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HEARINGS

BEFORE THE

SUBCOMMITTEE ON SPACE SCIENCES

OF THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS U.S. HOUSE OF REPRESENTATIVES

EIGHTY-SEVENTH CONGRESS

SECOND SESSION

ON

H.R. 10100

(Superseded by H.R. 11737)

MARCH 6, 7, 8, 13, 19, AND 20, 1962

[No. 2]

Part 4

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NOTE.—The chairman of the full committee and the ranking minority member, Hon. Joseph W. Martin, Jr., are ex officio members of all subcommittees.

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1963 NASA AUTHORIZATION

TUESDAY, MARCH 6, 1962

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON SPACE SCIENCES,
Washington, D.C.

The subcommittee met, pursuant to call, at 10:24 a.m., in room 100B, George Washington Inn, Hon. Joseph E. Karth (chairman of the subcommittee) presiding.

Mr. KARTH. The meeting will come to order.

Doctor, I have a short prepared initial statement. I have asked that you be furnished with a copy. The subcommittee members have been furnished with a copy and in the saving of time we are going to permit this to be copied into the record.

(The document referred to is as follows:)

OPENING STATEMENT OF CHAIRMAN KARTH

This morning, the Subcommittee on Space Sciences will begin hearings on the space sciences program of the National Aeronautics and Space Administration. These hearings will constitute an important part of our consideration of NASA's authorization bill for fiscal year 1963.

As all of you know, the Science and Astronautics Committee has the responsibility of authorizing NASA's programs, and expenditures for those programs, each year. The Subcommittee on Space Sciences has been assigned the specific responsibility of reviewing NASA's requests for the following programs: sounding rockets, scientific satellites, lunar and planetary exploration, Scout, Delta, and Centaur.

Our responsibility also includes authorization of funds for construction in connection with the above, as well as salaries and expenses for personnel assigned to these programs.

From my review of the budget estimates for fiscal year 1963, and the supporting data furnished by NASA, I am convinced that the space sciences programs are extremely important. These programs are designed to provide the scientific knowledge which is necessary to support our Nation's future manned space programs. In addition, information and data concerning the earth's atmosphere, radiation belts, solar flares, and other phenomena in our solar system are being developed which will make possible a greater understanding of our universe. The scientific satellite program also provides an important avenue for international cooperation. The launch vehicle programs, particularly Centaur, are of primary importance to the Nation's space effort, and the committee intends to take a close look at these developments and their management.

This morning, we will take the testimony of Dr. Homer Newell, Director, Office of Space Sciences, National Aeronautics and Space Administration. He is accompanied by Mr. Edgar Cortright, Deputy Director. I want to welcome you gentlemen to the committee.

Dr. Newell has an extensive prepared statement, and I understand slides will be shown during the statement. Following delivery of the statement, the committee will have some questions. I would like to go into each of these programs in some detail. Accordingly, we have scheduled 3 days of hearings this week, and we will probably find it necessary to schedule additional hearings next

week. Therefore, in order to discharge the subcommittee's responsibilities in an orderly fashion, I would suggest that, if time permits a question period today, the members limit questions to sounding rockets and scientific satellites, despite the fact that Dr. Newell may open with a general statement regarding the entire space sciences field. We will take up the other programs at subsequent meetings of the subcommittee.

Mr. KARTH. Now, Dr. Newell, if you would care to begin, the committee would be pleased to hear your statement.

If you would like, I would appreciate it if you would introduce those of your staff who are here and who will participate in the discussion.

Dr. NEWELL. I will be happy to.

To my right is Edgar Cortright, my Deputy in the Office of Space Sciences at NASA. He and I will be presenting the first portion of our statement.

Behind me is Mr. John Nicolaides, and next to him, Mr. Eldon Taylor, who is the resources witness for us, and Colonel Heaton behind Mr. Nicolaides, who will be talking later on the Centaur problem, and next to him, Dr. Tom Smull, who is the head of our Office of Grants and Research Contracts.

Next to him is Dr. John Clark, who will be speaking later on geophysics and astronomy programs, and next to him, Mr. Oran Nicks, who will be speaking later on lunar and planetary programs.

Mr. KARTH. Doctor, I might say before I ask you to begin on your prepared statement—and I assume you would like to go through this in its entirety—that last night after I returned home from a meeting which was necessary for me to attend, I had the opportunity about midnight to read the first 20 pages, and although I don't consider myself an engineer, or for the record, half an engineer, I might say that this is probably the most technical document that I have had the occasion to read or that I have had the occasion to find being submitted to our committee.

If you think it is necessary for this rather technical report to become a part of the proceedings, I trust you will proceed in that fashion. I do question the relationship that some of this very technical scientific information will have insofar as the committee membership finding it to be of a worthwhile nature in the presentation of their arguments in the support of your budget, if this happens to be called to the subcommittee's attention.

As a result of this report being highly technical, it may be necessary for the committee members to stop you once in a while and ask you if you would just put it in laymen's language, and this would be of great help to us.

Would you proceed, as you will, then, and excuse the interruptions we might make as we go through here to give us a better understanding of just what this thing says.

Dr. NEWELL. We would be glad to answer any questions at any time.

I do think, in describing this document and the purpose of bringing it forth, it might be well to point out that the space science part of the NASA program is in essence technical, and we find it not possible

really to describe our program and our motives and our objectives without getting into some of the technical aspects of the program.

Mr. KARTH. I felt, after giving it some consideration last evening, that it might be important that it be given to the committee and later on be written into a committee report for the edification of whoever may want to view the proceedings of this subcommittee and the committee as a whole.

During the process, you just might make some scientists and engineers out of some people.

Go ahead, Doctor.

Dr. NEWELL. Thank you. Before I start on the prepared text, per se, I thought I might review the suggested schedule that Mr. Hammill of your staff has suggested to us, which looks to be a fine arrangement for presenting to you the things that we are doing, and some of the problems that we have.

First, there would be this prepared text. Then, with your permission, tomorrow, Dr. John Clark would review geophysics and astronomy programs. Following that, Mr. Nicks would review lunar and planetary programs; and then because of its very great importance and your own expressed interest in this particular subject, we would like to have Colonel Heaton review for you the launch vehicle and propulsion programs, which will include, of course, the Centaur.

Mr. KARTH. Yes, sir, that would be fine, Doctor.

(The biographical sketch of Dr. Homer E. Newell follows:)

HOMER E. NEWELL, DIRECTOR OF OFFICE OF SPACE SCIENCES

Homer E. Newell was named Director of Office of Space Sciences on November 1, 1961. He was formerly Deputy Director of Space Flight Programs.

Before joining the NASA on October 20, 1958, Dr. Newell was Acting Superintendent of the Atmosphere and Astrophysics Division of the U.S. Naval Research Laboratory. He was also science program coordinator for Project Vanguard, the U.S. scientific earth satellite program for the International Geophysical Year.

A native of Holyoke, Mass., Dr. Newell earned both his bachelor and master of arts degrees from Harvard University and his Ph. D. in mathematics degree from the University of Wisconsin in 1940.

From 1940 to 1944 he was an instructor and later assistant professor at the University of Maryland, and a ground instructor in navigation with the Civil Aeronautics Administration from 1942 to 1943.

Dr. Newell joined the Naval Research Laboratory in 1944, and became head of the Rocket Sonde Branch in 1947. In this position, he was in charge of the upper atmosphere research program of NRL. In 1955 he was named Acting Superintendent of the Atmosphere and Astrophysics Division.

His scientific committee memberships have included the Special Subcommittee on the Upper Atmosphere of the National Advisory Committee for Aeronautics (1947–51), and the Rocket and Satellite Research Panel (formerly Upper Atmosphere Rocket Research Panel) since 1947. He was Chairman of the Rocket and Satellite Research Panel in 1959 and 1960.

Dr. Newell is the author of several technical books and numerous articles. He is a member of Phi Beta Kappa, Research Society of America, the American Geophysical Union, the American Rocket Society, and he is a fellow of the American Association for the Advancement of Science and of the American Astronautical Society.

Dr. Newell, his wife, and their four children live in Kensington, Md.

STATEMENT OF DR. HOMER E. NEWELL, DIRECTOR, OFFICE OF SPACE SCIENCES, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ACCOMPANIED BY MR. EDGAR CORTRIGHT, DEPUTY DIRECTOR, OFFICE OF SPACE SCIENCES; DR. THOMAS SMULL, DIRECTOR, GRANTS AND RESEARCH CONTRACTS, OFFICE OF SPACE SCIENCES; DR. JOHN CLARK, DIRECTOR, GEOPHYSICS AND ASTRONOMY PROGRAMS, OFFICE OF SPACE SCIENCES; MR. ORAN NICKS, DIRECTOR, LUNAR AND PLANETARY PROGRAMS, OFFICE OF SPACE SCIENCES; COL. DONALD HEATON, DIRECTOR, LAUNCH VEHICLE AND PROPULSION PROGRAMS, OFFICE OF SPACE SCIENCES; MR. JOHN NICOLAIDES, DIRECTOR, PROGRAM REVIEW AND RESOURCES MANAGEMENT, OFFICE OF SPACE SCIENCES; AND MR. ELDON TAYLOR, RESOURCES MANAGEMENT OFFICER, OFFICE OF SPACE SCIENCES

Dr. NEWELL. Space science is science carried out in space. (Fig. 353.)

There is nothing mysterious about it, although there is much that is exciting about it.

Space science calls upon a whole variety of disciplines—physics, chemistry, astronomy, biosciences, and other scientific disciplines—not shown here, to attack some of the most challenging and important scientific problems of today. Among these problems are the investigations of the Earth and Sun, the Moon and planets, stars, and galaxies, and life in space, from the vantage point provided by the orbiting satellite or the deep space probe.

Although the investigations of space sciences are conducted in space, far from the surface of the Earth, this activity of science in space is inseparable from all the rest of science carried out on the Earth. Indeed, one of the remarkable features of space science is its interdisciplinary character. Scientific disciplines that heretofore had gone their separate ways with only mild interactions, now tackle in close partnership the problem of understanding the phenomena and properties of outer space. For example, physics, astronomy, and geophysics are brought together in the investigation of the very important problem of Earth-Sun relationships. (Fig. 354.)

The NASA program of space science is basic research. Its principal objective is the advancement of knowledge. The motivation of the scientists who participate in the program is that disciplined curiosity that leads them to investigate, explore, and dig into the innermost workings of the universe about them. To them the attraction of space science is its breadth and scope, and the opportunity it affords to tackle some of the most important and fundamental problems on the frontiers of science today.

Because of this great breadth and scope of space science, and because of the many basic scientific problems that it encompasses, our country must have a sound and vigorous space science program if we intend to maintain our position of leadership in world science. Such leadership is of great practical importance in today's world in which the value of those ideals and principles for which we stand is measured in the minds of men in terms of achievement and accomplishment.

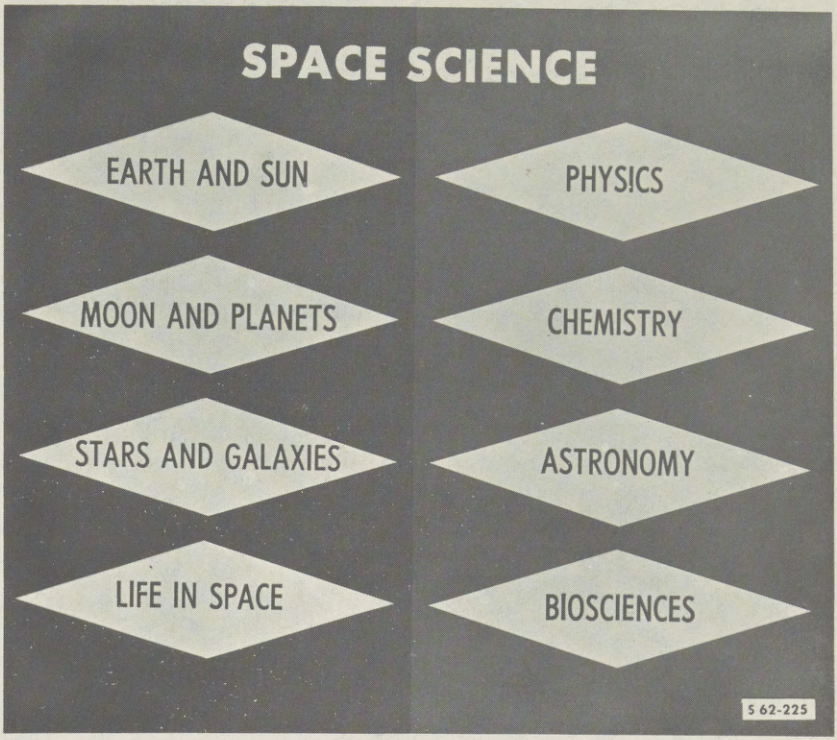

FIGURE 353

The space science of today is needed to sow the seeds for the harvest of future applications of space knowledge and technology. The weather, communications, and navigational satellites of today grew out of the scientific engineering and research of the past decades. Their perfection, and the development of new applications, will rest upon the space science and engineering of today and the years to come.

The space science program supports other activities. The distribution of harmful radiations in space, the times of their occurrence, whether or not their presence is predictable, and the influence of magnetic fields in space upon the radiation hazard, are all important problems that space science investigations must solve before one can safely proceed to send men out into space. Similarly, unmanned investigation and exploration of the surface of the moon will give data needed in the engineering of lunar landing craft and for planning the landing operation. In return, putting man into space will further the scientific exploration of the solar system.

Continued investigation of the atmosphere is essential to realizing the maximum benefits from weather satellites. Likewise, the influence of radiation belt particles on communications equipment and components must be known in order to design communications satel-

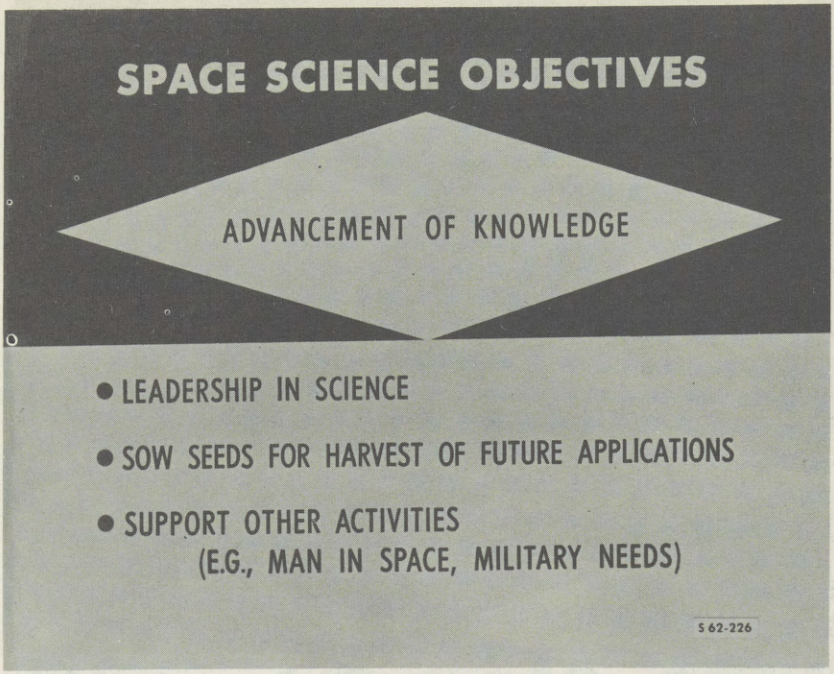

FIGURE 354

lites properly. Similarly, the knowledge obtained in the space science program supports the developments of military applications of space for communications, reconnaissance and surveillance, and other uses. (Fig. 355.)

I should like next to elaborate on the various areas of space science listed in the first slide. Before proceeding to do so, however, it may be well to devote a little time to some definitions and terminology.

You will find these definitions and this terminology will crop up throughout our entire presentation, so I felt it was worth spending a little time on it.

As is well known, all matter is made up of atoms and molecules. Aggregates of these atoms and molecules go to make up macroscopic matter as we know it. These atomic and molecular particles are exceedingly small. An atom of hydrogen, for example, is in size to a 2-inch diameter stone as that stone is to the entire earth. Each cubic inch of air, at sea level, contains something like a hundred billion billion such atomic and molecular particles.

But the atoms, themselves, are not the ultimate in particles. Each atom is in turn made up of smaller particles: protons, neutrons, and electrons. Each atom consists of a nucleus containing protons and neutrons about which circle an equal number of electrons. The electron is an extremely tiny particle, much, much smaller than the atom, itself.

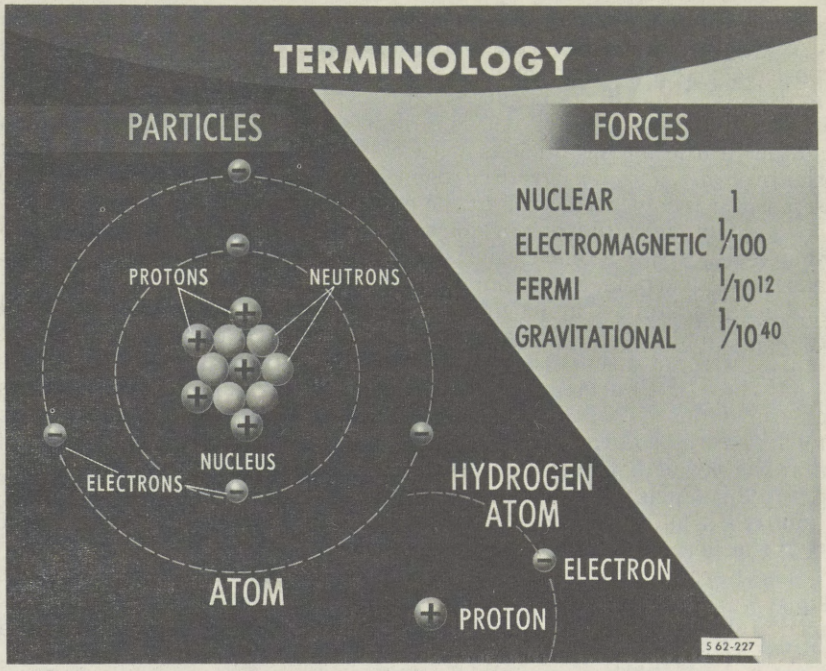

FIGURE 355

In fact, using the sort of comparison made above for the hydrogen atom, in size the electron is to a tiny speck of dust as that speck of dust is to the whole earth. Each electron bears a negative charge of electricity, the smallest known charge of electricity. The proton is positively charged, with a charge equal in magnitude but opposite in sign to that of the electron. The proton is about 1840 times as massive as the electron. A neutron has no charge whatever, and is almost equal to the proton in mass.

The combination of protons and neutrons in the atom's nucleus accounts for most of the mass of the atom. The positive charges on the nuclear protons give to the nucleus a net positive charge. The number of electrons circling about the nucleus equals the number of protons in the nucleus, so that their combined total negative charge just balances the combined positive charges of the nuclear protons, making the total atom electrically neutral. When an atom loses one or more of its electrons, the remaining electrons are no longer able to balance out the total positive charge on the nucleus, thus leaving the atom with a net positive charge. An atom in such a condition is said to be positively ionized, and the configuration is referred to as a positive ion.

Under extreme conditions, such as obtain in the sun and stars, all of the electrons may be stripped from the atoms, leaving just the positively charged nucleus with no electrons around it. The cosmic rays consist of such completely stripped nuclei.

Sometimes an atom gains one or more excess electrons. In this case, the combined negative charges of the electrons exceed the total positive charge on the nucleus. Such an atom is said to be negatively ionized, and is called a negative ion.

The hydrogen atom is the simplest of all atoms, consisting of a single proton as the nucleus with a single electron revolving about the proton. The positive hydrogen ion is simply the nuclear proton separated from the electron of the neutral atom.

The particle radiations in space, which are of great importance and interest in space science, consist of extremely fast moving protons, electrons, neutrons, and atomic nuclei.

The basic forces in nature are the nuclear, electromagnetic, and gravitational forces—there is an intermediate one called Fermi force, but we will not discuss that one.

Of these, the nuclear is the strongest, binding together the protons and neutrons into firmly packed nuclei of atoms. So strong is the nuclear force, so firmly does it bind the neutrons and protons together, that the density of nuclear material amounts to about one billion tons per cubic inch. The electromagnetic forces are about one one-hundredth as strong as the nuclear forces, and are the forces that hold the electrons in their positions in the atom.

The Fermi forces are shown here for the sake of completeness, but since we shall not have occasion to discuss them, let us pass on immediately to the last of the four forces, namely, those due to the gravitational properties of matter. Gravitational forces are much, much weaker than nuclear forces. To be specific, they are ten thousand trillion trillion trillion times weaker than the nuclear force.

To visualize the great difference between gravitational and electromagnetic and nuclear forces, let me call your attention to this 3-pound mass of iron. To say that this piece of iron weighs 3 pounds, is equivalent to saying that the entire earth pulls on the iron with a total force of 3 pounds. It takes a whole earth to generate three pounds of gravitational force on this piece of iron.

On the other hand, this very small magnet is capable of attracting the chunk of iron, with a magnetic force of even more than 3 pounds, enabling me to hold up the iron against the pull of the Earth.

By mentally comparing the size of this small magnet with the huge size of the earth, one is able to visualize after a fashion the tremendous difference in strength between the very weak gravitational forces on the one hand and the much, much stronger electromagnetic and nuclear forces on the other.

It is these nuclear forces that come into play in the innermost heart of the atom, in nuclear explosions, and in the production of most of the radiant energy of the sun and stars. The electromagnetic forces come into play in our everyday use of electricity and magnetism, the radio, and in the generation of light. Gravitational forces hold us to the Earth, bind the Earth and other planets of the solar system to the sun, and bind our solar system to our galaxy.

It is an interplay between the very weak and very strong forces in nature that is responsible for the birth and evolution of the stars and galaxies, the study of which makes astrophysics and space science the fascinating and important subjects that they are. (Fig. 356.)

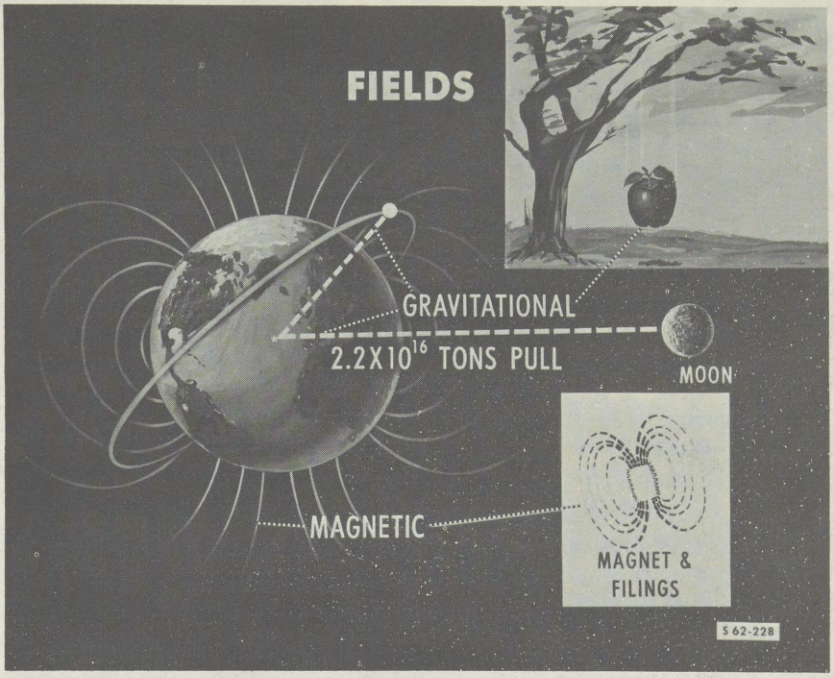

FIGURE 356

In our discussion of space science, we shall often refer to the study of particles and fields. The particles will be those that have been described above. Fields will be magnetic, electric, and gravitational. By a field, is meant a region of space throughout which certain forces operate.

For example, an aggregation of matter such as the Earth exerts a gravitational force on any other material object such as the Moon. In fact the Earth pulls on the Moon with a total average force of 2.2×10^{16} or 22,000 trillion tons.

Thus, the Earth is said to possess a gravitational field. This gravitational field, in addition to keeping the Moon in its orbit, accounts for the fall of the apple to the ground, which is said to have led Newton to his discovery of the law of gravitation. The gravitational field also keeps artificial satellites in their orbits. Indeed, an artificial satellite is, as everyone today well knows, nothing more than an artificial moon.

A magnetic field is a region of space throughout which magnetic forces are exerted. Thus, around an ordinary bar magnet one finds a magnetic field shaped as shown in the little inset in the lower right of the picture. The magnetic field of the Earth, which is believed to be created by currents circulating deep in the core of the Earth, has much the same shape as that of the bar magnet.

Finally, electric charges give rise to electric force fields in the regions of space surrounding them. (Fig. 357.)

