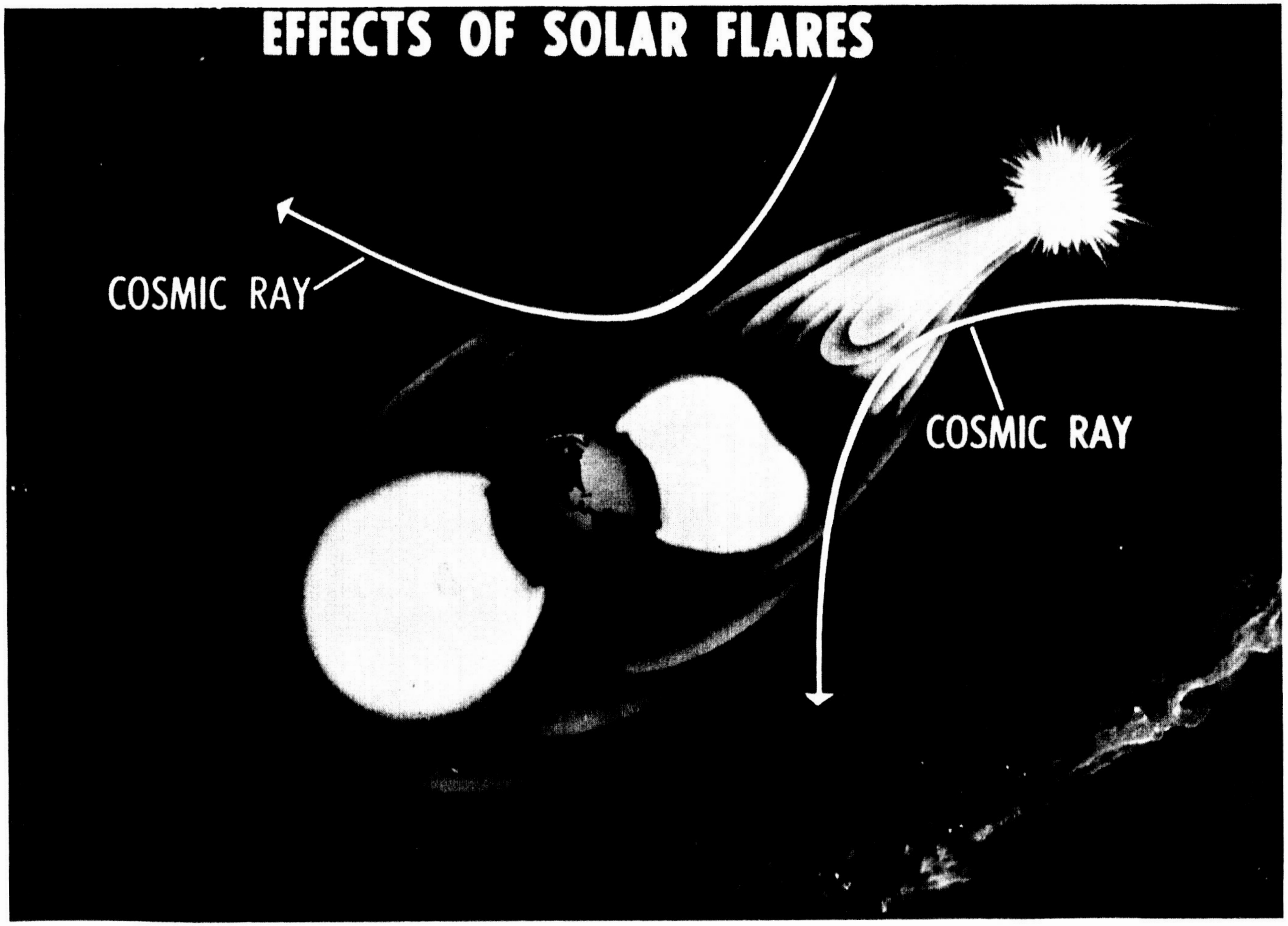

MAGNETIC FIELD
WHISTLER
IONOSPHERE
CURRENTS
He^+ IONS
1800°K


EARTH AND SUN
INTERPLANETARY MEDIUM
EXPL. XV IMP


MOON
MOON'S WAKE
SOLAR WIND
ORBITS OF IMP SATELLITE
TO SUN
MOON'S WAKE DETECTED DEC.15 1963
SHOCK WAVE
ZONE OF TURBULENCE
EARTH'S MAGNETIC FIELD
122,800 MILES
SOLAR WIND
OUTER BOUNDARY OF
RADIATION BELTS
SHOCK WAVE


OSO
360 Mi.


RADIATION BELT AND SOLAR DISTURBANCE
COSMIC RAY
COSMIC RAY
SOLAR
PROTONS


EFFECTS OF SOLAR FLARES
COSMIC RAY
COSMIC RAY