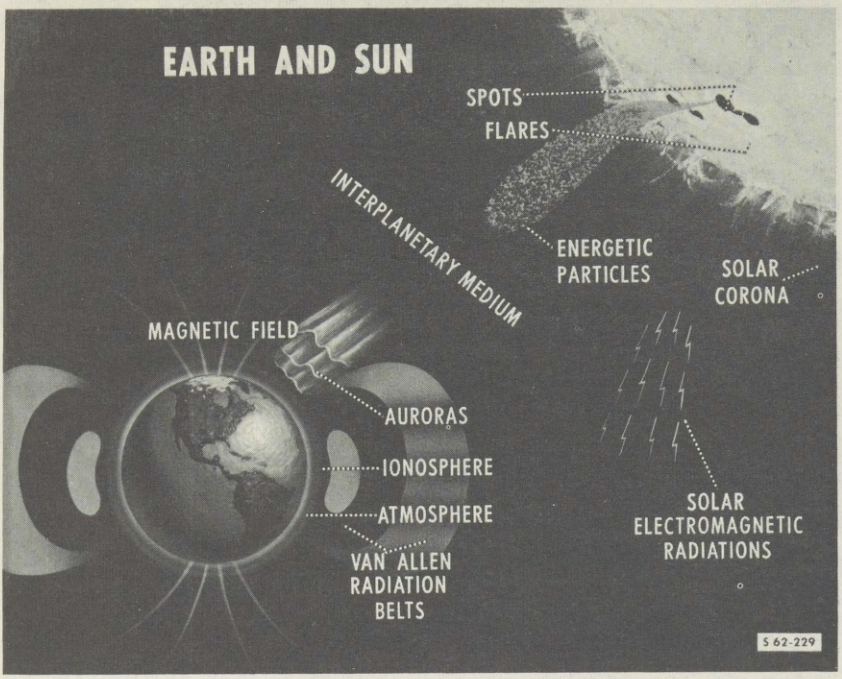

FIGURE 357

Let us return now to space science. As indicated on the first slide, there are many very broad and very important areas of research that come under the heading of space science. Among these are the investigation of the Earth, the Sun, and the influence that the Sun exerts upon the Earth.

Satellites and sounding rockets afford the scientist with a very powerful means of investigating the Earth on which we live. Equipment can be sent aloft to investigate the atmosphere at all heights, and to study the ionosphere, which lies in the upper reaches of the atmosphere and consists of large numbers of electrons and ions. The atmosphere is important because it comprises the source and substance of our everyday weather, and, of course, is the source of our breathing.

The ionosphere is important practically because it furnishes the means by which radio waves may be reflected beyond the horizon, thereby making it possible to communicate around the world. Since the ionosphere is highly variable, we would much rather not be dependent upon it, and hence look forward to the day when communication satellites will furnish us with a much better means of sending our messages around the world.

Satellite-borne instruments plot out the Earth's magnetic field, and measure the radiations to be found in the Van Allen belts. They, likewise, provide a new line of attack on the auroras which hitherto have had to be studied from observatories on the ground.

One can also use satellites to study the interior of the Earth. Observations on the influence of the Earth's shape and mass distribution on the orbit of the satellite enable one to determine the strength of the Earth's interior and measure the distribution of matter within the Earth.

Observatories above the Earth's atmosphere make it possible to investigate the Sun and its activity in a thoroughness not possible from the ground.

I would like to point out at this point that we have several observatory models here.

Here is the orbiting astronomical observatory.

Over in this corner the one with the large booms behind the satellite covered with the glass dome, is the orbiting geophysical observatory.

Observatories such as this operating above the atmosphere provide us with a powerful technique for studying the Earth and its environs.

The ultraviolet, X-ray, radio, and infrared radiations that do not reach the ground can be observed and measured from space platforms. Sunspots, solar flares and solar storms, electromagnetic radiations from the Sun, the solar corona and clouds of energetic particles expelled from the solar surface, are all amenable to investigation by means of satellite-borne and space probe-borne instruments.

The interplanetary medium consists of about 30 to 100 particles per cubic inch at our distance from the Sun. At this density, it would take 200,000 cubic miles of the interplanetary medium to equal in amount the material in one cubic inch of the Earth's atmosphere at sea level. One might well ask, then, if there is so little matter in interplanetary space, why should there be a great interest in it?

The first answer, perhaps, is that the question as phrased implies a misconception. Actually, there is more than just a little matter in space. Indeed, the total amount of matter in the space between the stars of our galaxy adds up at least the amount contained in the stars. It is just that the space throughout which this matter is dispersed is so vast that the matter exists at a very low density. So, we are not talking about a small amount of matter, but rather a lot of matter under conditions of low density. Indeed, this interplanetary material, existing at such very low densities, and imbedded in the weak magnetic fields that pervade the regions of the solar system, exists under conditions that are unattainable in the laboratory.

We have, therefore, an opportunity to study matter and physical processes under conditions that reveal much about the fundamental nature of the universe.

Furthermore, the interplanetary medium is the region through which the Sun exerts its influence on the Earth, giving rise to our weather, creating the ionosphere and the auroras, stirring up the radiation belts and causing magnetic storms, and at times completely disrupting radio communications on the surface of the Earth. (Fig. 358.)

The Moon and planets have long been observed from the surface of the Earth. They can now be observed in greater detail with satellite-borne instrumentation. But the great advances in the study of

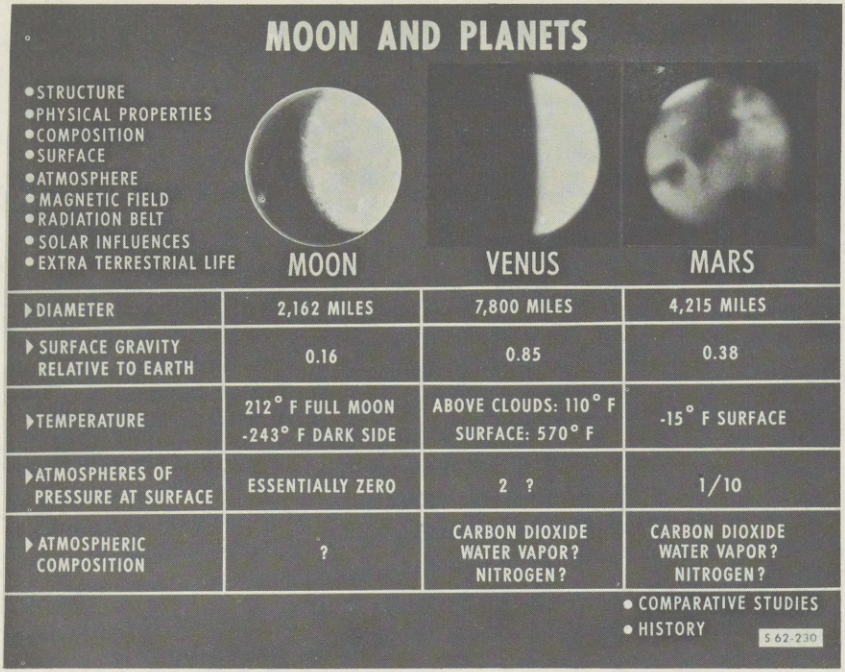

FIGURE 358

these bodies of the solar system will come when instruments, and eventually men, land on them. Some of the things that we wish to learn about these bodies are tabulated in the upper left-hand corner of the slide. As may be seen, we pose the same questions that we ask about our own Earth. The table shows that these objects are not completely unknown. But, especially in the case of Venus and Mars, they are more unknown than known.

As the investigation of the Moon and planets goes forward, it will be possible to make comparisons, thus shedding further light on our understanding of the solar system. The Moon, in particular, is of great importance in searching for the origin of the solar system, because it has for billions of years had no atmosphere to wear away and erase the markings of history—the impacts of meteors and so on—recorded on its surface. (Fig. 359.)

Satellite-borne instruments open a new era in astronomy. With them, not only the Sun and the solar system, but also the stars, interstellar gases, and external galaxies may be studied in wavelengths not observable from the surface of the Earth. The importance of being able to make observations in all parts of the spectrum is illustrated in some measure in the inset at the right lower corner of the slide. Here the same object is shown photographed in blue, yellow, red, and infrared wavelengths. The differences are quite striking. Even greater are the differences to be observed when observations are

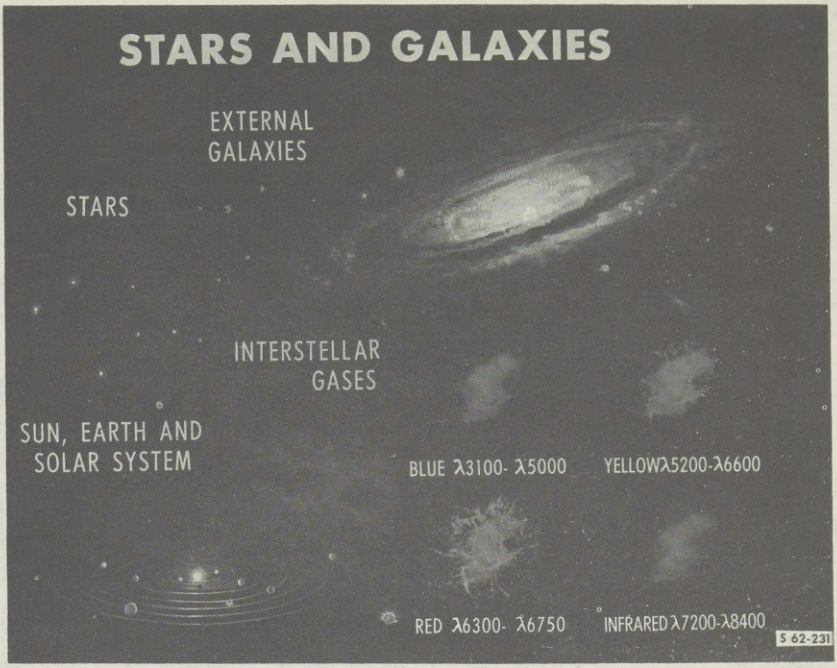

FIGURE 359

made, for example, in the ultraviolet and X-ray wavelengths. Much information about the most fundamental processes of stellar birth and evolution are to be found only in the ultraviolet region of the spectrum, for example. (Fig. 360.)

By life in space, we mean life that is already out there, perhaps on Planet Mars, and those living forms that go out into space from the Earth. Certainly, one of the most exciting aspects of the space program is the search for extraterrestrial life. For various reasons, many scientists feel that there is virtually no likelihood of finding life on the Moon, Venus, Mercury, or the far distant planets. It is conceded, however, that there may be some forms of primitive life on Mars. Indeed, from balloon observations, infrared radiations have been detected of the type that would be emitted by certain biological materials. This by no means establishes the existence of life on Mars, but it most certainly stirs the curiosity of the scientist.

We may one day have the opportunity of studying life that exists under conditions quite different from those obtaining on the Earth. These investigations will help in probing the question of the origin of physical life.

Both satellites and space probes give the bioscientist the opportunity to study the effects of strange environments on living matter. In the vicinity of the Earth there are the effects of the radiation belt and

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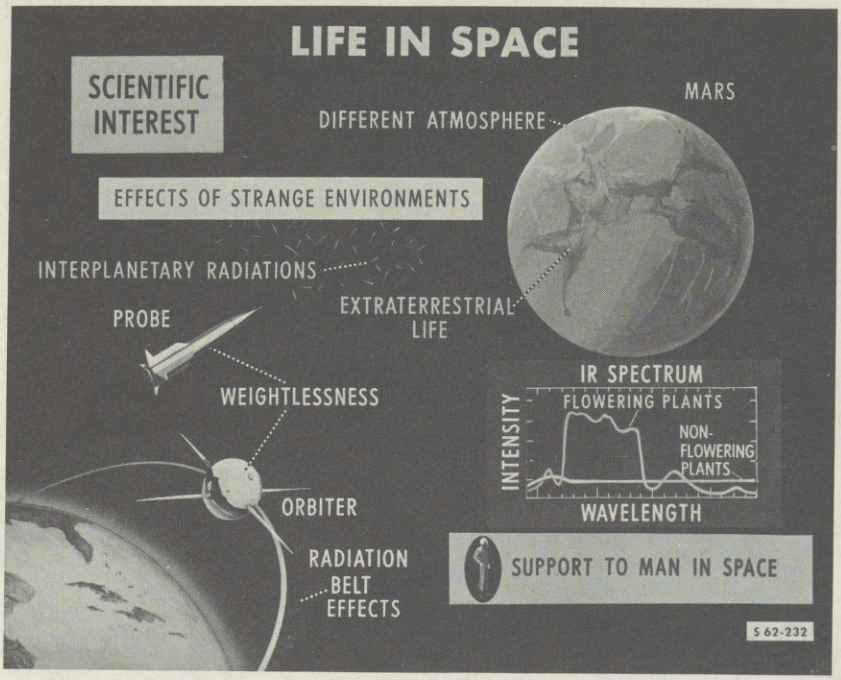

FIGURE 360

weightlessness to explore, while farther away in the regions of interplanetary space there are the interplanetary radiations.

The study of life in space is both of scientific interest and also a much-needed support to the man-in-space program. (Fig. 361.)

The basic tool that makes all these investigations possible is the rocket. With the rocket one may sound the immediate environs of the Earth in the same sense that the meteorologist sounds the lower atmosphere with his weather balloons and the mariner sounds the ocean depths with his lead line. In general, we reserve the term, "sounding rocket," for the vertical or near vertical probe that rises no higher than one Earth's radius. Rockets that go beyond this altitude, but still do not approach lunar or planetary distances, have come to be known as geoprobes.

Rockets that go far out into space are referred to as deep-space probes, and as appropriate, are more specifically called lunar probes, or planetary probes, or solar probes.

The artificial satellites make possible long-term geophysical and astronomical observations at and beyond the edge of the Earth's atmosphere. In the course of time, satellites about the Moon or about the planets will permit continuous observations of those bodies. (Fig. 362.)

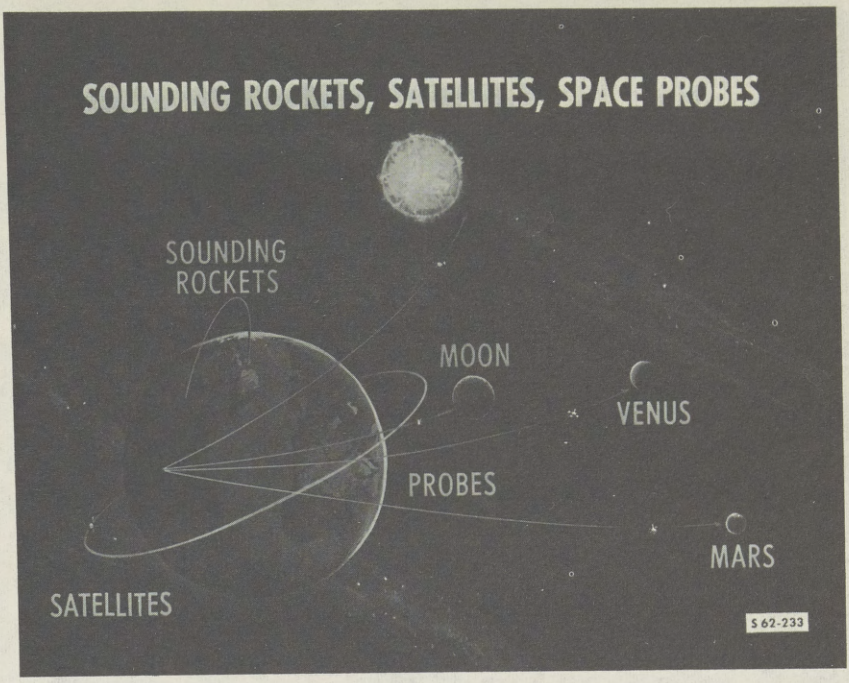

FIGURE 361

A host of sounding rockets is now available to the rocket experimenter. Literally dozens of different types of rockets exist, in varying sizes, and with varying payload capabilities and altitude performance. The wide choice that exists makes it possible for the experimenter to tailor his selection of a rocket to his specific need.

In the case of satellite vehicles and space probes, however, the rocket is so large, so complex, and so expensive that one can afford to have only a limited number of different vehicles. For this reason, NASA and the Department of Defense have agreed on a common national vehicle program. The light and medium launch vehicles shown here constitute the mainstay of the present NASA space sciences program. Scout, Delta, and Centaur are NASA-sponsored vehicles. The Earth-escape performance of Centaur is required for the Surveyor and Mariner programs, to be discussed later. Thor-Agena and Atlas-Agena have been developed by the Air Force. For later, more difficult missions to the Moon and planets, the NASA space science program will require the Saturn launching vehicle, now under development by NASA.

Later on Mr. Cortright will pick up the discussion of our launch vehicles. (Fig. 363.)

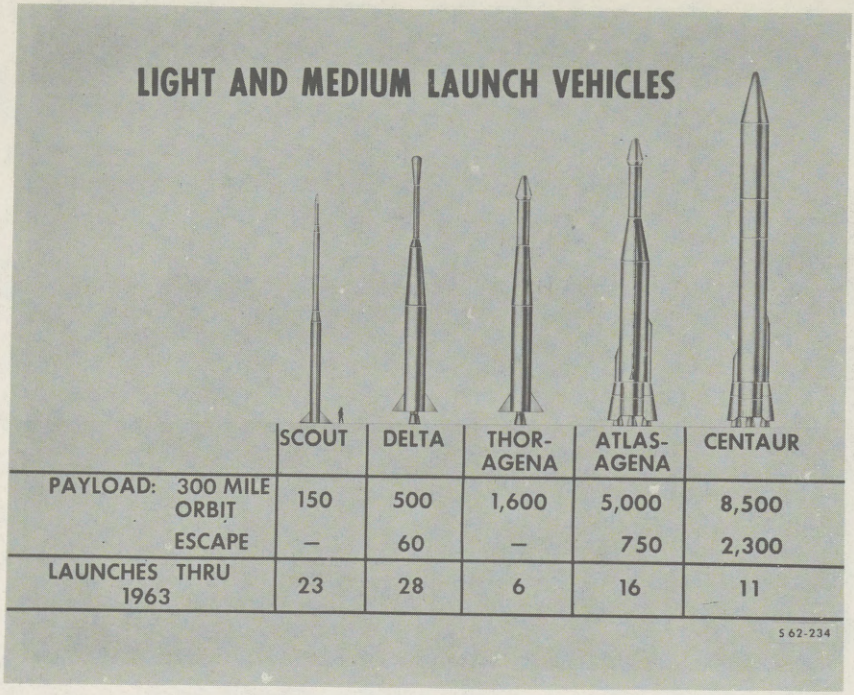

FIGURE 362

The space science program has made considerable progress since NASA began business in October 1958. The accompanying picture indicates this progress for the immediate past. The planned launchings for calendar year 1962 are: sounding rockets, 84; satellites, 11; and deep space probes, 5.

Mr. KARTH. They will be described later, Doctor?

Dr. NEWELL. Yes.

Mr. KARTH. Thank you.

Dr. NEWELL. The individual results, and various papers reporting on NASA space science experiments have achieved a considerable volume. It would be impossible in the time available to us here to review in detail all of the accomplishments. Instead, let us point out that gratifying progress has been made in all of the major areas of the program. In addition, let us consider a couple of areas in some detail. (Fig. 364.)

During 1961 there was considerable progress in the study of the Earth's radiation belt and the influence exerted upon these belts by the Sun. You may recall that last year Dr. Robert Jastrow described the then current state of knowledge about the sequence of events occurring during and after a solar flare. Under normal conditions the interplanetary medium appears to consist of a low concentration of relatively slow-moving electrons and protons, perhaps 100 per cubic inch, plus a still smaller number of the very energetic

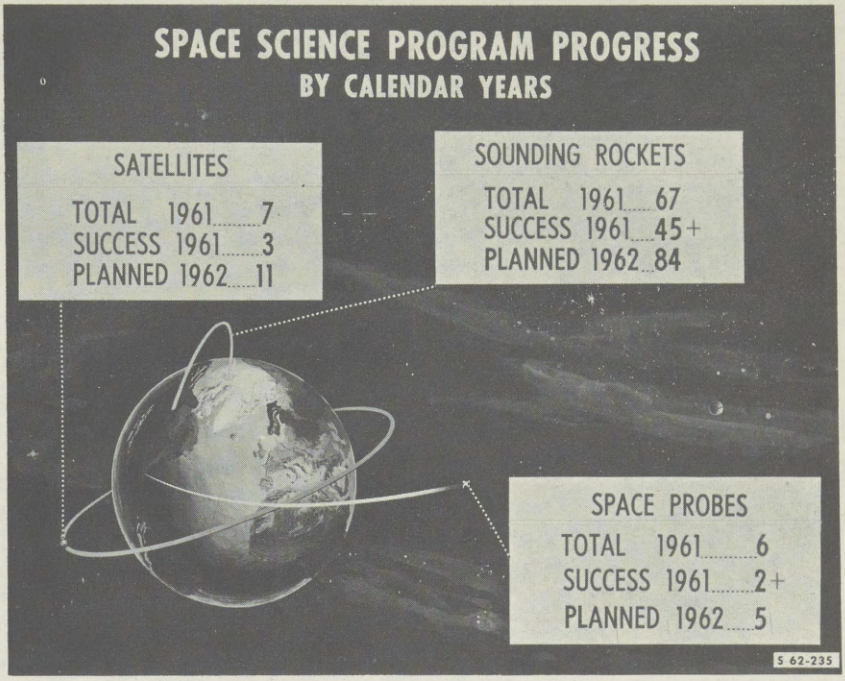

FIGURE 363

cosmic rays. Normally there is less than one such energetic cosmic ray per cubic yard. There is also a small interplanetary magnetic field of about 2 gamma in magnitude, which is to say about one ten-thousandths the strength of the Earth's magnetic field at the Equator.

Mr. BASS. May I interrupt? Do cosmic rays consist of particles, Doctor?

Dr. NEWELL. Yes. The cosmic rays are all atoms, nuclei of atoms that have been completely stripped of their electrons. So they are all positively charged particles, most of them are protons, about 15 percent of them are helium nuclei, and 1 percent of them consist of heavier nuclei, up to as heavy as iron.

Mr. BASS. Would it be correct to say they are ionized then?

Dr. NEWELL. Completely ionized; just as ionized as they can be.

Mr. RANDALL. Are Explorer X and Explorer XII as you show it there now still in orbit and still sending data back? Is that correct?

Dr. NEWELL. They are still in orbit, but they are no longer transmitting data back to us.

Mr. RANDALL. Thank you.

Dr. NEWELL. The Explorer XII model is over here [indicating]. We will describe Explorer XII in more detail later.

When a solar flare occurs, it appears that a tongue of plasma, that is, relatively slow-moving charged particles, erupts from the surface of the Sun at the site of the flare.

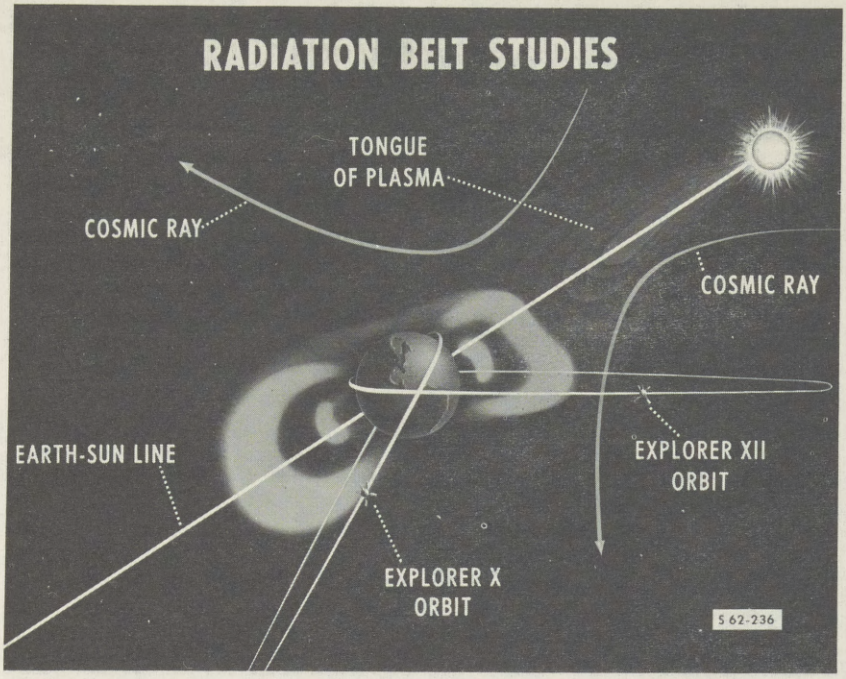

FIGURE 364

Mr. KARTH. Are those predictable with any degree of accuracy, Doctor?

Dr. NEWELL. Not yet. That is one of the big problems in connection with manned space flight. One of the big problems of the space program is to try to lay the groundwork for predicting these flares.

This tongue of plasma moves out across interplanetary space at a speed of roughly 1,000 miles per second. Moving at this speed, the plasma cloud takes about 1 day to reach the Earth. As it moves, the cloud drags with it lines of solar magnetic force, which are frozen into the cloud and forced to move with it by the laws of electromagnetism. These lines of magnetic force have their roots on the surface of the Sun in the vicinity of the flare, but as the tongue of plasma moves across space, the lines are drawn out with it like loops of taffy.

When magnetic lines of force become distended in this fashion, they weaken, and by the time such lines reach the Earth, they are perhaps as much as 500 times weaker than they were at the surface of the Sun. Nevertheless, the magnetic field within the plasma tongue is still sufficiently strong to screen the Earth partially from the cosmic rays which are normally observed.

This screening effect is referred to as the Forbush decrease, after Forbush of the Carnegie Institution, who discovered the effect about 20 years ago.

Mr. KARTH. Doctor, these tongues of plasma occur more at certain times of the year than others, do they not?

Dr. NEWELL. Yes, they do. They occur much more often during the maximum of the solar sunspot cycle.

Mr. KARTH. This is about what time of the year? Could you define that for the committee?

Dr. NEWELL. Yes. The sunspot cycle is an 11-year period in which the number of spots on the surface of the Sun varies from a maximum number to no sunspots. We are now approaching the minimum of the sunspot cycle, which will occur in 1964 and 1965. We went through the maximum during what was the International Geophysical Year, 1957–58.

Mr. KARTH. So at which time is it most convenient, most advantageous to have interplanetary travel?

Dr. NEWELL. From the point of view of avoiding radiations from flares, the solar sunspot minimum period would be the most advantageous.

Mr. KARTH. 1964 and 1965 are rather crucial years for interplanetary travel?

Dr. NEWELL. These would be the most convenient years.

Mr. KARTH. If we can't take advantage of it then in the proportions that we should, we will have to wait another 11 years?

Dr. NEWELL. Unless you can shield the man against the radiation.

Mr. KARTH. Yes. Thank you.

Dr. NEWELL. This plasma cloud impinging upon the Earth's magnetic field, distorts the Earth's field, markedly affects the intensity of the Van Allen radiation, and is associated in some way with magnetic storms and auroral displays.

When the Earth is enveloped in such a tongue of plasma, the imbedded solar magnetic field lines form a sort of channel to the Sun along with solar particles emitted in subsequent flares may be guided with very little delay. Such periods of time are very likely to be of especial hazard to manned space flight within the Earth-Moon system.

The point here is, if you have this channel, some of the participles that couldn't get to the Earth under other conditions, can now just come along that channel and hit the Earth.

This picture presented by Dr. Jastrow may be described as only the beginnings of an understanding of the effect of the Sun upon the interplanetary medium, the Earth's radiation belts, and the atmosphere. Many questions were left unanswered. During the past year Explorer XII, a satellite instrumented to measure energetic particles and magnetic fields, was launched on August 15. The satellite had an apogee of 48,000 miles and a perigee of 182 miles. It operated continuously for 112 days, passing through the radiation belts twice per orbit, for a total of 204 transits. This satellite revealed a large flux of medium energy protons trapped in the outer zone of the radiation belt. No protons had been seen in the outer belt before this measurement. The number of protons observed was probably about as many as the magnetic field of the Earth in that region of space could hold.

Measurements with the Explorer XII instruments, which were considerably more refined than those of previous satellites, failed to reveal the expected great increase in flux of lower energy electrons that had

been predicted earlier. Indeed, the total flux was observed by Van Allen to be about 100 million electrons per square centimeter every second, which is 1,000 times lower than had been estimated from earlier experiments. Some scientists believe that the earlier experiments had actually been misleading, and that the new results would also have been obtained in the earlier experiments had better instrumentation been used. It is, however, also possible that the decline in solar sunspot cycle, may account for the new measurement. Really there is a need to obtain more accurate and broader measurements throughout an entire sunspot cycle before the true facts can be regarded as fully known.

These values of electron intensity in the outer belt represent a far lesser radiation problem—for example, to solar cells and electronic components—than the earlier measurements had indicated.

Last year we described the NERV sounding rocket experiment, in which a stack of nuclear emulsions was flown into the inner Van Allen radiation belt. During the past year analysis of the emulsions, which were recovered from the Pacific Ocean by the Navy, has yielded some interesting results. At higher latitudes, a large population of low energy protons was observed.

I should interpolate here that solar protons are a particular hazard, hence the great interest in them.

It would appear likely that these protons are due to solar cosmic ray protons which strike the atmosphere of the earth in the polar regions at the time of certain types of flares on the Sun. These incoming protons generate neutrons in the atmosphere, and the neutrons, when they decay, produce the observed protons that are then trapped in the radiation belt.

Continued examination of earlier satellite and sounding rocket data has yielded a more accurate estimate of the radiation hazard due to streams of protons from the Sun. Some of Van Allen's results indicate that the total radiation dose that would have been caused by solar protons from one of the flares during the November 1960 solar events, would have exceeded 700 roentgens. Under very little shielding, this radiation dose would have been lethal, and indeed this new estimate of the hazard emphasizes the great importance to the manned flight program of continued careful observation and study of the radiations in space.

Mr. RANDALL. Mr. Chairman, before we proceed, this NERV experiment, this emulsion, does this have any relationship to—well, first, what form was that in, how was it? You said it was recovered from the Pacific by the Navy. In what sort of a capsule, or how was it recovered?

Dr. NEWELL. The NERV was a sounding rocket experiment.

The nose cone was parachuted to Earth after the sounding rocket had reached to its apex, carrying photographic emulsions.

Mr. RANDALL. Oh, it had no relationship; it was a part of the so-called needles that were sent up?

Dr. NEWELL. No.

Mr. RANDALL. I see; all right.

Mr. BASS. When you refer to protons, Doctor, do you mean hydrogen and helium protons only, or are there the protons of other types of atoms?

Dr. NEWELL. When I refer to protons, I mean hydrogen nuclei, completely ionized hydrogen.

Mr. BASS. Are there other types of protons in interplanetary space?

Dr. NEWELL. No. Protons are all the same particle. You find them in all the other atoms, but once you separate them from the other atoms, you don't know whether they came from hydrogen atoms or where they did come from.

Mr. BASS. I understand now.

Mr. KARTH. What was the apex of NERV?

Dr. NEWELL. It was about 1,200 miles.

The satellite Explorer X, launched on March 25, 1961, carried several highly sensitive magnetometers and a plasma probe for the measurement of the flux of low-energy protons. The satellite was powered by batteries designed to operate for about 55 hours; actual reliable operation was obtained for 53 hours. Whereas magnetic field measurements on Explorer XII indicated an abrupt end to the trapped particles and a merging of the Earth's magnetic field with the interplanetary magnetic field at about 10 Earth's radii, the Explorer X observations seemed to show the probe passed through the edge of the Earth's magnetic field at about 20 Earth's radii, not shown actually to scale on the slide.

From the slide one can see that the Explorer XII orbit was oriented in more or less the direction of the Sun, while Explorer X moved backward from the Sun at about 140 degrees to the solar direction. This would seem to suggest that a solar wind may be compressing the Earth's magnetic field on the side toward the Sun and blowing it out on the other side. Such a solar wind, if it does exist, was not observable all the time. The magnetic field during the more distant part of the flight of Explorer X changed in both direction and character. When the magnetic field intensity dropped to low values, the plasma probe observed a flux from the general direction of the Sun; but when the field intensity was high, no plasma flux was observed.

Mr. KARTH. It wasn't always true, Doctor, was it, the field was compressed on the side of the Sun—to the same degree?

Dr. NEWELL. Probably not.

Mr. KARTH. Was it always compressed more though than the opposite or far away side from the Sun?

Dr. NEWELL. That we don't know yet. That we suspect is so, and is one of the things that we want to look into in future flights.

It is quite likely that this portion of the field is always somewhat compressed, on the side toward the sun, and this other somewhat blown out. We don't have enough measurements to be able to prove it.

Mr. KARTH. Thank you.

Dr. NEWELL. The Explorer X magnetic field observations appeared to indicate a ring of electric current about the Earth at about 2 or 3 Earth's radii distance. This observation must now be added to those of the Soviets and Explorer VI, the latter indicating the possible existence of a ring current centered, perhaps, at 10 Earth's radii.

If there is anything true about this region it is that it is never the same from one observation to the next.

At the same time, continued analysis of the magnetic field measurements taken with the Vanguard III International Geophysical Year satellite, reveals a great deal of structure in the magnetic field over

the equator. Sometimes a ring current appears to be quite high, sometimes quite low.

Thus, observations during 1961 and further analysis of data obtained earlier continued to reveal the great complexity of the Earth's radiation belts and their relationship to solar activity. The intensity of electrons in the outer radiation belt appears to be 1,000-fold lower than earlier measurements had indicated. About as many medium energy protons as the field can hold have now been observed in the outer belt. The ultimate source of many of the protons in the inner radiation belt may well be solar protons entering the auroral regions. The Earth's magnetic field appears to be compressed in the direction toward the Sun and blown out in the direction away from the Sun. However, the measurements on which this conclusion is based are too sparse for one to feel certain about the conclusion.

It is interesting to know we are still putting together pieces of this puzzle with data obtained way back in the International Geophysical Year days. The pieces to the puzzle fit somewhere down the road, even if they don't necessarily fit at the time you get the pieces.

Mr. KARTH. How long does it take to evaluate the information you get back from Explorers such as X and XII—still working back in the geophysical year?

Dr. NEWELL. It normally takes about a year to get the data just organized.

Mr. KARTH. And to make sense out of it?

Dr. NEWELL. It takes many years thereafter. Sometimes it can be quickly done, sometimes it takes literally years just to explain a point.

Mr. KARTH. Whose responsibility is it to make sense out of this data, Doctor?

Dr. NEWELL. We look to the experimenter as the man responsible for carrying through his experiment to the point where he says, "I now understand what all that means," or at least, "I now understand the next measurement we should make."

Mr. KARTH. Isn't that a rather serious weakness in our whole program, though, if this man has the responsibility and doesn't have the staff to make the final analysis or to analyze the results of the experience of the experiment for, say, 2 years after the experiment actually took place, then it seems to me that subsequent experiments might not necessarily—might be somewhat repetitious and duplicative, is this right?

Dr. NEWELL. I agree with the point of your question that the real product and output is the data and the papers and the interpretation, and that it is of major importance to make sure that these data get analyzed and interpreted.

However, it is there in the nature of things that it sometimes takes a while to come to understand some of these things. We must provide the experimenter with a staff, the monetary support, and so on, to move ahead as fast as he can, but we also have to recognize that it cannot be moved as fast as we would like to have it moved.

Mr. KARTH. I was coming to the point, by the time we are ready to send man out to explore the surface of the Moon for example, we probably won't have the answer to the questions that were inherent in the satellites or the other experiments that we sent out from which we expected to see this, prior to the man's flight.

Dr. NEWELL. There are some answers we won't have, very likely. There are many answers that we will have.

It may well be that we will not have solved the problem of predicting solar flares, but we should be able to have measured the radiations in space and know what the shielding problem is, so that we should be able to provide a way of handling that difficulty.

The point that you bring out is a very important one that it is necessary to do now the fundamental research that you are going to need decades from now in some projects that you don't even know about now.

Mr. KARTH. Of course those experiments we are doing now, Doctor, may have very little relationship to the conditions that actually exist in 1964 or 1965, due to the 11-year cycle, isn't that correct?

Dr. NEWELL. This is correct, and this again emphasizes another important point that measurements must be made continuously throughout the whole solar-sunspot cycle.

Mr. KARTH. Once we have gone through the cycle and interpreted the results of the experiment, then, of course you have the answer, if it repeats pretty generally in the same fashion?

Dr. NEWELL. Yes.

Mr. RANDALL. Back on your comment about the experimenter, you used the expression "experimenter," or the analysis of these studies, and the fact there is a 2-year wait.

Is this done inhouse with NASA, or is it a research agency, is it assigned out? Is there any way that can be accelerated?

Dr. NEWELL. The experimenter is a term used to refer to the man who comes from the scientific community——

Mr. RANDALL. Explain that.

Dr. NEWELL. The scientific community includes NASA inhouse people, university people, researchers, professors, people in industry, people in research institutes, like the Armour Research Foundation, and so on.

Mr. RANDALL. It is a generic term you are using there, then?

Dr. NEWELL. It is a generic term, right.

Mr. RANDALL. At this point, it may be a matter of money, but is there any way that can be accelerated? I am very much impressed by the question of the chairman. There may be some repetition because of this delay, but are we going to have as much as we need or as much as we could have by the time we are ready for man's flight here? Maybe that will be the conclusion of your testimony, I don't know, maybe I am premature on it.

Dr. NEWELL. Well, this is a most important question, and it is one we have in mind all the time.

In the going over of data, we go through a series of different phases. First of all one takes a quick look, this quick look may be made right in the field at the station where the data have been brought in, to get the overall picture of any important items that may be in there that need further immediate study.

Then the data come back to be processed to organize it in the form of tables and charts, so that the scientist may then dig further into it.

Mr. KARTH. This data goes back to who, Doctor, to the experimenter?

Dr. NEWELL. No, it comes back to NASA or the NASA contractor which has been selected and given the job of doing this initial processing.

Mr. KARTH. I see.

Dr. NEWELL. After the initial processing of the data, the data then goes out to the scientist, for example, Van Allen, at S.U.I. or Simpson, at the University of Chicago, or whoever is the keyman on that experiment, and he, then, reviews it again quickly. Each man makes a continuing sequence of quick reviews that gets the most out of the data they could get out of it at that phase in the analysis.

The complexity of the thing we are studying, however, is such that each man will be found to be continuing to study his data years from the time when it was collected. He won't have waited until then before he begins publishing anything, he will have published pieces as he went along.

Also, we are prepared——

Mr. KARTH. The interesting question still is, Doctor, is there anyway we can speed that process up, which, at the present time, takes in the neighborhood of 2 years or more to get final data.

Dr. NEWELL. I think the way to speed it up is what we are doing, that is, to continue to bear down on it, to increase the efficiency of the initial processing of the data, to bring in additional experimenters and thinkers, which we are also doing. It simply requires continual attention which we are giving to it.

Mr. KARTH. Is there any merit to a suggestion that a special pool of scientists—that NASA have an inhouse capability composed of the special pool of scientists to do nothing but this?

Dr. NEWELL. You mean nothing but the analyzing of data?

Mr. KARTH. Yes.

Dr. NEWELL. This is worth thinking about.

Mr. KARTH. How many men do you think it would take, Doctor, to cut this so-called leadtime in half?

Dr. NEWELL. I couldn't give an answer to that, because you are asking how many men it will take to have the right ideas to solve hitherto unanswered problems.

Mr. KARTH. I understand this is a difficult question.

I was wondering if you could give us an estimate, so the committee would have a little better idea of what we can do with this information that our satellites do in fact return to us, but with which we don't really have the wherewithal to process it as it should be processed for a considerable length of time. It might well interfere with the objective of our man flight to the moon.

Dr. NEWELL. Well, I hope we are not leaving with you the impression these things are not being processed.

Mr. KARTH. No, no.

Dr. NEWELL. As fast as they can be at the moment.

Mr. KARTH. I realize that.

Dr. NEWELL. I am looking forward to the future, with you, as I assume you are, to continuing to handle the masses of data as the total masses become greater.

At the present time I would say we are getting these things through the mill about as fast as we can do it. We are never going to get to the point where people won't be looking at these data years after they were collected.

Mr. KARTH. How many Explorers have we sent up?

Dr. NEWELL. The last number was Explorer XIII. That means we have sent up 13 of them.

Mr. Cortright just pointed out to me that right now we have six to eight 7090's at work in this business of reducing data.

Mr. KARTH. You have six or eight what?

Dr. NEWELL. IBM 7090 computers, the large type computers.

Mr. KARTH. Yes.

Dr. NEWELL. Which at the present time is doing the job of getting the data out.

Mr. CORTRIGHT. In other words, the data reduction is automated as much as feasible at this time.

Mr. KARTH. Data reduction is no problem.

Mr. CORTRIGHT. It is the thought processes.

Mr. KARTH. Analyzing the results of the experiment. This takes up several years?

Dr. NEWELL. Yes.

Mr. KARTH. Of the 13 Explorers we put out, how many of those have we really analyzed to the final degree? The final degree that we expect to analyze them to?

Dr. NEWELL. The answer has got to be not all of them, yet on all of them there have been papers published and significant results brought out.

For example, on Explorer XII, which was the satellite that gave us additional data on the radiation belt, there have been extensive reviews of the data for the scientific community. Recently, at the Goddard Space Flight Center, a symposium was held on the results that the experimenters have arrived at. These data are being published in literature, e.g., the Journal of Geophysical Research. Also, they are being fed into the engineering community as fast as need for these data appears.

Mr. KARTH. Do you find in most of those, Doctor, that about 50 percent of the data you get back is pretty much what you have already received from one of the previous Explorers, and that about half of it is new data? What percentage of the data that you get from subsequent Explorers is in fact new data, different data?

Dr. NEWELL. Well, it is different data, it is always new data at this stage of the game, because it is new in time for one thing.

Secondly, the instrumentation for, say the Explorer XII satellite that we just mentioned, is designed on the basis of what we did learn from previous Explorers like Explorer VI, for example, and the Pioneer V, and so on. With this advance in instrumentation design you then get a different look at things. The data is actually new.

Mr. RANDALL. If I got your note down correctly, I think your partial answer to the Chairman's question was, not only the instrumentation design and the time, but I think you said if anything is true, it is that these regions are never the same from one observation to another. I thought that was one of the most significant statements you made.

In other words, it is going to be a continuing process?

Dr. NEWELL. Yes.

Mr. RANDALL. You use a figure there. Is it an average figure? I have fixed in my mind you said it runs about 2 years before we can reach a conclusion. What is the 2-year period?

Dr. NEWELL. It is not 2 years before you can reach conclusions. The statement should be that at the end of 2 years or so, people are still working on these data. Results and papers have been coming out all throughout this period.

Let's take, for example, the field of ionospheric research, research on the upper atmosphere.

There is an extremely powerful technique of studying this by means of radio waves propagated from a rocket or satellite. When this experiment was first performed it took the designers of the experiment 3 years to understand what they had, and we had to wait patiently, we prodded them, we offered them all the additional support that they needed in order to get that data out, but that was not what was needed. It was 3 years of "think" period that was required. It now takes 6 weeks to get a set of such data out.

Mr. RANDALL. That is all.

Mr. CORTRIGHT. May I make an extra point here?

The type of data that are particularly difficult to understand are the data on phenomena that keep varying, as Mr. Randall has pointed out. There will be other areas in space science that won't be this contrary.

For example, when we obtain measurements on the surface of the moon and planets, such as the structure of these bodies, the topography, the constituents, the hardness, the physical parameters, and so forth, these will be interpretable relatively quickly. So I think the nature of the problem varies, depending on what we are measuring.

Mr. KARTH. Because the data received generally disagrees with that data that you have received from the previous Explorer, because of time, or whatever has happened?

Mr. CORTRIGHT. You have to do one of two things.

Mr. KARTH. To cause the difference. In fact what you are going to do when you get all this data in, is pretty much generalized?

Mr. CORTRIGHT. Yes, sir, you have to generalize in terms of basic understanding or you have to get a statistical knowledge for the parameters that are varying all the time.

Mr. KARTH. Which can vary on a day by day basis.

Dr. NEWELL. One could use another analogy. One is familiar nowadays with the term "radioactive half life".

The activity of a sample of radioactive material decays steadily with the passage of time. After what is called the half life, the total activity is reduced to one-half of what it was at the start, and this goes on over the years.

Mr. KARTH. Yes.

Dr. NEWELL. Then if you think of the mass of data that comes back from a satellite experiment in these terms, the data provide information at a rapid rate to begin with, and then after certain half life the rate is reduced and after another half life, the rate has reduced again.

People will still be poking into that data every time a new question comes up that makes them wonder, now, did I interpret that right 2 years ago? Or half a year ago? And so on.

Mr. KARTH. Except, here is an area in which you don't have to generalize, after you have made your analysis, Doctor. After a certain period of time it is half life, after a certain period of time it is a quarter life, and so on and so forth, so you have what is left, which is rather negligible.

Dr. NEWELL. Yes.

Mr. KARTH. Here we are running into a situation which varies from day to day, and probably won't repeat itself for another 365 days, if forever. I understand the extent of your problem in that connection. I was just trying to find out if there is an answer to it, and apparently there isn't.

Dr. NEWELL. To return to the radiation belt studies:

We pointed out that the more recent observations showed the intensity of the electrons in the outer belt appeared to be a thousandfold lower than earlier measurements indicated. That about as many medium energy protons as the field can hold were found in the outer belt, but the ultimate source of many of the protons appears to be solar protons coming in through the auroral regions. That the earth's magnetic field appears compressed on the side toward the sun and blown out on the other side.

If the field is distorted in such fashion, the presumption is that a steady solar wind is the cause. On the other hand, there have been no firm observations of such a solar wind, although fluctuating glimpses of a plasma flux were obtained in the Explorer X satellite associated with fluctuating magnetic field observations. Finally, although the existence of a ring current around the Earth, appears established, the various measurements disagree as to where this current is actually located.

The various observations and analyses of the past year have combined to indicate that the radiation hazard in the Van Allen belts may be appreciably less than had been thought earlier, while the hazard due to energetic solar proton streams may be considerably greater.

Considerable progress has been made in this area during 1961, but in large measure that progress has been a continuing revelation of the complexity of the problem and of the need for much more detailed observation such as can be obtained with a monitoring-type satellite.

Mr. KARTH. Does the outer limits of that belt vary, Doctor, from time to time, and if so, how much?

Dr. NEWELL. The outer edges of the belt varies quite markedly. It may vary from 40,000 miles above the surface of the earth, out to 60,000 or more miles. In fact, one of the early measurements made by Van Allen showed that the intensity may vary more than a factor of 1,000, between periods of solar quiet and solar activity.

Mr. DOWNING. What is the apogee and perigee of the Van Allen belt?

Dr. NEWELL. If we look at this figure, toward the sun, you get measurable radiation increases in the equatorial region at about 500 to 600 or 700 miles, marking the inner edge of the belt. The outer edge of the belt extends to perhaps as much as 10 earth radii, that is 40,000 to 45,000 miles. If you are on the other side of the Earth, away from the Sun, indications are you would have the same sort of height for the inner edge of the belt, that is, 500 or 600 miles altitude, but the outer edge may go out to perhaps as far as 20 Earth's radii.

Mr. DOWNING. Do we have any test vehicles in the Van Allen belt?

Dr. NEWELL. The Explorer XII, as you see, went through it this way.

Explorer X went through it this way.

And previous to these we had Explorer VII which was going through it at about like that.

So we crisscrossed it pretty well.

Mr. DOWNING. Thank you.

Mr. RANDALL. I am not sure I got the apogee and perigee. You said the apogee was 10 Earth radii, is that right?

Dr. NEWELL. Yes.

Mr. RANDALL. The perigee is from 5,000 to 7,000 miles?

Dr. NEWELL. No sir, 500 to 700 miles. Actually we don't use the terms "perigee and apogee."

Mr. RANDALL. Then the nearness and extent?

Dr. NEWELL. Yes.

Mr. KARTH. One further question, Doctor, just to clear up in my mind the data that you finally ascertained that a satellite has given.

As I understood you, each succeeding Explorer satellite gives you new information?

Dr. NEWELL. Yes.

Mr. KARTH. But it might also be a fact you will never use this information, or that this information will never be important because the condition that existed at the time that that particular satellite got the information may never be duplicated again. I mean the same condition may never again exist. My question is, what have you learned outside of those things that you generally learn from each one of them, that certain conditions do exist, but these conditions change and fluctuate from day to day, and that they are never stable. Is this pretty much what we learn?

Dr. NEWELL. This is the problem that faces the natural scientist and the geophysicist. He is looking at a horribly complex picture which never really is the same, yet he wants to get out of that picture some of the order that does exist behind the scenes. There is an "almost-the-sameness" that he is looking for. What is the general picture of the variation in the belts throughout the sunspot cycle?

What is the overall picture of what occurs when a solar flare happens and these particles are thrown at the Earth?

Although each event is different, in some way, from each other event, nevertheless there are similarities that the scientist is looking for so that he can get his hands on a theory about what is happening.

Mr. CORTRIGHT. It is a bit like studying the weather.

Mr. KARTH. Duplication in this area is absolutely necessary, is that correct?

Dr. NEWELL. Yes, it is, absolutely.

Mr. CORTRIGHT. I was just pointing out the analogy of studying the weather. You might never have quite the same type of storm in your hometown, but on the other hand you have——

Mr. KARTH. But it is only a matter of degree?

Mr. CORTRIGHT. Yes.

Mr. KARTH. I think it is good that we have that in the record, Doctor.

Dr. NEWELL. Mr. Chairman, I would like to turn to a second example of progress, reemphasizing as I do that these are typical examples of how the program is moving ahead:

This is in the area of gamma ray astronomy. (Fig. 365.) Gamma Ray Astronomy.)

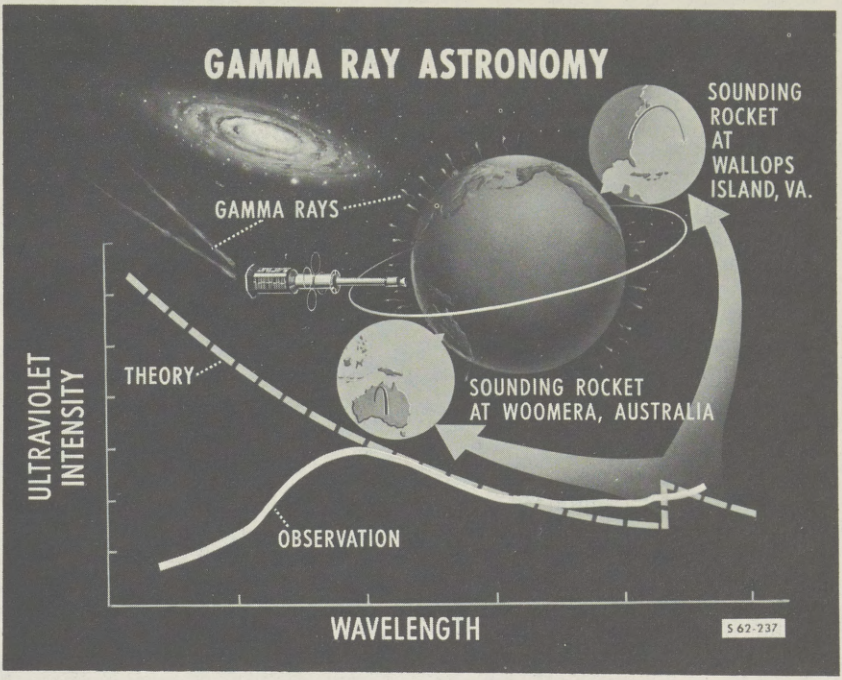

FIGURE 365

Rocket astronomy was begun by a naval research laboratory group under Herbert Friedman a number of years ago. During the past year, the NASA program not only made exciting advances in rocket astronomy, but also inaugurated gamma ray astronomy.

Explorer XI was launched on April 27, 1961, carrying an instrument designed to observe and measure gamma rays. Gamma rays are similar to X-rays, but are of much higher energy. The gamma ray telescope was provided by Dr. Kraushaar and Dr. Clark of the Massachusetts Institute of Technology.

The gamma ray detector gathered data until last September. Most of the gamma ray counts that were received came from the Earth. This Earth count rate was consistent with previous gamma ray measurements made in the upper atmosphere. About 20 percent of the observed counts came from space and not from the Earth. These counts did not come primarily from any one direction. They seemed to be well distributed in space with some preference for the plane of our galaxy. The count rate of the detector is quite low, but it is about what one might expect from gamma rays arising from collisions between cosmic rays and the gas existing throughout the galaxy.

Mr. BASS. Doctor, for my information, is a gamma ray or X-ray consisting of particles or not?

Dr. NEWELL. X-rays are light, of higher frequency, than ultraviolet light. And gamma rays are of even higher frequencies than X-rays.

Mr. BASS. There are no particles involved in gamma rays?

Dr. NEWELL. No, these are electromagnetic radiations.

Mr. KARTH. Thank you, Doctor.

Dr. NEWELL. The observed counts are a thousandfold fewer than would arise from the interaction between positive protons and negative protons if one certain theory of the universe were true; namely, that theory that holds that matter and antimatter are being created continuously at equal rates.

Matter is matter, as we know it. Antimatter is the "Alice through the looking glass" opposite of matter. If we had one object of matter and another object of antimatter, putting the two together would destroy them both, and we would wind up with a little burst of radiant energy, but all the matter would be gone.

Mr. KARTH. It is like the unstoppable meeting the immovable?

Dr. NEWELL. Just about. One theory of the universe holds that matter is being created continuously, and that as the universe expands the matter that goes over the horizon, so to speak, is replaced by new matter that has just been created.

In that theory, some hold that matter and antimatter are created at the same rate, and if they are created at the same rate, then in colliding they create these gamma rays at a certain rate, and you can look out and see that gamma rays are being created at that rate. The MIT people have found that they are not. We have at least the esthetic satisfaction of having disproved one possible theory of the universe.

We have not seen any gamma ray stars, that is, points of gamma ray light. Inasmuch as the gamma rays arise from some of the most fundamental processes of nature, their investigation is of great importance to the scientist.

The NASA Goddard Space Flight Center has flown a number of sounding rockets instrumented to observe and measure the ultraviolet radiation from a number of stars and galaxies. Flights have been made at Wallops Island in Virginia and from the Woomera Rocket Range in Australia. The Australian flights were intended, of course, to observe the southern skies.

The results of these rocket experiments were most startling. For example, of the 10 stars observed on one of the flights, only 1 star, one of the cooler ones, at about 12,000° F., appeared in the ultraviolet as one might expect it to from a knowledge of the Sun. The other stars showed great disagreement with current theory, and the hotter the star, the greater the disagreement.

Here is a plot against the wavelength in the ultraviolet radiation, and the ultraviolet intensity. The one curve shows the way the theorist said the star would look, and the other shows the way the star did look.

The theorists could fit fairly well with things where the astronomers could see from the ground, but when they got away from the regions supported by actual data, their theories went awry.

To explain the observations, the Goddard scientists have suggested that quasi-molecules such as helium hydride ($HeH++$ and $HeH+$), might be responsible for the observed output of ultraviolet radiation from the stars. Those who have been through an elementary course in chemistry will recall learning that helium under conditions met with on the Earth does not form compounds. It is most interesting to

be probing into conditions where the rules of the game admit many things that do not happen under the conditions existing on Earth.

These exciting results comprise only the beginning to the NASA astronomy program. They afford, however, a promise of even more exciting things to come when solar observatories and astronomical observatories to be described later are launched into orbit.

Mr. RANDALL. Mr. Chairman.

Mr. KARTH. Mr. Randall.

Mr. RANDALL. The last slide, I want to get to this before you get away from it completely. You referred to it as gamma ray astronomy. I want to be certain that I am right about this, this Orbiting Astronomical Observatory. It will use the gamma ray method, is that right?

Dr. NEWELL. This will use—the ordinary techniques of ordinary astronomy, plus ultraviolet techniques, plus X-rays, plus gamma rays.

Mr. RANDALL. You said "infrared" way back in your testimony. All of the methods will be used in this Orbiting Astronomical Observatory?

Dr. NEWELL. Right.

Mr. RANDALL. All right, thank you. (Fig. 366.)

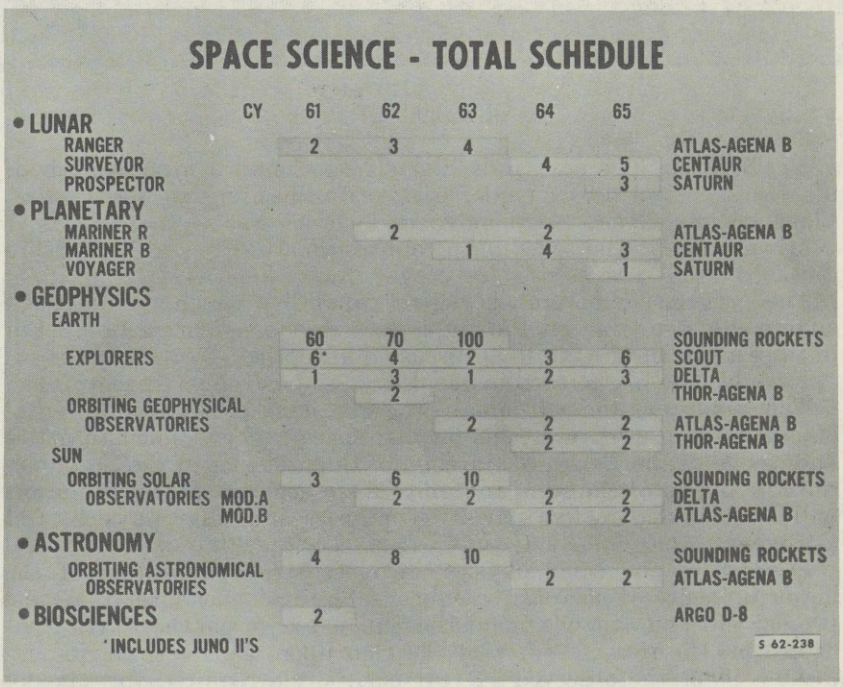

FIGURE 366

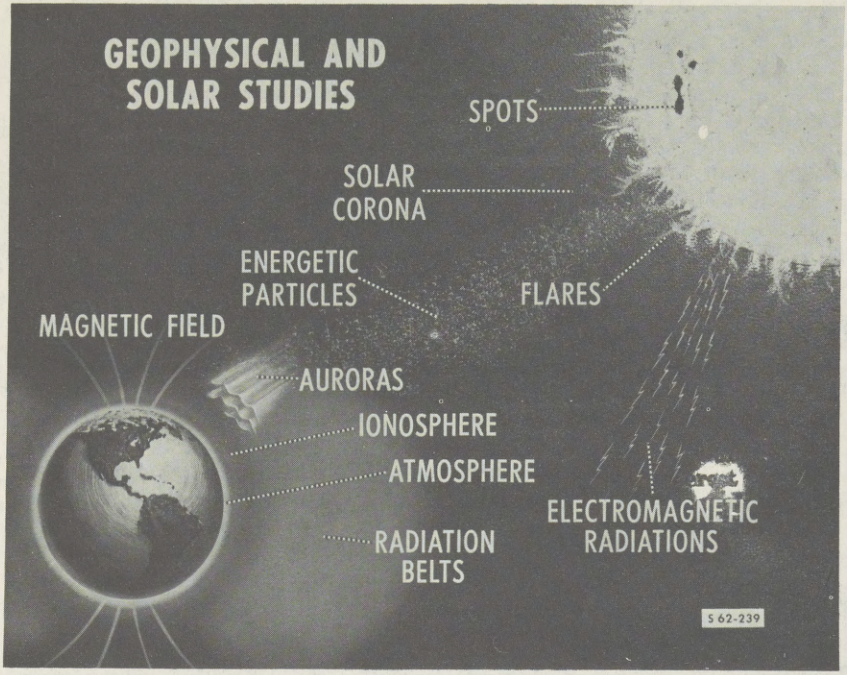

FIGURE 367

Dr. NEWELL. The next slide summarizes the total proposed schedule for space sciences. Under each major heading we have lunar, planetary, geophysics, astronomy, and biosciences.

Mr. KARTH. Is that schedule in your testimony?

Dr. NEWELL. Yes, it is.

The progression of launch vehicle capability which permits such advance is seen over on the right, and in subsequent sections each of these major headings will be discussed in detail.

I would now like to turn to geophysics and astronomy programs.

The geophysics and astronomy programs have as their fundamental objective the use of the technology of space flight to increase man's knowledge of the Earth, of the Sun, of the influence of the Sun upon the Earth, and of the stars and universe in general. These programs will be discussed in two parts: geophysics and solar physics; and astronomy. (Fig. 367.)

Geophysics and solar physics are closely related because of the major influence of solar activity on geophysical phenomena. At the present time, our knowledge of the Sun as seen from the Earth indicates that the relative effect of the Sun upon the Earth varies immensely over the observed 11-year solar cycle required for sunspot activity to go from a minimum to a maximum and back to a minimum. The next minimum is expected in 1964–65. One of our major long-range objectives is to make observations of the Sun, as seen from

outside the obscuring layer of the Earth's atmosphere, for at least a complete solar cycle.

A number of Sun-Earth related phenomena also vary over much shorter periods of time than the 11-year solar cycle. For instance, daily and annual variations in that electrically charged portion of the upper atmosphere known as the ionosphere, which has a predominate role in radio communication, are believed to be caused primarily by the Sun. Thus, another objective of the program is to measure and understand more about these shorter period effects.

Other phenomena such as solar flares do not occur with well-defined or predictable periods. These solar flares, which may be regarded as the hurricanes or typhoons of space flight, need to be studied in detail on an urgent basis so that the information can be used to assure that manned spacecraft, such as Apollo, will have a maximum chance for either avoiding the storms or of being designed to protect the astronauts from the effects of the storm.

As I indicated earlier, we are sure we will be able to provide the data to do one or the other. We may, however, not be able to lick the problem of predicting the storms.

Mr. DOWNING. Did you say storms in space—fire storms?

Dr. NEWELL. No, they are storms on the Sun which then eject clouds of energetic particles, that are a radiation hazard to the space flight crew.

When we talk about a storm in space, we are really talking about an electrical and magnetic storm rather than water-vapor type storm we have in our atmosphere.

Mr. DOWNING. Is there heat generation?

Dr. NEWELL. There is a heat generation, but because of the low densities involved that is not the real hazard. The real hazard is the extreme speeds of these charged particles.

Mr. RANDALL. Though you might be able to predict the storm by the end of this period, 1964–65, that is your target date for that, you will have the conclusion from that which again is ahead of our project for Apollo, that you will be able to learn by then, you hope to be able to learn by then, how to avoid these to the maximum or the optimum, or else learn enough about shielding; is that your statement?

Dr. NEWELL. That is correct.

Mr. RANDALL. Thank you.

Dr. NEWELL. The attainment of these objectives involves the combined efforts of many individuals in a number of scientific disciplines working together with those familiar with the advanced engineering and complex technology of space flight. Among the more important specialized scientific areas of study are:

Atmospheric physics and chemistry, the study of the composition, temperature, pressure, density, and chemical reactions of the upper atmosphere;

Ionospheric physics, the study of the electrical nature of the upper atmosphere;

Energetic particles and fields, the study of the nature and origin of cosmic rays, radiation belts, and magnetic and electric fields; and

Solar physics, the study of the nature of the Sun and its radiations. (Fig. 368.)

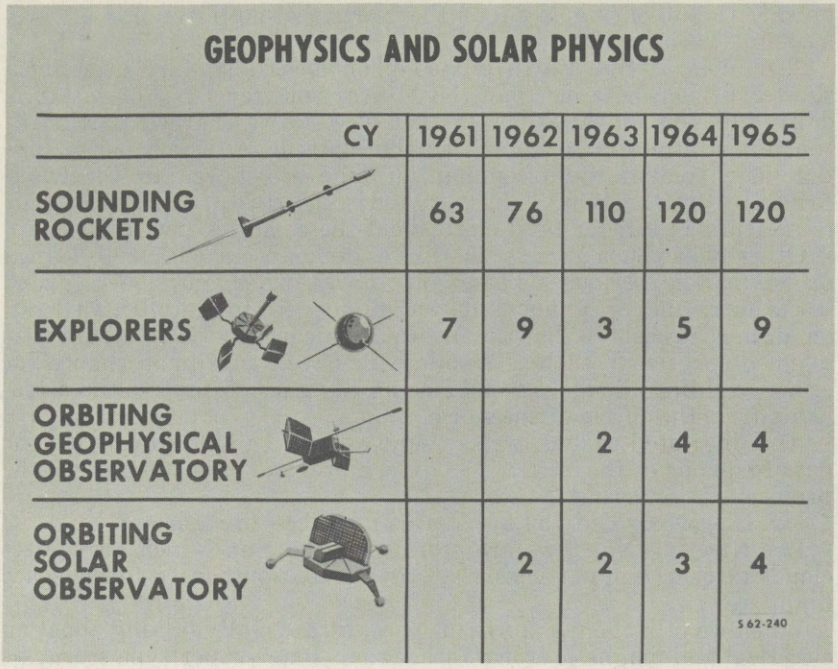

FIGURE 368

The magnitude of the program in geophysics and solar physics is indicated by the chart of planned number of launch attempts.

Mr. KARTH. Is that chart, Doctor, also attached to your testimony?

Dr. NEWELL. Yes, it is.

Mr. KARTH. Thank you.

Dr. NEWELL. The numbers shown through calendar year 1961 are actual launches, while those after 1961 are planned programs and extensions of these programs. The program shown involves sounding rockets, small satellites (Explorer type) and large observatory-type satellites. As is indicated by the number of launches prior to 1962, this is an "on-going" program firmly based on previous flight experience.

The sounding rocket program is a continuation of a program whose roots go back to the period after World War II, with the first V–2 rocket soundings of the upper atmosphere, and more recently to the vigorous U.S. and international sounding rocket program of IGY, the International Geophysical Year.

Mr. KARTH. Doctor, do these numbers indicate the exact number you expect to fire or send into space in that year, or are they just additions to the year before?

Dr. NEWELL. No, these are the actual numbers we hope to send into space.

Specific sounding rocket experiments are being conducted in all of the scientific disciplines mentioned previously—to measure the variation of atmospheric and ionospheric phenomena and solar flares by recoverable payloads, and to check out new experimental techniques and instrumentation for possible use in satellite or space probe programs. NASA sounding rocket experiments are conducted from a number of launching sites, but primarily from Wallops Island, Va., and Fort Churchill, Canada. The experiments are carried by a wide variety of available vehicles designed for special purposes, but the majority are carried by four vehicles which allow experiments, involving 50 to 200 pounds of instrumentation, to be conducted over an altitude range from less than 50 to more than 1,000 miles.

Mr. KARTH. What do you do in Australia, Doctor; what is the purpose there?

Dr. NEWELL. The purpose of firing there was to make observations of the southern skies for our rocket astronomy program, which observations you can't make in a sounding rocket launched from the Northern Hemisphere.

Mr. KARTH. What kind of an intensive program do you have scheduled?

Dr. NEWELL. That program was conducted last summer. There is no planned follow-on at the present time.

The next category of larger spacecraft includes the Explorer-type satellite and the Geoprobe. These relatively small, 100 to 500 pound, payloads are generally placed into satellite orbits by either Scout or Delta launch vehicles. However, on occasion, they are launched by the Scout vehicle in a ballistic trajectory to altitudes above 4,000 miles. This part of the program is a logical extension of the type of special purpose mission exemplified by the long line of Explorer satellites. From the launch sites at AMR, Wallops, and Pacific Missile Range, these satellites will be launched into a wide variety of orbits, as required by the special nature of some of the experiments.

The last category, which includes our largest spacecraft, has no previous history. The first of our Orbiting Solar Observatories (OSO) will be launched this year. Next year the first Orbiting Geophysical Observatory (OGO) is scheduled for launch. These observatories will be large complex spacecraft with the ability to point continuously at the Earth or the Sun, and to perform a large number of simultaneous experiments (20 or more) relative to solar and geophysical phenomena.

The first of the solar observatories will be launched by Delta vehicles, but later versions of this observatory as well as the geophysical observatories will require the larger capabilities of the Thor-Agena and Atlas-Agena launch vehicles. In order to meet the scientific objectives for obtaining a basic understanding of Sun-Earth relationships, several basic types of observatories should be in orbit at all times. The achievement of this goal is a major objective of the engineering research and development effort required in geophysics and solar physics as indicated by the fact that several launch attempts per year are anticipated for the period shown. Another important prerequisite for obtaining this objective is the achievement of a 1-year lifetime for the observatory.

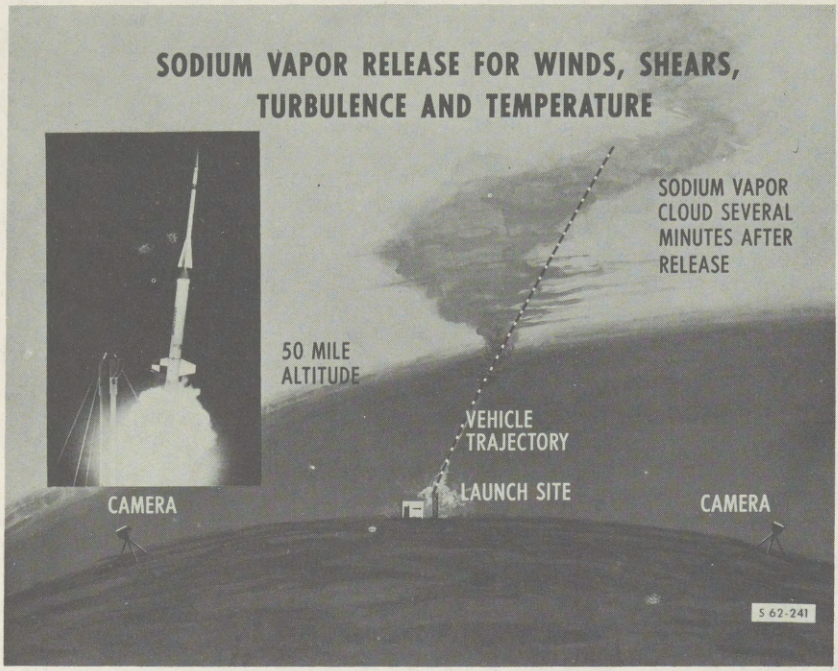

FIGURE 369

A review of some of the specific flight projects will further illustrate the status and results of these programs. (Fig. 369.)

The sodium vapor sounding rocket experiment shown here illustrates several aspects of the geophysics program. In these firings, sodium vapor is ejected from the container carried in the nose cone of the last stage of a sounding rocket vehicle. The firings are conducted at twilight, either in the morning or in the evening, so that the sodium vapor will be illuminated by the sun against the relatively dark sky. No telemetry is required in the sounding rocket. Ground-based cameras, which can photograph the sodium vapor cloud as it expands, allow the measurement of a number of upper atmosphere characteristics, including winds, density, and temperature. The simple nature of the equipment required for this experiment makes it particularly suitable for coordinated flights with other countries not equipped with elaborate launching sites. Beginning in 1959, a dozen successful flights have been conducted from Wallops Island in this program. A series of launches, in September 1961—actually, there has been one since then—was coordinated with similar flights by the Italians from their launch site on Sardinia. (Fig. 370.)

The satellite shown here is Explorer XII which was launched into orbit on August 15, 1961, and stopped transmitting on December 6,

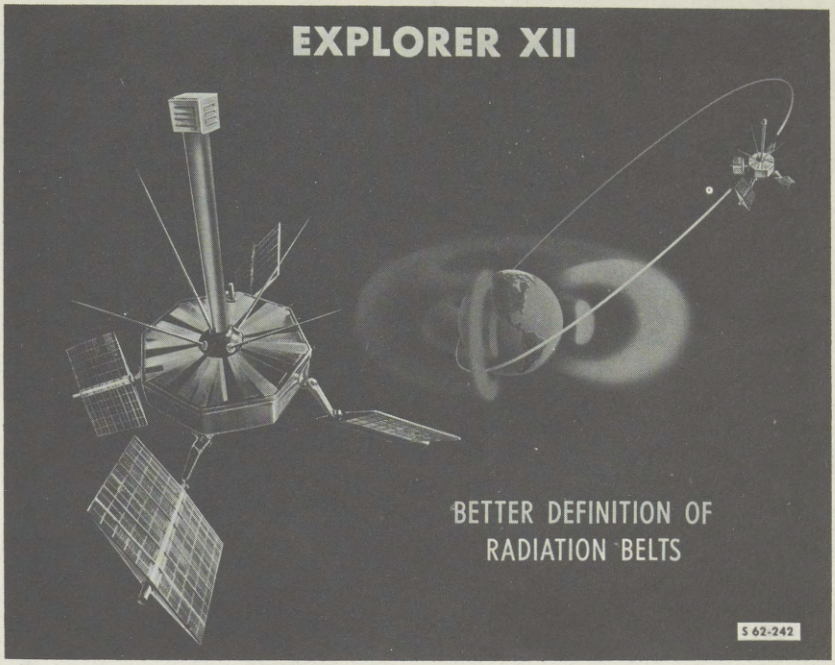

FIGURE 370

1961. This is one of the satellites considered earlier while discussing results in radiation studies. Another satellite essentially identical to Explorer XII is undergoing final tests and evaluation. Later this year an attempt will be made to launch it into an orbit similar to that of Explorer XII. Such an orbit is of especial importance for exploring geophysical phenomena, being highly eccentric and swinging over a large altitude range. (Fig. 371.)

Another orbit of particular interest for a number of experiments involving the measurement of the properties of the atmosphere and the ionosphere is the low-altitude 600-mile, polar orbit as illustrated here for the Canadian Topside Sounder satellite. This cooperative Canadian-United States satellite project, nicknamed Alouette, is one of several special-purpose satellites designed to measure the characteristics of the ionosphere. During the past year, two types of sounding rocket flights were made in support of this project. One successfully tested the antenna elements which unfold to a length of about 75 feet after the satellite is placed in orbit. The other demonstrated for the first time the use of the topside sounding experimental technique to obtain ionospheric data (the technique is derived from a similar one long used to study the ionosphere by use of ground-based radio transmitters and receivers). Alouette has passed its ini-

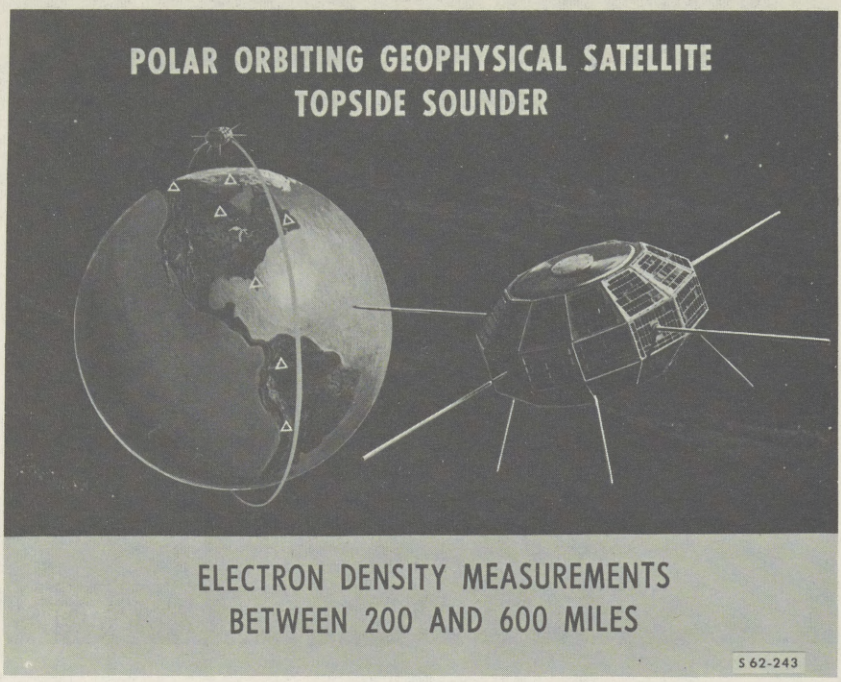

FIGURE 371

tial design tests and flight hardware is now being fabricated for a launch attempt this year, using a Thor-Agena vehicle from PMR. (Fig. 372.)

The first of the observatories designed to point instruments at the Sun for long periods of time is shown in the next figure. The first of these spacecraft, called Orbiting Solar Observatories (OSO), has been built by the Ball Bros. Research Laboratory in Boulder, Colo., and is now undergoing final tests and calibration.

As a matter of fact, time has passed us by. It will be launched shortly. The equipment is all ready.

One of the instruments that is being provided by the Goddard Space Flight Center (GSFC) is an X-ray spectrometer. It is known primarily from previous sounding rocket experiments that the Sun is a generator of X-rays. These X-rays cannot be seen from the ground because they are absorbed by the atmosphere. However, knowledge of the intensity and hardness of X-ray radiation is important to understanding the exact nature of the physical processes which take place in the Sun. The X-ray spectrometer shown here will be able to give us such a detailed picture of this radiation. Last year this instrument was tested on an Aerobee sounding rocket. This sounding rocket flight verified the design of the instrument and ob-

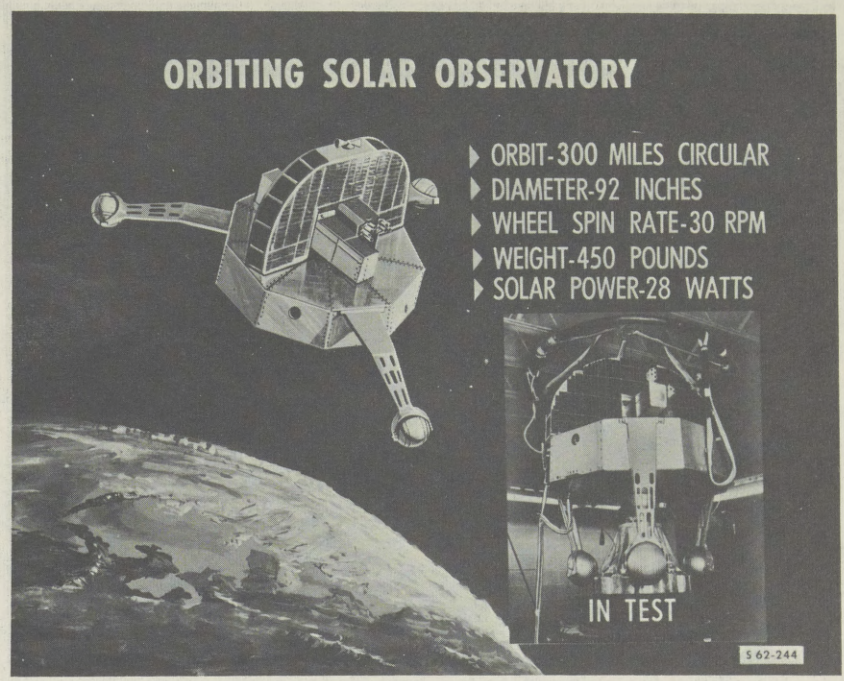

FIGURE 372

tained some of the most detailed information yet obtained on solar X-radiation. The longer times of observation available from the satellite, hopefully months instead of a few minutes, are necessary to study the variation of solar X-radiation over long periods of time and during solar storms. (Fig. 373.)

For a little over a year now, the Space Technology Laboratories (STL), under the technical guidance of Goddard Space Flight Center, have been working on the design and development of an Oribiting Geophysical Observatory (OGO). This is part of a program to develop and operate a standard spacecraft capable of orienting experiments in a desired direction relative to the Earth and the Sun simultaneously, and to carry out a large number of easily integrated scientific experiments in a wide variety of orbits. The first observatory will be placed in an eccentric orbit with perigee about 160 miles and apogee about 70,000 miles.

For this reason it is referred to as EGO for Eccentric (Orbiting) Geophysical Observatory. The experiments (a total of 20) and experimenters (from universities, NASA, DOD, and other Government agencies) were selected for EGO in November of last year and work is proceeding on the development of flight-qualified hardware. It is expected that the construction, test, and calibration of the EGO

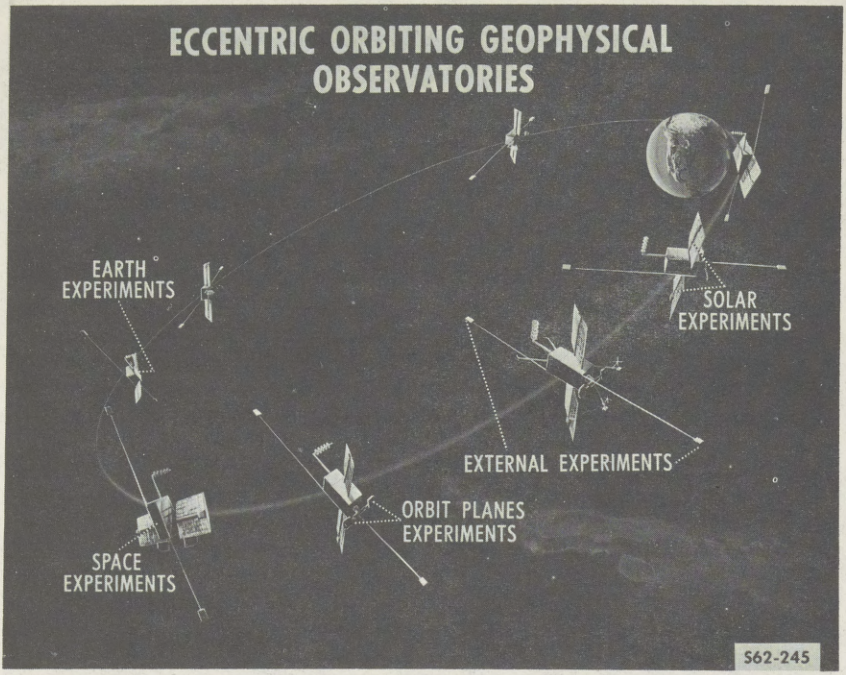

FIGURE 373

spacecraft and experiments will be completed in about a year, so that the first launching of EGO will take place in 1963. The experiments selected for EGO emphasize the study of Sun-Earth relationships. EGO will allow us for the first time to make continuous simultaneous observations of both solar and geophysical phenomena. (Fig. 374.)

Astronomy, the oldest of the sciences, sometimes called the Mother of Science has the broadest objectives of all, to understand the origin, present state, and evolution of the universe by observation of the stars, nebulae, and other celestial bodies. The NASA astronomy program is directed toward the utilization of space technology to make these observations of the stars and other celestial bodies from above the obscuring and distorting influence of the Earth's atmosphere.

A major scientific objective of the present program is to make observations and to develop the necessary instrumentation and techniques for use in the ultraviolet portion of the light coming from the stars. Since the ultraviolet portion of a star's light is not visible from ground-based observatories and because the techniques involved are in themselves on the forefront of science and technology, this program is one in which nearly any measurement is more likely to reveal the unexpected than the expected. (Fig. 375.)

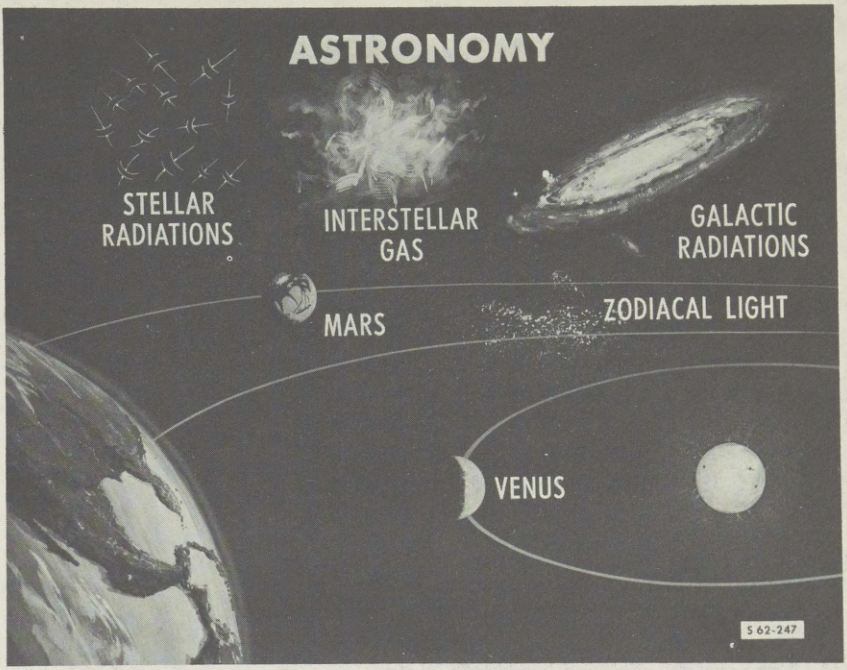

FIGURE 374

The magnitude of the program in terms of planned number of launch of experiments in astronomy is shown on this chart. These numbers do not reflect the true magnitude of the program. For one thing, the study of the Sun as a star is also a very important part of the space astronomy program. However, solar physics was discussed previously with geophysics. At the present time, the astronomy flight program is predominantly a sounding rocket program. The Aerobee sounding rocket has been a particularly useful vehicle for carrying out exploratory measurements because it has low acceleration as compared to many other vehicles which allows it to carry safely the relatively delicate instrumentation required in this program. It is expected that this vehicle with later improvements, such as a stabilized pointing control, will be used to develop instrumentation and to carry out significant experiments in the area of ultraviolet observations of the stars for at least the next few years.

During 1961, in the next slide, several sounding rocket experiments carried out in this program were of particular significance. Four skylark (A British sounding rocket vehicle developed during the IGY) vehicles were launched from Woomera, Australia, with instrumentation designed to explore in ultraviolet light the sky as seen from the Southern Hemisphere. Prior to these flights, the small amount of data available covered only that portion of the sky seen from the Northern Hemisphere.

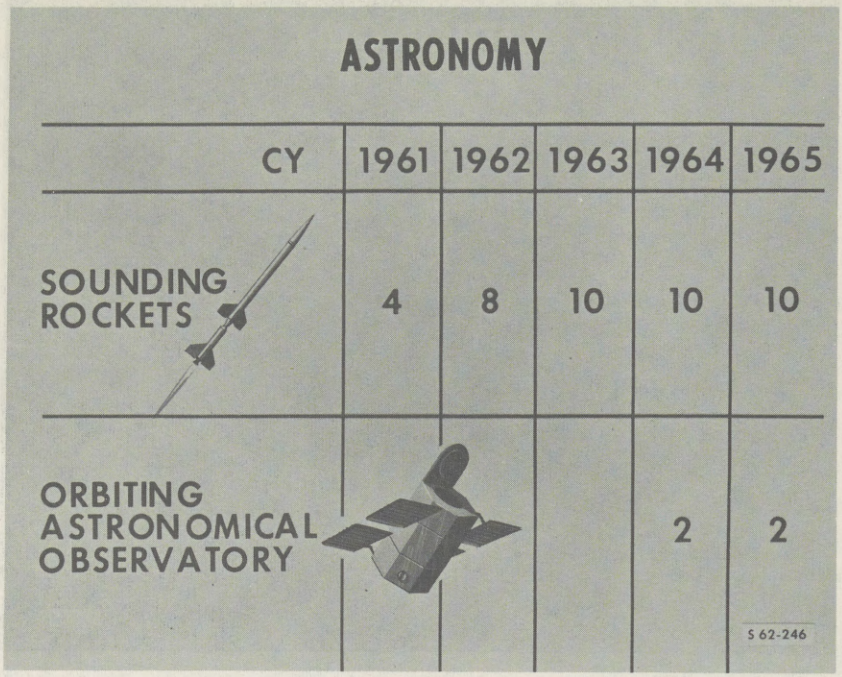

FIGURE 375

We mentioned these earlier. These four flights provided a total of about 15 minutes of observation, and just about double our knowledge of the ultraviolet sky. (Fig. 376.)

Explorer XI, which was discussed in detail earlier, was the first satellite experiment in astronomy. This is a duplicate of the spacecraft. But the major emphasis in the astronomy program is on the Orbiting Astronomical Observatory (OAO).

Mr. KARTH. Doctor, I hesitate to interrupt you, but we do not have permission to sit while the House is in session. This is permission one must get from the House itself. Generally, we don't do it unless it is vitally important that the committee sit during the session. We have not sought to get this permission, and as a result we don't have it, so we are going to have to adjourn the meeting at this point. The meeting tomorrow will begin at 10 o'clock, and will be held in room 214–B, which is the regular committee hearing room in the New House Office Building. So if we could proceed from this point tomorrow morning at 10 o'clock, Doctor, we will be very appreciative. We hope we don't inconvenience you too much.

Dr. NEWELL. Not at all.

Mr. KARTH. We are just running out of time.

Mr. RANDALL. May we inquire what page in the manuscript you got down to? I got down to 30.

Mr. BERESFORD. Page 32.

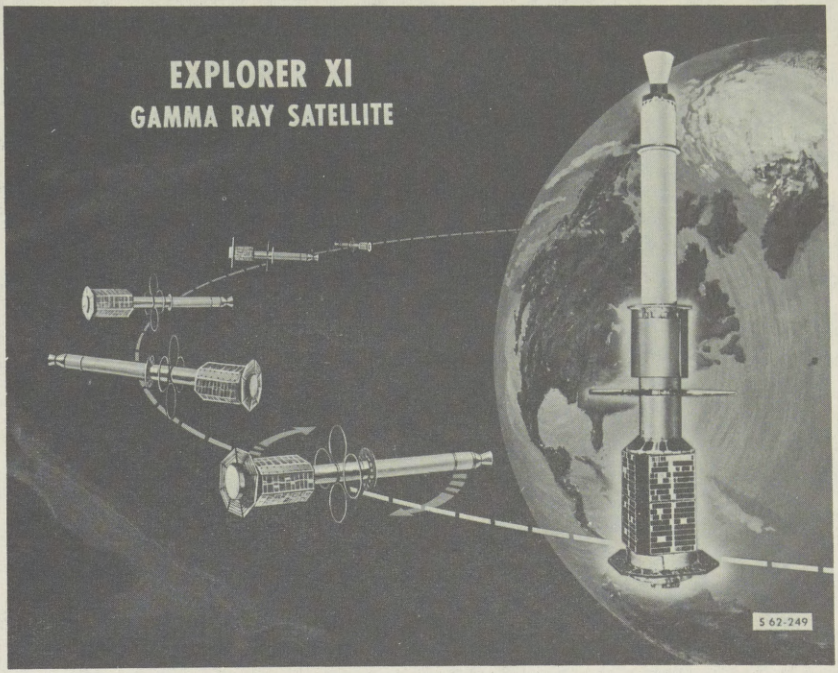

FIGURE 376

Mr. KARTH. The top of the page.

I might say these 32 pages are about as much as the subcommittee can probably digest at one time.

This is a very interesting and fascinating subject.

Thank you very much, Doctor, we will see you tomorrow morning. The meeting is adjourned.

(Whereupon, at 12:10 p.m., the subcommittee was adjourned to reconvene at 10 a.m., Wednesday, March 7, 1962.)

1963 NASA AUTHORIZATION

WEDNESDAY, MARCH 7, 1962

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON SPACE SCIENCES,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10 a.m., in room 214–B, New House Office Building, Hon. Joseph E. Karth, chairman of the subcommittee, presiding.

Mr. KARTH. The subcommittee will be in order.

Dr. Newell, if you would like to proceed with this highly educational report, you just fire at will.

STATEMENT OF DR. HOMER E. NEWELL, DIRECTOR, OFFICE OF SPACE SCIENCES, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ASSISTED BY MR. EDGAR CORTRIGHT, DEPUTY DIRECTOR, OFFICE OF SPACE SCIENCES; MR. ORAN NICKS, DIRECTOR, LUNAR AND PLANETARY PROGRAMS, OFFICE OF SPACE SCIENCES; MR. JOHN NICOLAIDES, DIRECTOR, PROGRAM REVIEW AND RESOURCES MANAGEMENT, OFFICE OF SPACE SCIENCES; MR. ELDON TAYLOR, RESOURCES MANAGEMENT OFFICER, OFFICE OF SPACE SCIENCES

Dr. NEWELL. Thank you, Mr. Chairman.

As I recall, yesterday we had come to the point in the text that concerns the orbiting astronomical observatory.

If I may have the slide for this. (Fig. 377.)

For more than a year, the Grumman Aircraft Engineering Corp., Bethpage, N.Y., under the technical direction of GSFC, has been working on the design and development of the OAO.

The basic design was firmly established during 1961 and is shown in the chart. This will be the largest of the scientific satellite observatories. As shown in this photograph of the engineering prototype, it is about 10 feet in length and will weigh about a ton and a half.

Experiments for the first observatories are being developed by astronomers from the Smithsonian Astrophysical Observatory (SAO), the University of Wisconsin, GSFC, and Princeton University; and contracts for the detailed design and construction of the first three of these experiments were let during 1961 with Electro-Mechanical Research Corp. (EMR), Cook Electric Co., and the Kollsman Instrument Co.

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FIGURE 377

The experiments for this program have been designed with an effort to anticipate the long range needs of astronomy, but keeping in mind the basic discovery nature of the program.

Mr. KARTH. Dr. Newell, what vehicle is to launch the OAO?

Dr. NEWELL. This system is to be launched by the Atlas-Agena vehicle.

The first observatory is being equipped to carry both the Smithsonian and Wisconsin experiments, one in each end of the spacecraft. The major objectives of both of these experiments are aimed at survey type observations.

The Smithsonian experiment is designed to make a map of the sky as it looks in ultraviolet light; that is, to map the brightest stars in ultraviolet light. An Aerobee sounding rocket is expected to flight test this experiment very shortly.

The Wisconsin experiment is designed to give more details about ultraviolet stars; that is, something about the amount and distribution of ultraviolet light in selected stars.

The GSFC experiment will be designed to obtain more detailed data on selected stars by means of a large telescope with a 36-inch primary mirror, and a spectrometer which can select very narrow portions of the ultraviolet light for detailed study.

The Princeton experiment will be designed for even more detailed ultraviolet studies involving observations to determine some of the characteristics of the gas between stars.

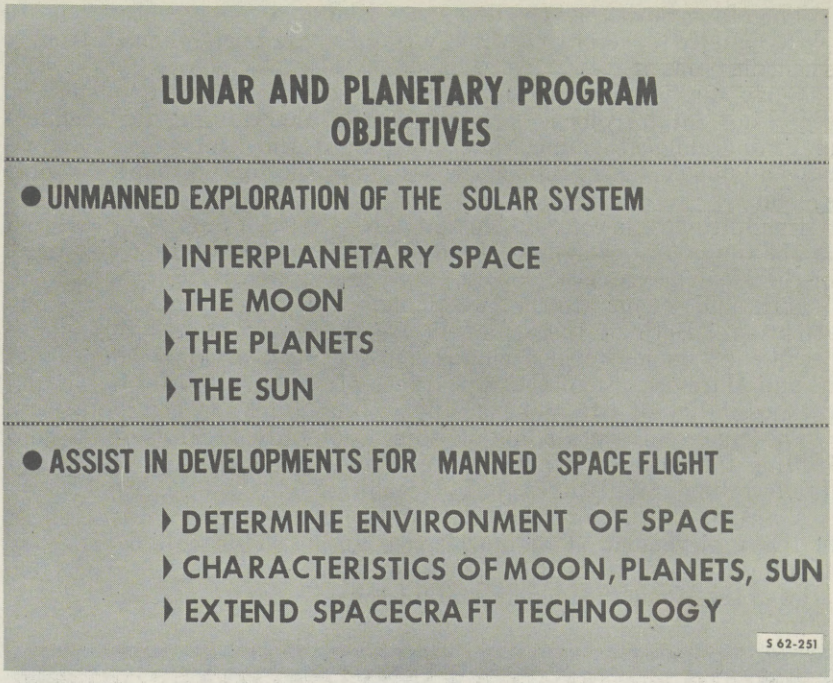

FIGURE 378

The specifications for the OAO were set on the basis of the requirements of all of the experiments which could be reasonably foreseen.

A fundamental objective of the program is to develop a basic spacecraft which will have the precise pointing capability, power data handling equipment, and other requirements necessary to carry a wide variety of future astronomical experiments.

The ultimate guiding accuracy of the OAO is expected to approach .1 second of arc. This is about equivalent to the accuracy required to use a telescope located in Baltimore to pick out either the right or left eye of an individual in Washington for detailed study as to its color and brightness.

This requirement alone will call for a major engineering effort over the next few years.

The previous history of astronomy assures us that this effort will be rewarded by a significant increase in our knowledge of the universe. (Fig. 378.)

In the lunar and planetary program the major objective is unmanned exploration of the solar system. Interplanetary space, through which any trip away from the Earth must be made, constitutes an environment about which much is yet to be learned, and which must be better understood before man can safely venture into space.

Every planetary vehicle is instrumented to obtain data throughout the interplanetary trip. Indeed, for some flights, the primary objective is to obtain data on the interplanetary medium.

The Moon represents the first space island to which we can venture with manned spacecraft. It is an object of much interest from a scientific point of view.

Early flights will provide a detailed survey of the lunar surface, searching for its physical characteristics, determining its chemical and mineralogical composition, and its physical properties. Knowledge of this type may unlock the secrets of the formation of the solar system.

In addition, it is conceivable that early life forms may lie preserved in the lunar dust which has been collected over the billions of years of the Moon's existence.

Mars and Venus are the two planets which will receive our early attention. Both of these planets are extremely interesting; Venus because of its mysterious clouds and our lack of knowledge about it, and Mars because of the appearance of certain qualities indicating the possibility of life and perhaps a climate not too hostile to man.

The Sun represents a major object of study because of its controlling influence on life as we know it. It is a dynamic body and its effects on our daily lives are far reaching.

A second objective of the lunar and planetary program is to assist in the achievement of manned space flight. This will be done by defining the environment of space, and by determining the characteristics of the Moon, the planets, and the Sun.

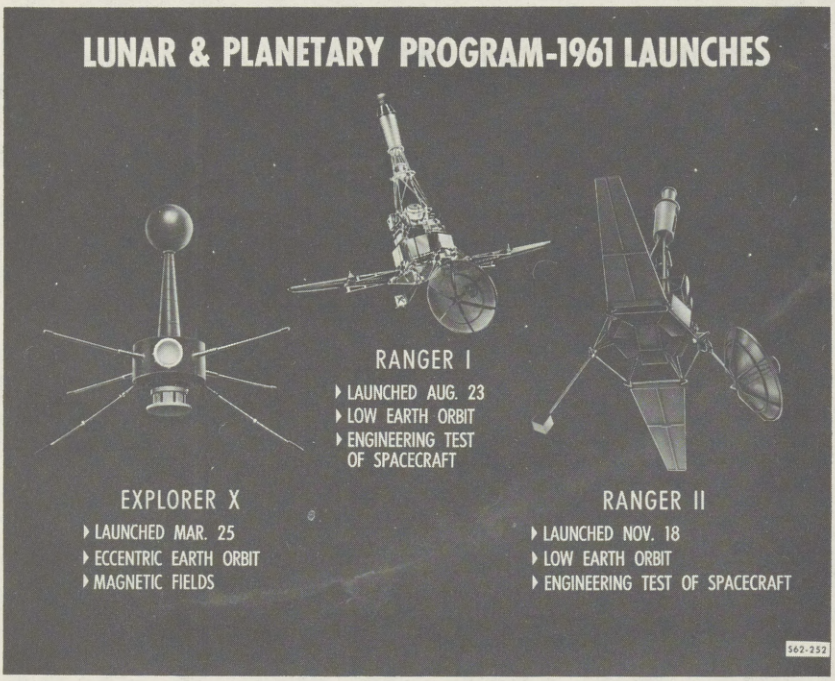

FIGURE 379

In addition, the experience of developing spacecraft and other technology for unmanned exploration of space, will contribute to the development of safe manned flight into space. (Fig. 379.)

In 1961 there were three launches for lunar and planetary missions. The first, in March 1961, was Explorer X, which was to measure interplanetary phenomena. This flight, discussed earlier, was a success and yielded data about the geomagnetic field and low energy plasma fluxes.

The Ranger I and II launches were intended to test the spacecraft which will eventually be used in the lunar landing missions, and to obtain interplanetary data at the same time.

Both of these flights achieved a significant measure of success in demonstrating proper operation of the spacecraft. The launch vehicle, however, did not project the spacecraft into interplanetary space where the desired scientific measurements would have been made. (Fig. 380.)

In 1962 the Ranger spacecraft will attempt to make lunar rough landings with a capsule designed to survive the landing and return data to Earth for a period of approximately 1 month. TV pictures and lunar radiations will be obtained on approach to the Moon.

In 1964 the Surveyor spacecraft will make the first soft lunar landing attempt. This spacecraft has a refined control system which will



FIGURE 380

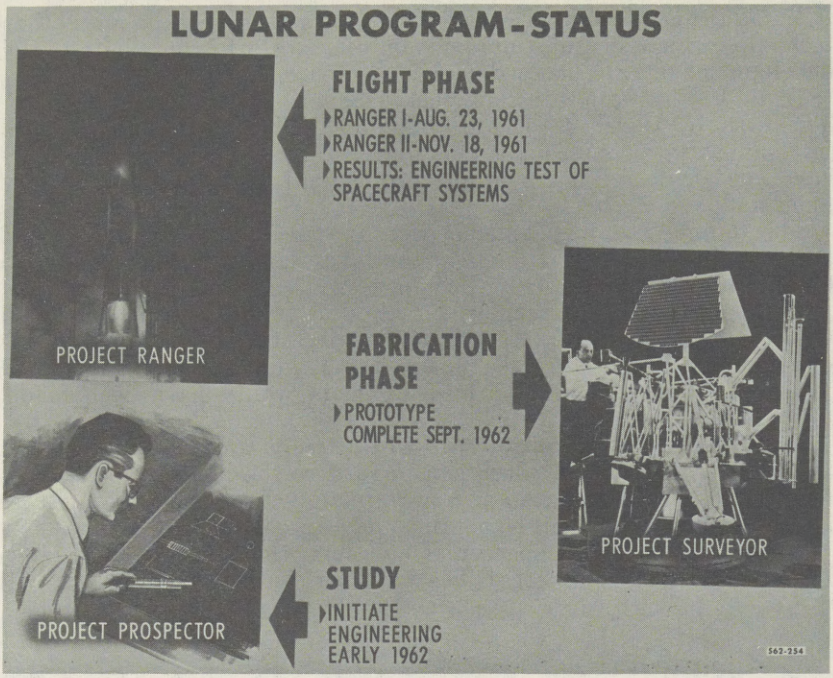

FIGURE 381

allow soft touchdown, and has four television cameras which can take pictures before and after landing. Surface measurements will be made directly on the lunar surface.

I might pause here to point out the Ranger model is over here [indicating], and the Surveyor model is here at the end of the table.

Also in 1964, it is planned that the first Surveyor lunar orbiter will be launched. This spacecraft is to provide the first reconnaissance and mapping of the Moon, and in addition will provide an anchored monitoring station at the Moon's orbit for measuring radiations and other data pertaining to the lunar environment.

In 1966, it is hoped that the Surveyor mission capability can be extended by use of the Prospector, with capability to land anywhere and to employ a roving surface vehicle, for site surveys. It may also carry an Earth return system with a small rocket to bring back a lunar sample, and multiple scientific payloads. (Fig. 381.)

The lunar program is an ongoing program in three phases. The Ranger project is in its flight phase with two launches having been made, and with seven remaining to be made in 1962 and 1963.

Actually, time has passed us by here. We have had one additional.

The Surveyor project is in the fabrication phase, and is expected to be ready for a launching in late 1963.

The Prospector phase has been under study for some time, and it is expected that engineering will be initiated early in 1962. (Fig. 382.)

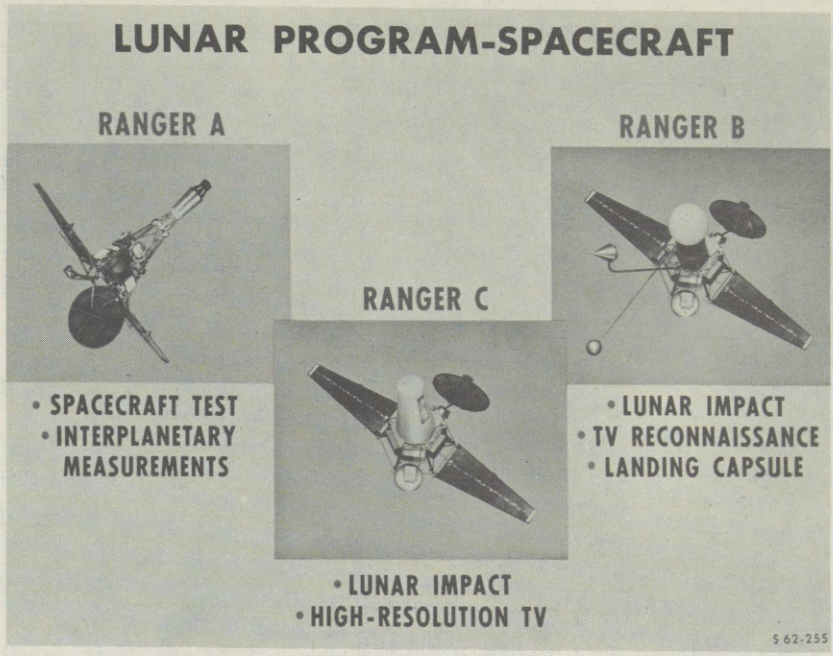

FIGURE 382

This chart shows photographs of the three Ranger configurations being employed in the Ranger project. The Ranger "A" is the test spacecraft with interplanetary measurements, two of which were built and fired in 1961 as previously mentioned.

The Ranger, launched by the Atlas-Agena B, carried eight scientific experiments and one engineering experiment, and was a complex system from a scientific and data handling standpoint.

The Ranger "B" is designed to land a capsule on the lunar surface, to take photographs on the approach and to measure gamma-ray radiations in the vicinity of the Moon.

The last four Rangers are designed to take high resolution photographs as the spacecraft approaches the Moon. Six cameras will be employed to obtain pictures of localized regions hundreds of times better than those obtainable from Earth. (Fig. 383.)

The Surveyor "A", to be launched by Atlas-Centaur, is designed to accomplish a lunar soft landing and to make extensive measurements of the lunar surface and subsurface. This spacecraft will carry about 200 to 300 pounds of scientific instruments and includes four television cameras and a drill for subsurface sampling.

The Surveyor "B" is an orbiting spacecraft, an adaptation of the Surveyor "A," which will be put into near polar orbit around the Moon, and which will take television photos of varying resolutions of all portions of the Moon. Radiation measurements and other

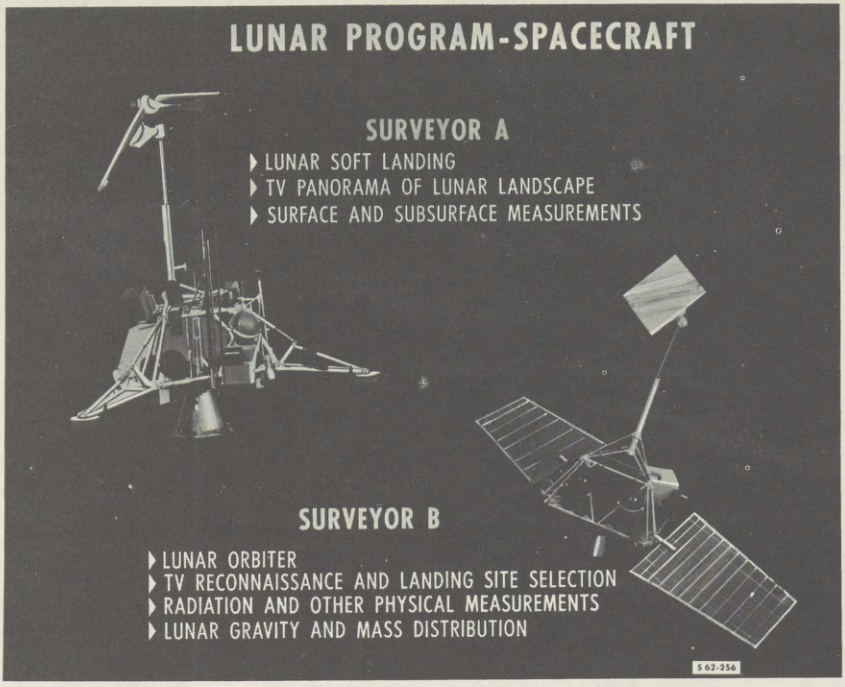

FIGURE 383

physical measurements will be made at the same time by this spacecraft. It is intended that it have a lifetime of at least 6 months.

Mr. KARTH. When was Surveyor "A" and Surveyor "B" originally scheduled for flights?

Mr. CORTRIGHT. Surveyor "A" was originally scheduled for the summer of 1963.

Mr. KARTH. When is it scheduled for now?

Mr. CORTRIGHT. There may be a test flight possible still in 1963, but the first complete mission is scheduled for early in 1964.

Mr. KARTH. How about Surveyor "B"?

Mr. CORTRIGHT. Surveyor "B" is scheduled to be ready to fly in the second quarter of 1964.

We have some flexibility as to whether we fly "A" or "B" on various missions in 1964.

Mr. KARTH. What constitutes the flexibility?

Mr. CORTRIGHT. Well, we can, for example, if we have an early success with the landing, decide with a few months advance notice to launch the orbiter and try to get some photographic data.

The spacecraft are on schedule and will be ready.

Mr. HAMMILL. Following the Chairman's question, why have these schedules been revised?

Mr. CORTRIGHT. They have been revised because of revision in the Centaur launch vehicle schedule.

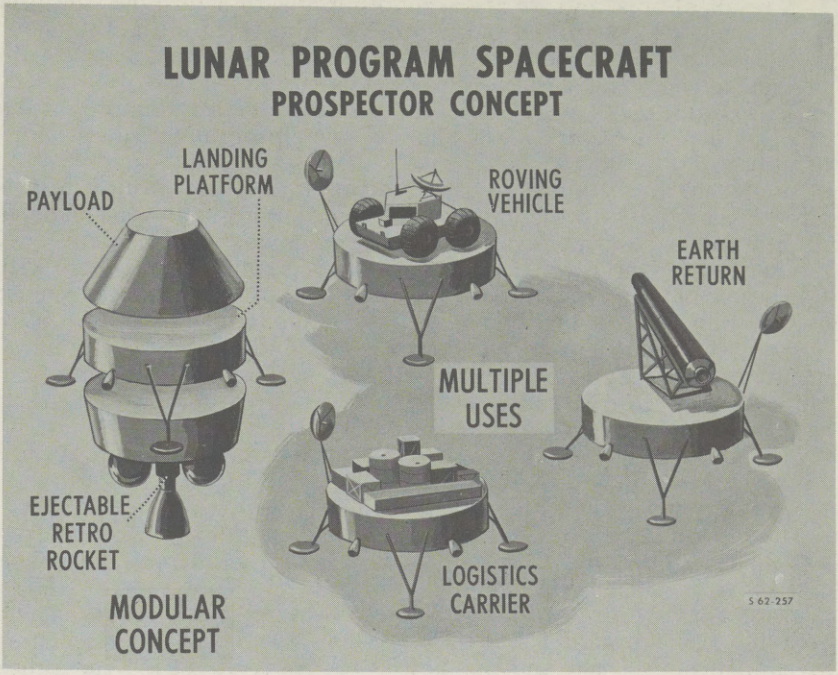

FIGURE 384

Mr. HAMMILL. We will get into a detailed discussion of that a little bit later.

Mr. CORTRIGHT. Yes.

Dr. NEWELL. Yes. (Fig. 384.)

The concept of the Prospector which would use the Saturn launch vehicle is shown. A landing platform, an ejectable retrorocket, plus the payload would comprise major modules.

The landing platform should be designed to accommodate various payloads as indicated, and would not share systems with the payload but rather would be self-sufficient such that continual use and development will provide reliability and flexibility.

Mr. KARTH. What is the weight of the Prospector, Doctor?

Mr. CORTRIGHT. The Prospector launch vehicle is not yet firmly established. The Prospector could be built in sizes anywhere from two or three times the weight of the present Surveyor, which would place it in the 5,000- to 10,000-pound category, or could be built in a very large size to fly on a large Saturn. If you built a Prospector for the C–5 size, it could total as much as 80,000 pounds.

Mr. KARTH. What size do you intend to build?

Mr. CORTRIGHT. We have not determined that, sir. This is currently under intensive study.

As you will recall, the Saturn went through an evolutionary period where it was increased in size to be properly suited to the manned lunar landing. Our plans on the Prospector are being reevaluated

as a result of this, and we are attempting now to determine what the best launch vehicle will be and in what weight to build this vehicle.

There is money in the Blue Book which is in front of you, the 1963 budget, to begin the engineering phase on the Prospector program.

Mr. HAMMILL. Is it possible the Prospector program might be scrapped as unnecessary if the manned lunar program advances more quickly?

Dr. NEWELL. I think the answer to this is that in a project of the Prospector type, both the unmanned science program and the manned program have to work together to determine what will be done.

There will be need for the unmanned-type exploration. There will also be need for logistic support of the manned program. Between us, one way or another, we will have to provide for these needs. It is not yet determined as to whether we will build a Prospector as a growth version say of Surveyor, or whether the manned people will build a Prospector as a logistic support to their program. In either case we will both make use of it.

Mr. KARTH. Whoever builds it, Doctor, what is the target date for Prospector?

Dr. NEWELL. I don't know.

Mr. CORTRIGHT. I think the manned space flight office has not yet established a target date for logistic supply on the lunar surface over and above their basic mission of landing the three-man team. They probably are the group to describe what their logistic requirements are. We went through a study phase where we tried to combine logistic supply and science, and this is why we are reevaluating the Prospector right now.

Mr. KARTH. Didn't NASA last year give us a timetable on Prospector?

Mr. CORTRIGHT. Yes, we did.

Mr. KARTH. What was it last year?

Dr. NEWELL. For the science program we have a target date around 1966. When you introduce the logistics for the manned flight program, this whole thing has to be reviewed in the light of that additional need.

Mr. KARTH. This need was there when we talked about this subject last year, Doctor.

Mr. CORTRIGHT. Yes. You see the problem, Mr. Karth, is a technical one as to sizing. We now have very large Saturns being built for the manned program. The Prospector becomes a large, expensive program, if it is designed to fly on the large Saturn, the C–5. If the Apollo system has a remote landing capability as part of a manned program, it can accomplish its own logistic supply for the man on the moon, and the justification for a completely separate program disappears.

On the other hand, the Surveyor that we now have is not capable of landing everywhere on the moon. It is restricted, as you will see in another slide or two, to the left hand portion of the moon as we look at it.

It is also smaller and less versatile than we require for an ultimate scientific vehicle to explore the moon. Therefore we are looking very hard right now for the optimum approach to get an automated spacecraft larger than the Surveyor, but a growth version of it, onto the

lunar surface in the 1966 time period so we can do some useful work with it prior to manned landing.

Mr. KARTH. I appreciate the reason, Doctor, that you are probably not as definite for the timetable of this program as you were last year, but it seems to me the committee would be very interested in finding out why this timetable that was presented to the committee last year is no longer necessarily a true timetable, or the anticipated target.

I think you answered it in your last statement where you said that if we can accomplish some of these things in the manned flight program, we may also answer some of the questions as a result of expediting that particular portion of the space program.

Mr. CORTRIGHT. Yes, sir.

Mr. KARTH. If that should occur, then what about all the money that might have gone into Prospector, for example?

Mr. CORTRIGHT. We haven't spent much money on Prospector yet.

Mr. KARTH. How much are you asking for this year?

Mr. CORTRIGHT. $10 million.

Mr. KARTH. You see you are talking about 1966, or maybe 1967; before you finally make that decision it may well mean we have spent $100 million or more on the project, is that correct?

Mr. CORTRIGHT. If the Prospector project were to be prosecuted as originally conceived, namely as a new spacecraft development to ride on the Saturn, it would cost $200 or $300 million to develop and fly a series of test birds before you had it working.

Mr. KARTH. My question is: At what point are we going to ascertain or determine that we are not going to spend any more money on Prospector or that we are going to go ahead with the program?

Mr. CORTRIGHT. Well, I can't speak for the manned space flight group on their logistic supply problem, but speaking for the Office of Space Sciences, we hope to determine within the next 3 or 4 months whether we are going to a growth Surveyor-type spacecraft at a relatively modest cost, or whether we are going to stick with the Surveyor exactly as it is until the manned program has their huge vehicles developed.

Mr. KARTH. I think that answers the question.

Mr. CORTRIGHT. We have a definite scientific desire, plus a desire that is motivated by support of the manned program, to upgrade our capability beyond what we can do with Atlas-Centaur, although Surveyor is very good on Atlas-Centaur. There are things we ought to do that simply require a larger spacecraft. We might call it Prospector or any other name, but that is the technical requirement.

Mr. KARTH. What portion of the total Prospector program was designed to get information that would help in the manned lunar landing flight?

Mr. CORTRIGHT. Well, any Prospectors that land near the lunar equator, or any Surveyors that land near the lunar equator, obtain information on the terrain that is directly applicable.

Mr. KARTH. Is it primarily designed to get this kind of information for manned space flights, or was it primarily planned to get scientific information, a large portion of which would not be attributable to manned flight?

Mr. CORTRIGHT. That is a good question. I think the only answer is that it has been conceived as a dual-purpose vehicle, no one has ever

tried to weigh it quite the way you have suggested, that is, is it mostly useful for the manned program or mostly useful for science? It is important conceptually to both.

Mr. KARTH. Thank you, Doctor.

Mr. RANDALL. Mr. Chairman, I think we are on a path of inquiry that should be pursued. I would like to know the advantages, just what are we talking about. We are talking about $10 million. You are asking for $10 million this year; is that correct?

Dr. NEWELL. Yes.

Mr. RANDALL. Apparently the decision hasn't been made here yet; is that right?

Dr. NEWELL. That is correct. The $10 million that is listed in the Blue Book is for the initial phases of the Prospector program.

As Mr. Cortright mentioned, in the Office of Space Sciences we are going to have to make up our minds in the next quarter or third of a year, as to our needs in the space science program.

Mr. RANDALL. It is said that the Congress proposes and the Executive disposes, but of course there is a question whether we should provide this or not. Maybe you will make up your mind before we get around to it here. That is the question I am raising, Mr. Chairman.

I would also like to know—I have learned there is a difference in size—but what are the advantages, either for science or for manned logistics between the Prospector and the Surveyor? Just briefly. It is a question of size, of course, and what else?

Dr. NEWELL. To answer directly, the first part of your question, these moneys are needed whichever way we go, whether it is initial work on the uprating of the Surveyor, or whether we are eventually going to jump to the use of the very large type of logistic vehicle that the manned program may need.

In the case of the second part of your question, the Prospector-type vehicle would have in addition to the uprating in weight capability, the ability to move about over the surface, to carry out a greater number of functions than the Surveyor. To collect a sample, perhaps, and return it to Earth. To do a number of things that the Surveyor, with its design and weight limitations, cannot do.

Mr. RANDALL. I am not quite clear yet. I would like to come back to it later on, Mr. Chairman. Thank you.

Mr. KARTH. Doctor, do we expect to find that the surface of the Moon facing the Sun is pretty much the same as the surface of the Moon facing away from the Sun?

Dr. NEWELL. I think there may be a misconception in the way in which you phrased the question. The Moon does not always have only one side facing the Sun. If you think of the Moon as my fist here, and this is the Earth's axis [illustrating with the other fist] the Moon in going around the Earth keeps one face toward the Earth, but as it changes the direction in which that face is pointing, it presents a different aspect to the Sun.

Mr. KARTH. How often does this aspect change?

Dr. NEWELL. Once a month—a lunar month. So you see when——

Mr. KARTH. Then we could just recast my question, I guess; probably I should ask it this way: Do we not expect that the surface of the Moon is pretty much similar in all areas?

Dr. NEWELL. There is one question that was raised by the Soviet photographs, and that is whether or not on the other side of the

Moon there may be a mountain range of the type that we see on the Earth. On the face that always looks at us we have seen no such mountain ranges; that is, those that are created by the folding and wrinkling of the body.

The Soviet photographs indicate that there might be such a mountain range on the other side, but except for that, the two sides apparently look quite alike.

Mr. BASS. Mr. Chairman.

Mr. KARTH. Mr. Bass.

Mr. BASS. I gather from what you say, then, Doctor, that the Soviet photographs of the other side of the Moon adds sufficient resolution to convince you they were bona fide, and that they do bring new knowledge, concrete knowledge, of what is on the other side of the Moon; is that correct?

Dr. NEWELL. The Soviet photographs appear to be valid, good photographs. The scientists who have worked with us as consultants to NASA and in our program, began by being doubtful, but many of them have wound up by being convinced that they are legitimate photographs.

Their resolution, however, leaves enough doubt as to what you are looking at, in the case of the mountain I mentioned, for example, that one needs better photographs before you are sure of what you are seeing.

Mr. BASS. So that there is some difference of opinion now in the scientific community as to whether these photographs perhaps are bona fide or not?

Dr. NEWELL. No. The opinion in the scientific community is that they are bona fide, but the opinion also is that we need additional photographs of better resolution.

Mr. BASS. Thank you, Doctor.

Mr. CORTRIGHT. Mr. Chairman.

Mr. KARTH. Yes, sir.

Mr. CORTRIGHT. In your last question, were you driving at the point of whether or not the lunar surface on the face we are looking at is uniform, or simply whether or not the front and the back are similar?

Mr. KARTH. Well, I am not so sure that my question would indicate the uniformity of it. My question primarily was to ascertain whether or not we had any knowledge as to the composition and the makeup of the moon, and let me phrase it this way, Dr. Newell: The same on the side that always faces the Earth, as well as it being pretty much the same on the side that does not face the Earth? The reason I ask the question is that if we are pretty much of the opinion that this is true, certainly we should have some knowledge of it at this point, and perhaps it would not be wise to spend $200 or $300 million, you see, to merely substantiate what we already know.

Dr. NEWELL. Yes.

Mr. KARTH. Perhaps the Prospector program would not be necessary. The space effort is a large one anyway, and there are going to be many hundreds of millions of dollars spent in it—billions, in fact. If there are some areas of duplication, or if there are some areas where we have sufficient knowledge, and in all likelihood it would merely substantiate what we know, by carrying the previous experiment just

a little farther, I am not sure this is required or needed, and this is the reason I raised the question.

Dr. NEWELL. I see the point you are trying to bring out, and I think one of the answers here, one of the considerations at least is that——

Mr. KARTH. I didn't want to make the question so obvious to you, Doctor, but now that you know what it is, I will give you a chance to comment on it.

Dr. NEWELL (continuing). Yes. Is that the Moon, like the Earth, is a body of the solar system, the understanding of which will require a tremendous amount of careful study.

One of the major elements of primary interest in connection with the Moon is that it may be able to tell us something about the origin of the solar system.

Mr. KARTH. We can ascertain this in the manned lunar program, can't we, Doctor?

Dr. NEWELL. Not necessarily. The answer to your question is "Maybe yes, maybe no."

Mr. KARTH. As I understand this whole manned program, I understood the implications were that man could do just a little bit better job, or elaborate on that type of job that was done by instruments. He could do the same job that the instrument does and just a little bit more than the instrument does. Isn't this a fact?

Dr. NEWELL. He can. He can do things instruments can't do, but on the other hand you must recognize that the Moon is a very large body, and you are going to be landing men at certain points. They will need to add to their local observations additional observations, just as in the study of the Earth, which we have been investigating for centuries now. One still hasn't learned all that one needs to know, scientifically, about the Earth, even though we populate most of the Earth.

In the same way, in the case of the Moon, you are going to have to add to the human observations the things that orbiters, picture takers, soft landers, and at the present time I think, roving vehicles can also add.

Mr. KARTH. Doctor, what is the anticipated range of this roving vehicle? Are we talking about ranging all over the surface of the Moon, or are we talking about ranging in a 1-square-mile area, 5 square miles, 10, or what do you anticipate will be its capability?

Dr. NEWELL. The ranges we have been thinking about go into the hundreds of kilometers.

Mr. CORTRIGHT. Mr. Karth, the first thing we would do in uprating the Surveyor is to give it a land anywhere capability, on any given surface of the Moon. The terrain is not uniform by best estimates. There are crevices, probably rock fields, and maybe dust hollows. There are crater rims and large declavities of various sorts.

Mr. KARTH. But this is true all over the surface that faces the Earth, isn't it?

Mr. CORTRIGHT. That is correct.

Mr. KARTH. If you land on one, you answer the questions for all of them pretty much, don't you?

Mr. CORTRIGHT. You can't prove that by one landing. You need more observations than that. Of course the men, in picking their landing site, would like to pick one of the best, and we are quite anxious to determine where they are most likely to find a level, relatively un-

rocky surface to land. Therefore one of the first things we would do, with up-rating the Surveyor, is to give it this land anywhere capability.

Mr. KARTH. If you build this capability in the Surveyor, then does this further decrease the necessity for the Prospector?

Mr. CORTRIGHT. Yes. As a matter of fact, if launch vehicle capacities (short of the huge Saturn C–5) grow in the 1965–66 time period, which there is some reason to believe they will, the Surveyor can be grown, and hence it wouldn't be an all-new project. That is what Dr. Newell was trying to point out when he said the $10 million which we requested would cover either contingency. Believe me, we are not anxious to start any new project that we don't absolutely need.

Mr. KARTH. We are not anxious, either.

Mr. CORTRIGHT. I am sure you are not.

Mr. KARTH. I wonder if we could just leave the subject, Doctor, so that you could continue, by asking that your good offices keep us informed on the progress you make in this area, and as soon as you make a decision on it that you will properly inform the committee.

Dr. NEWELL. We will be glad to do so.

Mr. KARTH. Either one way or the other.

Dr. NEWELL. All right.

Mr. RANDALL. Maybe for the benefit of the full committee, couldn't we put in the record what you do contemplate as an overall expenditure for a Surveyor and Prospector as you now see it—that is not simply for this year, but down the road, what do you contemplate?

Dr. NEWELL. Do you have those numbers?

Mr. CORTRIGHT. Mr. Taylor, our financial management officer, might want to check me out on this, but as I recall, the cost of a seven-shot series of Surveyor landers, including the development costs, is $250 million.

Mr. RANDALL. $250 million. Now, reference was made a moment ago to the Soviet making photographs. As I understand it that was on the dark—first I think we should put in the record, maybe we don't think about it, but the Moon rotates not at all, it stands still, and there is always one side that is dark and one that is light, is that true? Is there any rotation of the Moon?

Dr. NEWELL. Yes, there is.

Mr. RANDALL. How much?

Dr. NEWELL. There is one rotation per month.

Mr. RANDALL. One

Dr. NEWELL. One per month. I think we can demonstrate it this way: If we have a cup here, and mark an X on the side toward the Earth, we will use the microphone to represent the Earth, as the Moon goes around the Earth, that X stays toward the earth. Now you see it is rotated one-half rotation, you see at this point, three-quarters of a rotation here, and one complete rotation when it comes back to where it started. So the Moon rotates once a month.

If you think now of the Sun back there where the flags are, the Sun now is shining on X part of the Moon, the Earth sees a full Moon—sees the Moon fully illuminated.

When the Moon gets on the other side of the Earth, you have a new Moon, the Earth sees the dark side, which is the X side, now. Then, after completing the revolution, we come back to full Moon.

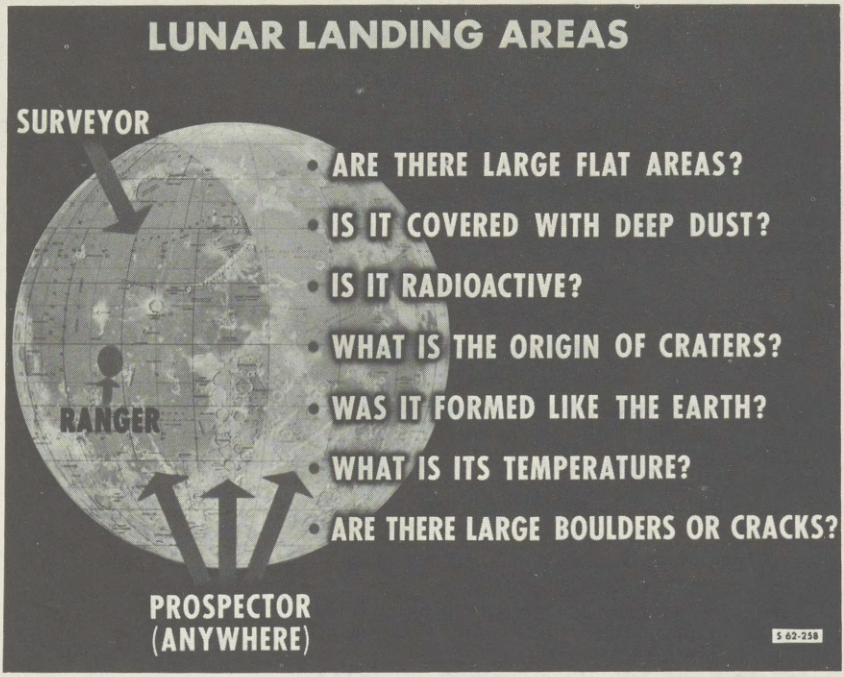

FIGURE 385

Mr. RANDALL. The point I am trying to develop is: Have we made any effort to conduct a series of photographs and things of that kind? Is there any way we can cut down this overall expenditure and fit it in with the manned landing?

In other words, maybe we will have a logistics problem as you said in your department, but it occurs to me with those facts in mind maybe this could be reduced somewhat.

Dr. NEWELL. Well, we will make every effort to do what has to be done most efficiently and most economically, to use the man where he can best be used and to use the unmanned vehicles only when they are absolutely needed.

Mr. RANDALL. That is all, Mr. Chairman.

Mr. KARTH. Proceed, Doctor. (Fig. 385.)

Dr. NEWELL. On the next slide we indicate the Moon with the areas where various spacecraft are able to land, and together with this some of the questions of significance that we hope to answer about the Moon.

The Ranger spacecraft as it is now presently conceived will have a relatively small potential impact area on the Moon. This results from the requirement that the Ranger approach impact on a nearly vertical trajectory, and do so at a time when it can be seen from the Goldstone Tracking Station in California.

The Surveyor, on the other hand, can land at slant angles up to 45 degrees. This extends its landing capability to roughly half the Moon as indicated. With the Prospector, we hope to be able to approach

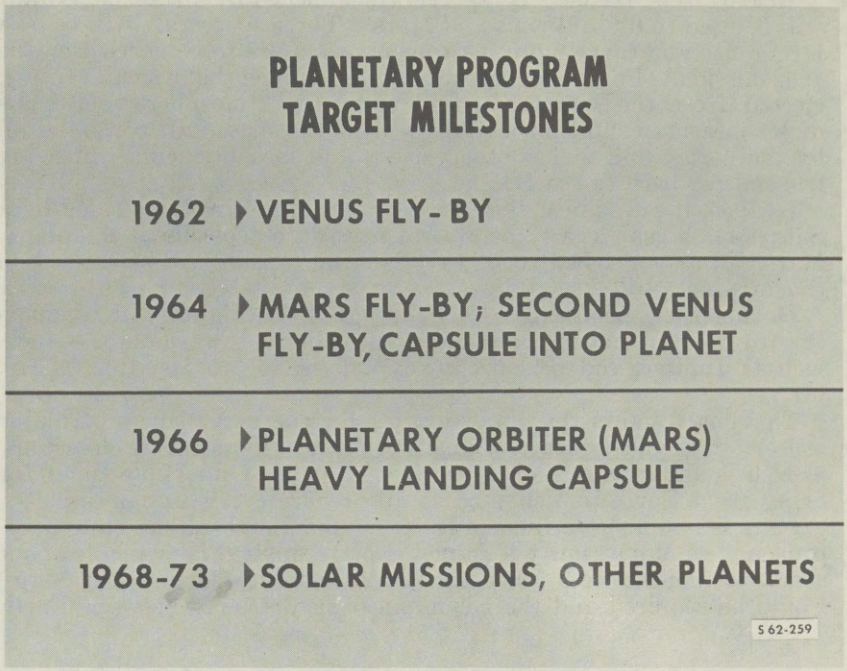

FIGURE 386

the Moon, inject into an orbit about it, and then land from the orbit at any point on the Moon.

Mr. KARTH. This is what we would like to have you give serious consideration to, building this capability in this area.

Dr. NEWELL. Yes. Some questions of significance, scientifically and to the manned program, are indicated here. Are there large flat areas suitable for safe landing of man? Is the Moon covered with deep dust as some speculate? Is it radioactive?

If it is like the Earth it may have some radioactive materials present and because of the radioactivity it might have a hot core or have had a hot core like the Earth. What is the origin of the craters? Are they volcanic, or from meteors, or both? Was the Moon formed like the Earth? Was it formed by the accretion of interplanetary dust and stones? What is its internal structure? What is its temperature and temperature history?

This is important to an understanding of lunar structure, chemical differentiation and origin. Are there large boulders or cracks on the Moon which might endanger the landing of spacecraft? (Fig. 386.)

In 1962, using the Atlas-Agena B vehicle and a Mariner spacecraft, two launches will be made to Venus. It is planned that these spacecraft will fly by the planet, obtain data enroute through the interplanetary medium, and make measurements of significance in the vicinity of the planet Venus, including direct measurements of the planet.

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In 1964, the Mariner "B" spacecraft launched by an Atlas-Centaur will be used to fly by Venus and Mars. These spacecraft will be of a larger size and carry more instruments than are to be carried on the 1962 mission. For the Mars mission, it is planned that a small capsule, ejected from the spacecraft, will enter the atmosphere and make direct measurements on the planet, while the spacecraft continues on by the planet and makes observations and measurements which are transmitted back to the Earth.

In 1966, it is planned that the Voyager spacecraft, launched by a Saturn-class vehicle, will be able to retro into orbit about the planet Mars. It may also be that a heavy landing capsule will be carried on this mission.

During the period from 1968 through 1973, flights will be made toward the Sun, out of the plane of the ecliptic, toward outer planets such as Jupiter, and perhaps in toward the sun to Mercury. (Fig. 387.)

This chart shows the opportunities for the two planets of major concern in the near future, Venus and Mars. Venus at its closest approach is about 28 million miles from Earth. Opportune times for firing from Earth to Venus occur about once every 19 months.

Mars is about 35 million miles from the Earth at the closest approach. An opportunity to launch a Mars mission is available about every 26 months. At other times considerable amounts of energy would be required and the communication distances between Earth

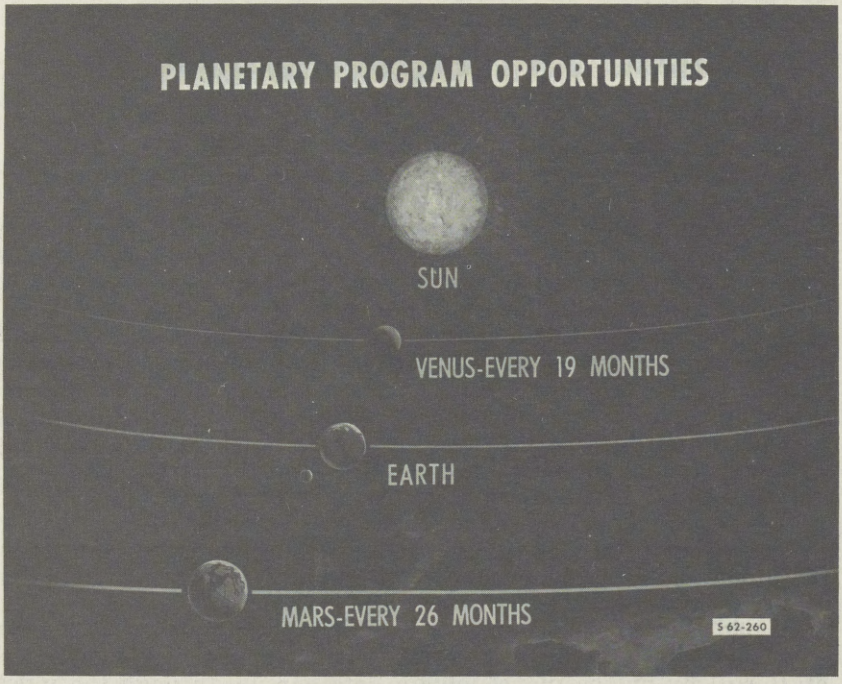

FIGURE 387

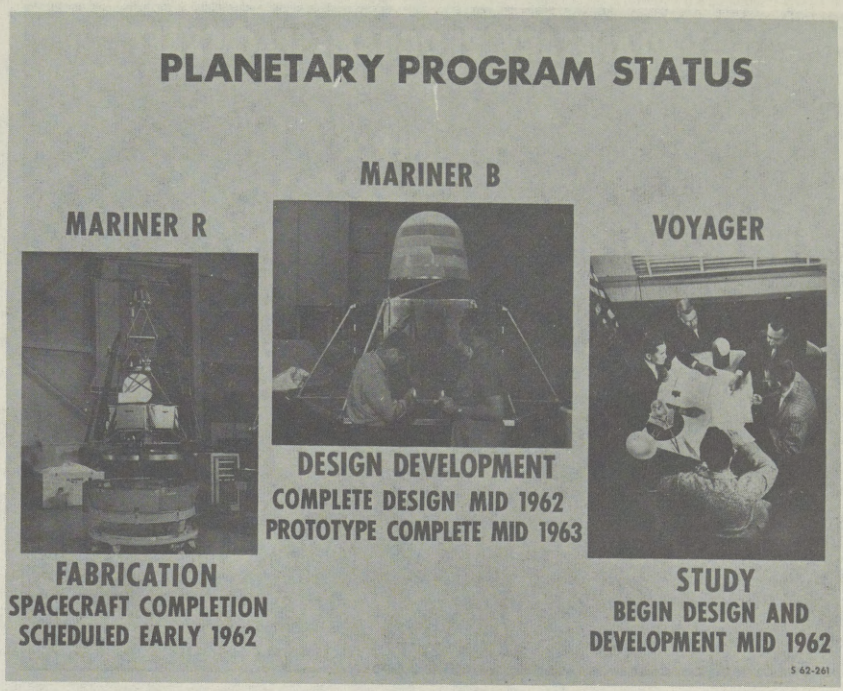

FIGURE 388

and the spacecraft at arrival at the planet would be prohibitive on the basis of current knowledge.

Because these opportunities are available approximately every 2 years, and only then for a period of 1 to 2 months each, it is imperative that at least two firings be made at each opportunity. In this way, some of the possibilities of failure can be overcome, and a higher probability of success assured. (Fig. 388.)

Like the lunar program, the planetary program is in various phases at the present time. Mariner "R" is now being built, and is scheduled for flight to Venus in 1962.

Mr. RANDALL. May we develop the word "opportunity"? You didn't elaborate but you mean the shortest possible distance, is that what you mean?

Dr. NEWELL. Yes, the least energy requirement.

Mr. RANDALL. The same thing, the shortest possible distance. Because of their circle, they come nearest to the Earth?

Dr. NEWELL. Yes.

Mr. RANDALL. All right.

Dr. NEWELL. Mariner "B," which is intended for both Mars and Venus missions, is under design and development, and should be completed in mid-1963.

A Voyager is under study, and some design and development are planned to begin in 1962. (Fig. 389.)

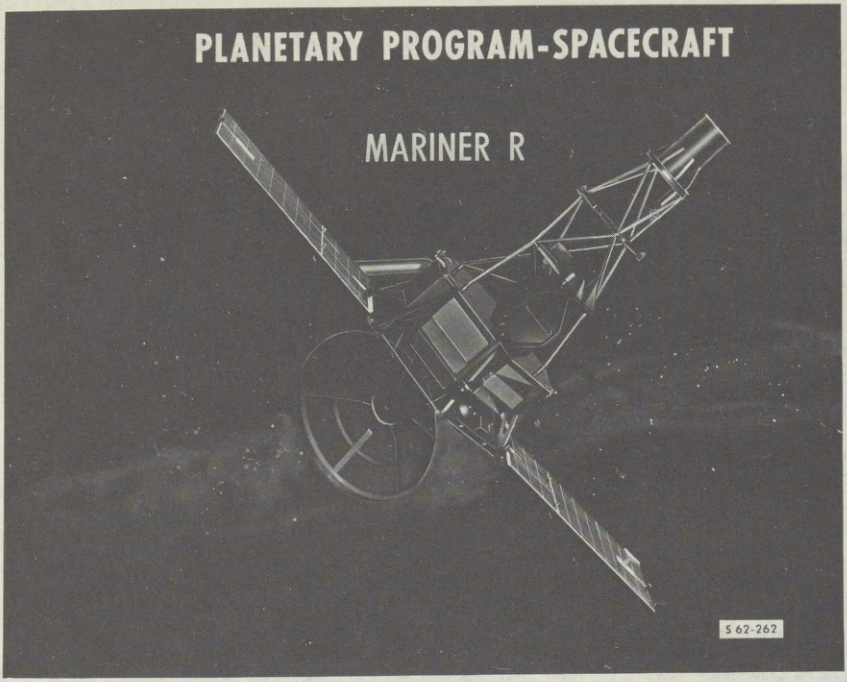

FIGURE 389

This picture indicates the gross configuration of the Mariner "R" spacecraft which, as we stated above, will be used for the Venus missions in 1962. It is a composite of the Ranger spacecraft and Mariner "A" which was being designed for the Centaur but was canceled in favor of the advanced Mariner "B" version.

This spacecraft carries instrumentation to measure particles and fields in interplanetary space and in the vicinity of the planet. Its principal mission, however, is to make direct measurements of the temperature of Venus, and to obtain data about the planet's surface. (Fig. 390.)

This spacecraft is designed with a dual capability of going to either Venus or Mars. It will also be capable of carrying an entry capsule which can be ejected into the planetary atmospheres.

It is designed with much needed redundancy to provide systems reliability, and will be able to make detailed interplanetary and planetary measurements.

It is planned that this spacecraft will be used on the several Mars and Venus opportunities beginning in 1964 and extending at least through 1968. (Fig. 391.)

This chart, which does not depict an actual design, illustrates the concept of a Voyager which is a large Saturn-launched spacecraft capable of a long operating life-time at the planet.

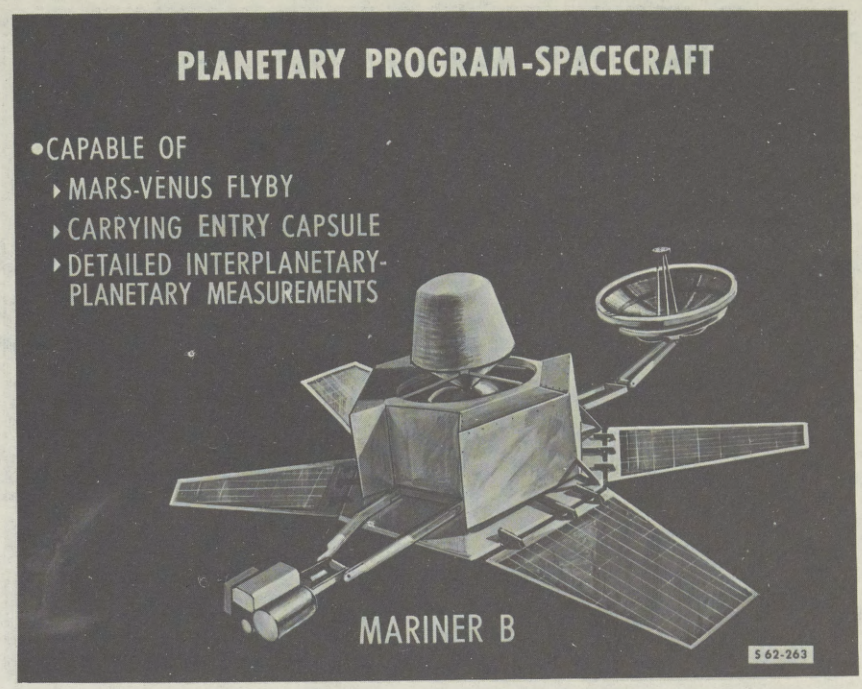

FIGURE 390

The three basic modules of the spacecraft are shown separated from each other, although at launch they would be assembled into a single package.

Voyager will be designed to go into an orbit about the planet. It will also carry a landing capsule, to obtain detailed measurements on the planet's surface. (Fig. 392.)

As illustrated in this slide, three types of the trajectories are planned for the various spacecraft in the vicinity of the planets. Early missions of the Mariner "R" and Mariner "B" will provide flights close by the planets to enable direct observations in the vicinity of the planet itself.

In late 1964, it is planned that a Mariner fly-by of the planet Mars will also include injection of a capsule which will enter the planet's atmosphere and make direct measurements.

Mr. KARTH. What is the difference between Mariner "A" and Mariner "B"?

Mr. CORTRIGHT. You will be hearing some more about this when Mr. Nicks talks about lunar and planetary in a couple of days.

Basically the Mariner "A" was the first concept of a planetary spacecraft, and was designed to fly to Venus in particular. It was not designed to carry a capsule to be ejected into the planetary atmosphere for landing.

Mr. KARTH. What year was it scheduled to fly?

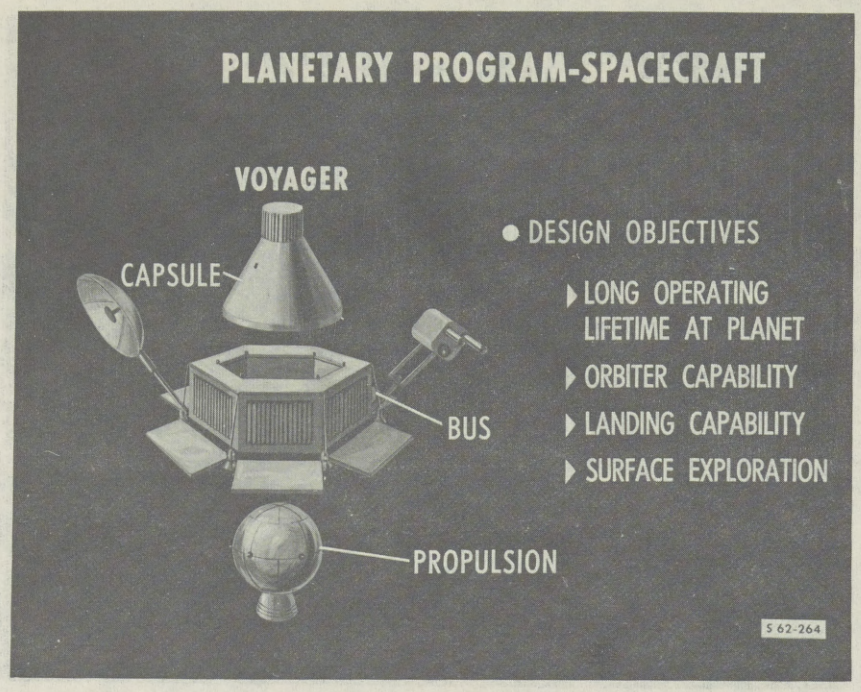

FIGURE 391

Mr. CORTRIGHT. It was designed to fly this coming summer, in August 1962.

When this was canceled, the people and the technology that had been developed were diverted on to Mariner "R," and hence it was possible to do in 1 year what normally would be a 2- to 3-year development project; we expect to make our launch dates this summer with the Mariner "R."

The Mariner "B" is designed heavier than Mariner "A" was, and designed with the capability of carrying a capsule. As the spacecraft flies to the planet and by it, it separates from the capsule and the capsule goes on in and impacts the planet, survives, and transmits data from the atmosphere and from the planetary surface back to Earth. This timing comes out in the case of Mars with launch in late 1964 and with arrival at the planet in early 1965. This is in the same time period when our large 240-foot dish will be completed. We could thus listen to this capsule right on the planetary surface.

So with the Mariner "B" we have taken advantage of the time we spent working on Mariner "A" and Mariner "R," and we are putting everything we can into a planetary spacecraft that will have use for 4 or 5 years, as Dr. Newell pointed out.

Mr. KARTH. Was Mariner "A" canceled because of the delay in Centaur?

Mr. CORTRIGHT. Yes, it was.

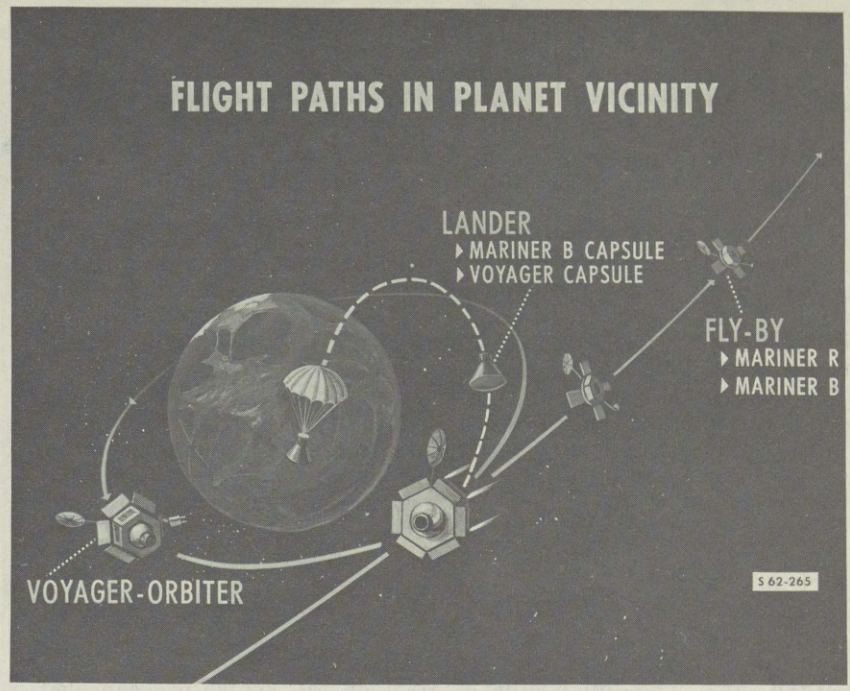

FIGURE 392

One point I forgot, sir, and that is, Mariner "B" is designed for dual capability with minor modification. That is, it can fly to either Mars or Venus. The Mariner "A" was designed for Venus and the more we got into the design the more we realized it would be a major modification to make it fly to Mars.

You run into trouble for several reasons: At the time of arrival, Mars is much farther from the Earth than Venus is, and we have a communications problem. At the same time that we need extra power for communications, we are farther away from the Sun, with only about one-quarter the solar energy per square foot of solar panel area.

So there are communications problems and power supply problems. We have put all our know-how in getting a multipurpose vehicle in Mariner "B."

Mr. KARTH. As far as Mariner "A" and Mariner "B" are concerned, that research and development that went into Mariner "A" was directly applicable to Mariner "R." Is that correct?

Mr. CORTRIGHT. Very definitely.

There were some losses, obviously, but in a major way the work was directly applicable.

Mr. RANDALL. Succinctly as possible, what is the distinction between Mariner "A" and Mariner "R"?

You described the difference between Mariners "A" and "B," but between "A" and "R," what is the difference?

Mr. CORTRIGHT. Mariner "A" was an 1,150-pound spacecraft, designed to carry something like 14 experiments.

Mariner "R" weighs about 450 pounds, and will carry fewer experiments. It will have a lower communications bandwidth, and we won't get as much data back either on the way or at the planet.

Mr. KARTH. The reason for this is Centaur won't be used, which had the launch capability to put Mariner "A" where you intended it to go; is that correct?

Mr. CORTRIGHT. That is correct.

At the time we made the decision, it looked as though we were going to have to fly Mariner "A" on either the second or third Centaur. It wasn't considered worth the risk of funds to continue with that development in the face of a possible slippage of Centaur, which would make it unavailable and which has since occurred.

Mr. KARTH. How far along the way had Mariner "A" been developed before you decided to convert it into Mariner "R," Doctor?

Mr. CORTRIGHT. There were procurements underway for some of the subsystems, and the engineering design had been completed. Some of the subsystems which were procured were directly applicable to Mariner "R."

Mr. KARTH. The contract quota spent on Mariner "A" was approximately how much?

Mr. CORTRIGHT. I will have to ask Mr. Taylor for that number.

Mr. TAYLOR. I'm sorry I missed the question.

Mr. CORTRIGHT. The unrecoverable funds.

Mr. KARTH. The dollar value of Mariner "A," which was canceled.

Mr. TAYLOR. I think it was around $5 million.

Mr. CORTRIGHT. I am told it was about $5 million.

Mr. HAMMILL. That represents a loss, because you had to reorient the program?

Mr. CORTRIGHT. It is hard to say. I don't think it does exactly, because the same components are flying on Mariner "R," in part and will apply to Mariner "B." Others which were not flown were utilized to develop mean time to failure data, for example. We ran them through intensive ground tests and found out what makes them fail. Therefore all this feeds in indirectly. We have tried to determine what is a fair loss to charge to this change in program. It is very difficult to do.

I think it is safe to say that it is less than $5 million. That is a conservative statement.

Mr. HAMMILL. But there has been a loss.

Mr. CORTRIGHT. There has been some loss, of course.

Mr. HAMMILL. Isn't the Mariner "R" more or less an upgraded Ranger vehicle?

Mr. CORTRIGHT. Well, according to the JPL engineers who were building it, they say there is more Mariner "A" in it than there is Ranger. It is a combination of both.

Mr. KARTH. In trying to establish the loss, Doctor—certainly we recognize that there are going to be losses in this whole space program, because this is new advanced technology and there is just no way to avoid it—but as I understood you, you indicated you felt your losses were somewhere in the neighborhood of $5 million.

Mr. CORTRIGHT. Or less.

Mr. KARTH. Or less.

As I understood the answer to my question previously, it was that you had only invested $4 million in "A." Could you lose more than you invest?

Mr. CORTRIGHT. This is Mr. Nicks, who will comment on your question.

Mr. NICKS. The planned number was on the order of $7 million. When we changed the plan and went ahead with Mariner "R," we were able to use between $4 and $5 million as booked against the Mariner "A." The other part of it was diverted to the Mariner "R" and Mariner "B."

Mr. KARTH. That answers my question.

Dr. NEWELL. The Voyager spacecraft will be designed to enter an orbit about Mars and Venus and, in addition, to inject a capsule to the surface. This capsule will then communicate by way of this orbiting spacecraft to Earth. (Fig. 393.)

The most important question about the planets is whether life exists there. Although no real answers to this question are presently available for either Venus or Mars, the high temperature of the Venus surface appears to leave Mars as the only good prospect.

Moreover, cloud cover over Venus precludes even the meager observation of the surface that can be made in the case of Mars.

One key to the question of life on a planet lies in its atmosphere. Life as we know it requires water, and most forms we know depend

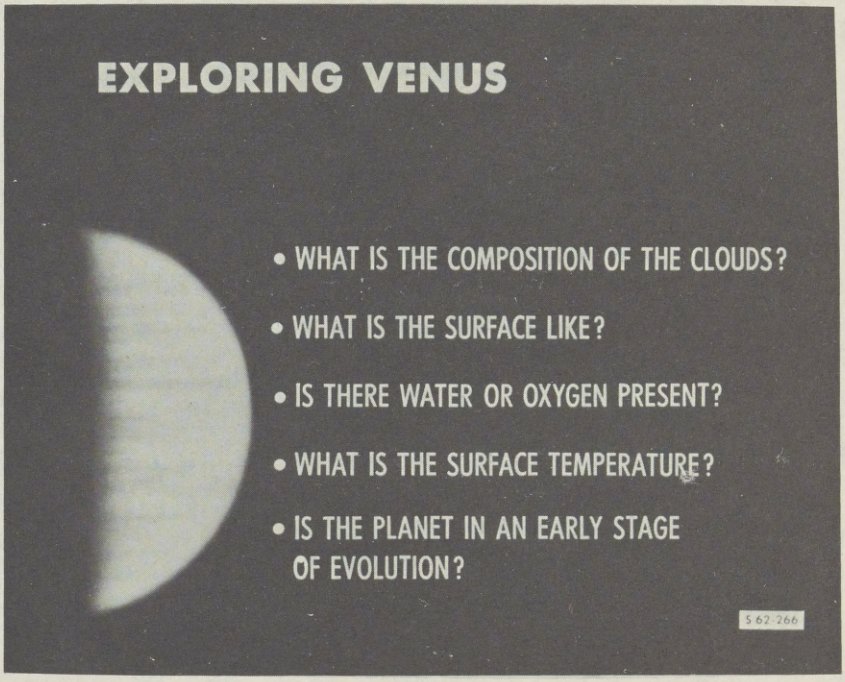

FIGURE 393

on oxygen. In addition, the surface and atmospheric temperatures must lie within a range compatible with the growth and survival of living organisms.

Venus is enshrouded in mystery because of its cloud cover. We do not even know the composition of the clouds. But it is known that the atmosphere contains appreciable amounts of carbon dioxide, which can act like the windows of a greenhouse to trap solar radiation so as to raise the surface temperature to a level incompatible with lifelike organisms.

With the Mariner "R" and Mariner "B" spacecraft, the surface temperature will be determined. As mentioned earlier, evidence to date indicates a temperature as high as 600°F. Instruments will be included to establish the quantity of water vapor in the atmosphere of the planet.

These and other instruments may even be successful in peering through the cloud curtain to provide some information on the planet's surface and rotation. (Fig. 394.)

Mars is a planet which may well sustain some form of life. It is not generally thought, however, that life on Mars would show anything like the variety that we know on Earth.

The polar cap is composed of ice crystals and shows seasonal changes, almost disappearing during the Martian summer. The color of the planet also changes with the seasons. There are indications of extensive duststorms.

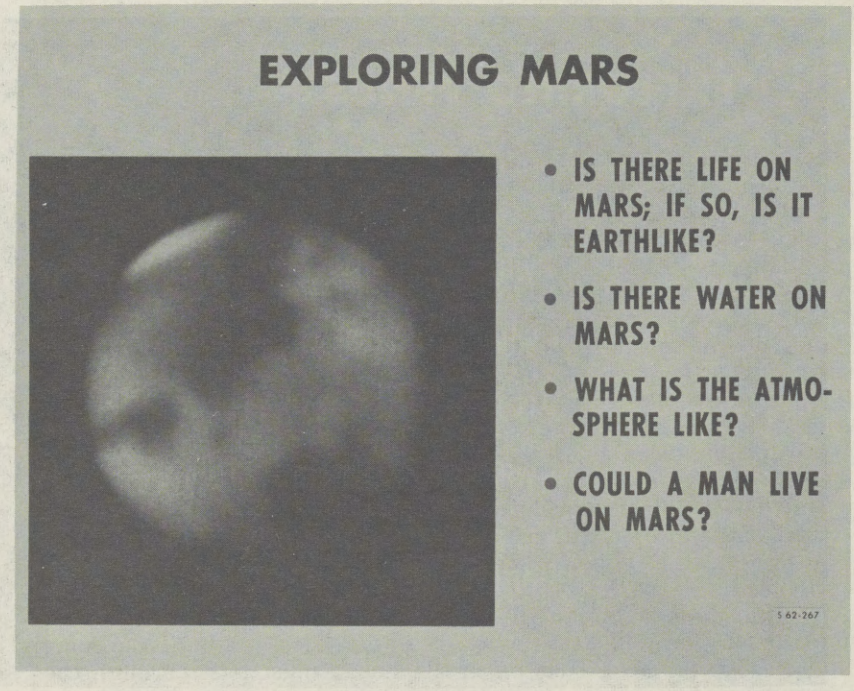

FIGURE 394

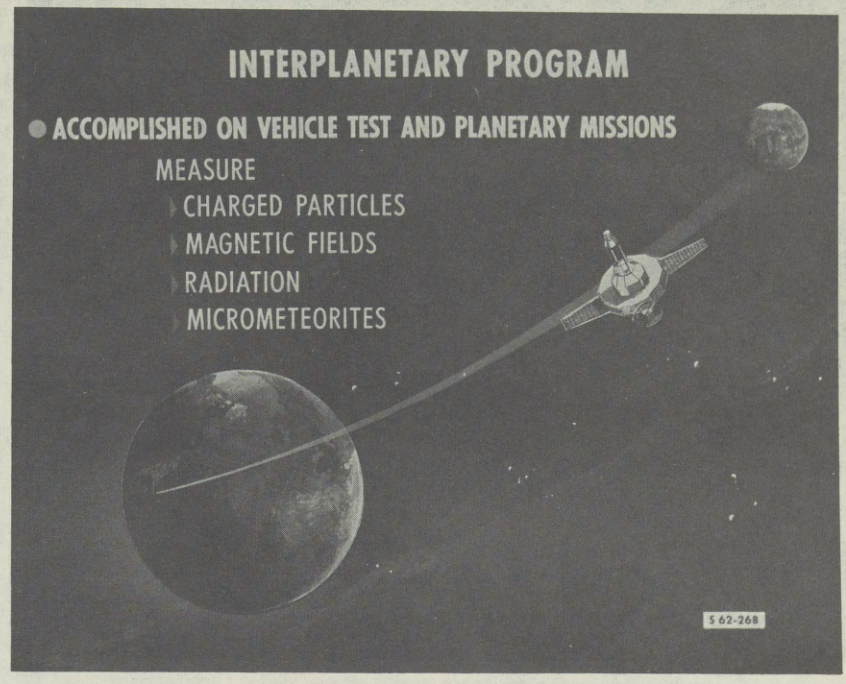

FIGURE 395

There is doubtless a Martian meteorology, but quite unlike terrestrial meteorology. Indeed, in spite of the polar icecaps, the planet appears to have little water. The duststorms, if duststorms they be, suggest a generally dry and sandy topography, modified by the seasonal changes.

Very little is known of the composition of its atmosphere. It may be that ultraviolet rays from the Sun can penetrate directly to the surface, making it impossible for earthlike life to survive without protection.

The atmosphere is thin and is subject to extremes of temperature, similar in some respects to those that might be found on a high desert plateau such as the Gobi Desert in Asia.

The Mariner program will be used to study the atmosphere of Mars, its composition and meteorology. Pictures will be taken providing a better understanding of the geology of the surface and we hope, during this program, to establish whether any lifelike forms are present on the surface. (Fig. 395.)

Although we have already discussed interplanetary physics at some length, it may be well to reiterate its importance. Any of the solar radiation and particles that reach the Earth must pass through the intervening space, which is filled with plasma, magnetic fields, high-energy cosmic rays, and cosmic dust.

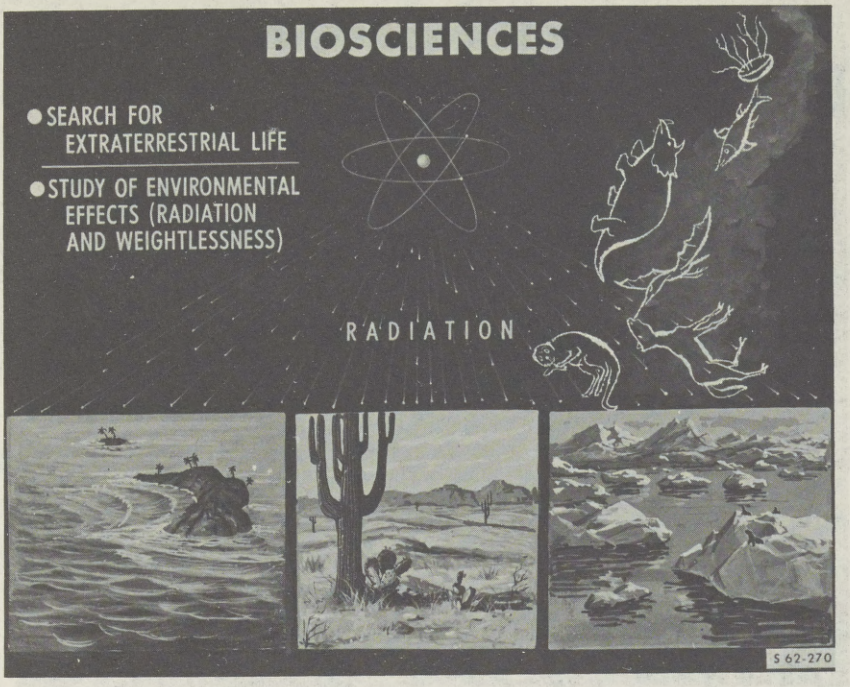

FIGURE 396

This region is in some ways an extended solar atmosphere, having its own meteorology or weather, except that that weather is electrical and magnetic in character. The Mariner spacecraft are equipped to study interplanetary phenomena on their long trips to the planets. (Fig. 396.)

The objectives of space biology are like those of the space sciences as a whole; namely, the acquisition of new knowledge. The specific objectives of space biology, however, are the search for extraterrestrial life and the study of the effects of strange environments, particularly those of space and the planets, on living organisms.

This slide illustrates the wide range of environments met with on Earth, from the teeming coral reef to the arid desert to the icy cold of the polar regions. But this entire range of environments is benevolent to life as we know it in comparison with the environments to be encountered elsewhere in the solar system.

At the very threshold to space one meets the lethal radiations of the Van Allen belts and the interplanetary medium. No region on Earth is so arid, so hot, so cold, so exposed as the Moon. Even Mars is bone dry in comparison with a terrestrial desert. And the searing temperatures of Venus are far more forbidding than the freezing cold of the Earth's poles.

Yet there may be life out there, perhaps on Mars. There may be havens out there where some forms of earth life can survive. And this is what we seek to learn.

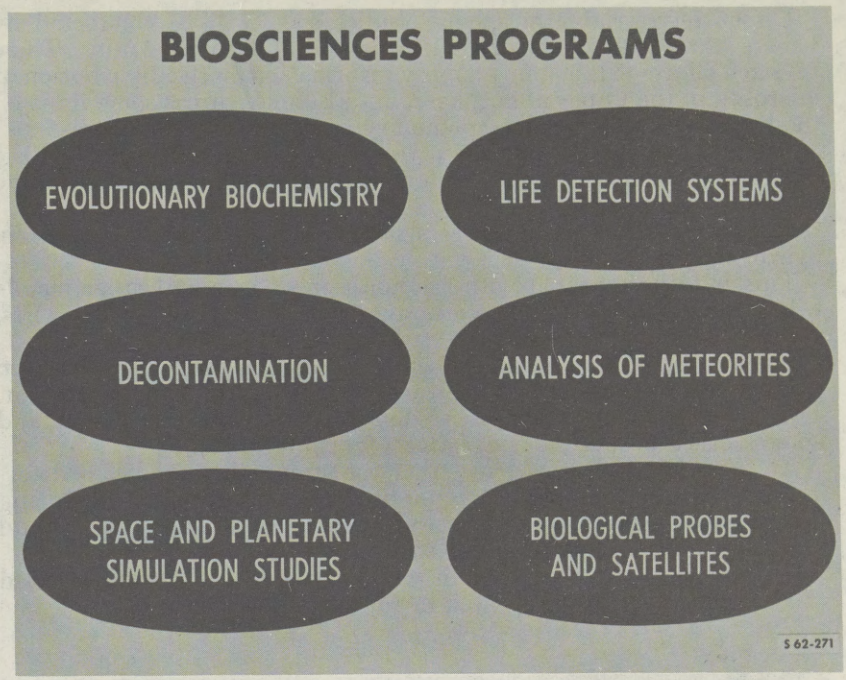

FIGURE 397

In the upper right of the slide a portion of the evolutionary tree of life is shown under free fall, posing in symbolic form the question of what role gravity has played in the development and evolution of physical life. What effect will weightlessness have on biological processes?

Summarizing, we ask: Is there life on other planets of the solar system? Elsewhere in the galaxies? In the universe? Is there organic matter on the Moon or perhaps living micro-organisms beneath its surface? How did organic matter, nucleic acids, genes, protoplasm, cells, life, originate?

What are the effects of the fluxes and intensities of space radiation on biological materials and organisms?

What are the peculiar effects of zero "g" on life phenomena such as cell division, fertilization, plant growth, photosynthesis, chemical and physical processes? (Fig. 397.)

The NASA bioscience program consists of evolutionary biochemistry, development and use of life detection systems, space and planetary simulation studies, and experiments on biological probes and satellites.

The analysis of meteorites may also give some information on the existence of biological materials, or even living matter in space.

Also, to protect the interests of the bioscientists, proper attention must be given to sterilization and decontamination of space probes that may land on the planets.

Upper terrestrial atmosphere studies soon will be conducted by Elberg at the University of California and by General Mills. These research efforts will not only supply information on the distribution of microbes in the upper atmosphere, but also may throw some light on the theories concerning interplanetary transfer of living spores.

In evolutionary biochemistry, we are trying to recapitulate in the laboratory, chemical events which transpired 2 billion years ago in the Earth's primeval atmosphere.

Already amino acids have been synthesized from ammonia, methane, hydrogen, and water.

This is to be repeated with the addition of iron and other metals with the expectation that enzymes, also essential to the creation of life, will be formed.

In addition, from the amino acids mentioned earlier, it has been possible to form proteinlike substance by the application of dry heat. The bodies formed by this process look like small round bacteria, and possess other properties suggestive of primitive cells.

An interesting observation is that the size of these bodies is determined to some extent by the amount of the gravity force acting during the synthesis periods. In other words, the bacterialike sphere would be large if formed on Jupiter and small if formed on Mars.

An experiment to check this in zero "g" flight last November failed (BIOS), but it will be repeated in future flights. (Fig. 398.)

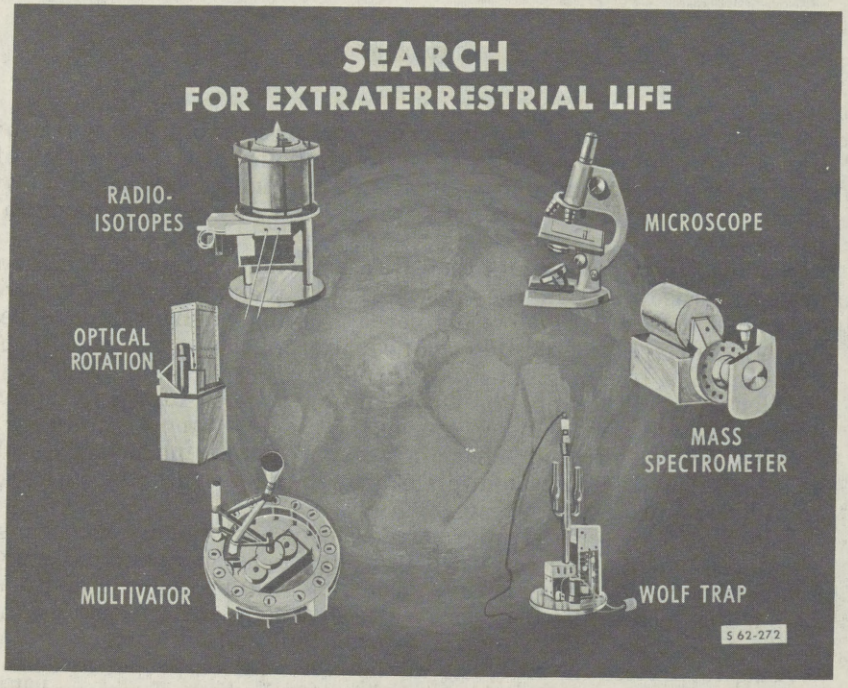

FIGURE 398

The most direct way of studying extraterrestrial life short of sending man into space to look for it is to send instruments which will examine the planet for evidence of organic compounds, proteinaceous substance, or the living organisms themselves.

The instruments on this slide are intended to symbolize the effort underway to adapt known laboratory techniques and devices to the search for and study of life on the planets.

Although some of the devices shown here are depicted in the form used on Earth, it should be understood that they must be modified and adapted to automatic, remote, telemetered operation.

In such adapted form, at least one of these devices will be flown on a capsule to Mars in 1964, and one or more on a Voyager to Mars in 1966.

The radioisotope device we shall discuss in connection with a later slide.

Certain complex organic molecules, such as desoxyribonucleic acid, emit light waves in the ultraviolet whose plane of vibration rotates as the light travels. Such optical rotation, as it is called, can be used to identify these complex molecules, which are associated with life.

Thus, the detection of optical rotation in the light from Mars would add to the evidence suggesting the possibility of life on that planet.

The instrument illustrated on the slide for measuring optical rotation is being developed for use in the space program by the Melpar Co. in nearby Virginia.

The "Multivator," depicted schematically in the slide, was devised by the Nobel Prize winner, Dr. Joshua Lederberg. This instrument is, in essence, a miniature biological and biochemical laboratory, designed to make 23 different scientific observations on micro organisms.

The "Wolf Trap" was designed by Wolf Vishniac now at the University of Rochester. The device, after being landed on a planet, sucks in a soil or air sample that is then used to inoculate a culture medium. Subsequent biological activity, caused by the growth of the organisms in the sample, is then detected by the production of turbidity or cloudiness in the originally clear broth, and by a change in the acidity of the medium.

The mass spectrograph commonly used for the analysis of inorganic materials can also be used to identify life related organic compounds. The instrument we are planning to use is under development and test by Dr. Bieman of the Massachusetts Institute of Technology.

A high resolution TV camera would detect plants and organisms if such a camera landed in an area where larger living forms were abundant. However, we are placing our bets on small organisms—micro-organisms—bacterial to be precise, because they are ubiquitous here on earth and if our theory is correct, they are the most likely to be found anywhere on Mars. For this purpose, we must use a microscope in conjunction with the television. The microscope will, however, not look like the conventional instrument shown here. (Fig. 399.)

Instead, the microscope will have a general layout as shown schematically on this slide. With this quite complicated device and by means of TV, we will actually see the organisms if they are present. In addition, organic and inorganic particles will be separated by

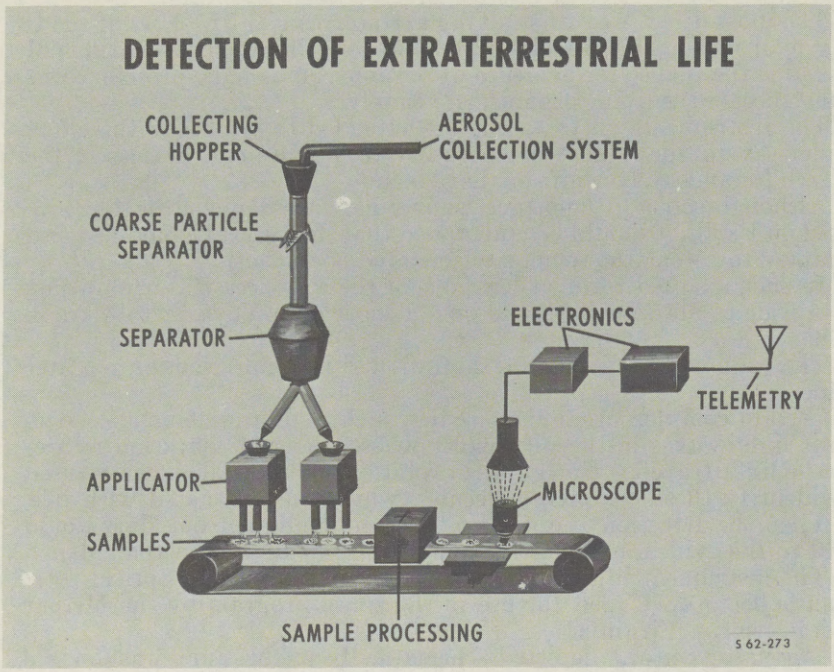

FIGURE 399

density so that soils and crystals may be observed. The resolution, or smallest observable dimension for our TV microscope, will be about one ten-thousandth of an inch. (Fig. 400.)

The remaining one of the life detection devices indicated earlier is based on the identification of metabolic carbon dioxide by means of a radioisotope, carbon 14. The C^{14} is in a nutrient broth and is evolved in the form of CO_2 as the organism grows and multiplies. The radioactivity is monitored by a solid state counter and the count is signaled to the earth. If organisms are present on Mars and if they produce the radioactive CO_2 we will obtain on earth a flattened S-shaped curve typical of microbial growth in culture.

The organisms are brought into the culture medium by means of a tethered projectile which shoots out a sticky string about 100 feet from the device. A capstan immersed in the medium inset winds the string into the broth and thus accomplishes innoculation. A recent field test in Rock Creek Park on a cold frosty morning gave us a positive signal within 45 minutes.

The device is about the size of a pint jar and weighs less than 2 pounds. (Fig. 401.)

Mr. RANDALL. Doctor, everything up to now has had some descriptive name. What is the name of this? What do you call it?

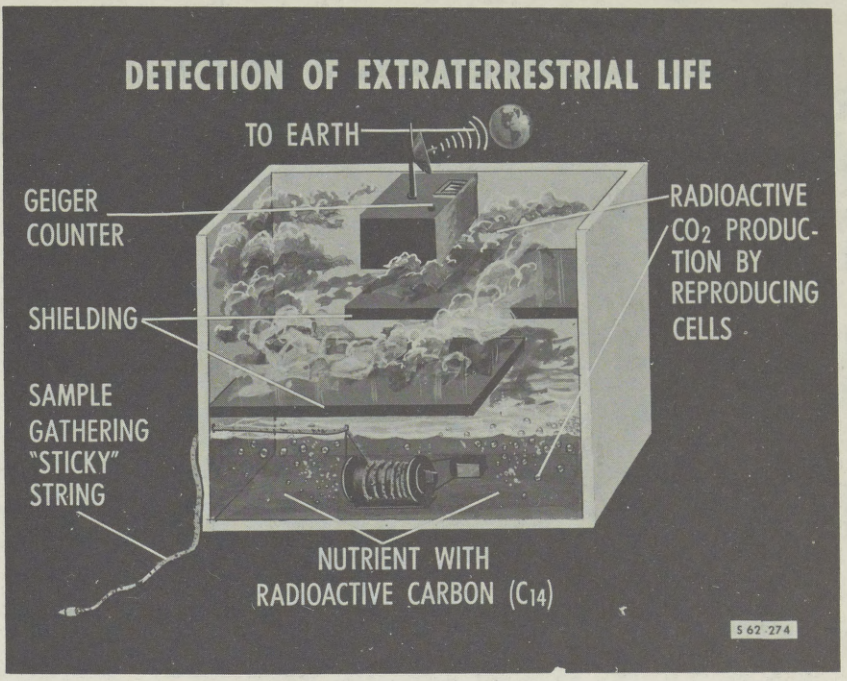

FIGURE 400

Dr. NEWELL. This is a radioactivity detection device. It has no man's name associated with it.

There are some studies which can be made of the strange environments of space and planets by artificially simulating the planetary atmosphere here on earth. The vacuum of space and the planetary atmospheres can be created in appropriately designed chambers. The temperature and the nature of the light may be simulated as well. The only major environmental component which we can reproduce only in part is the space radiation. Because of the heavy particles in cosmic rays, the space radiation spectrum can be fully studied only in space itself. At any rate we have simulation studies involving micro-organisms and lower forms of plant life underway now at the National Research Corporation's high vacuum facilities and at the Armour Research Foundation. Results from these and future works will tell us what the likelihood of extraterrestrial life is and what kinds of organisms they will be—bacteria, anaerobes, algae, lichens, ferns, club mosses, etc. We already have a list of eighteen microbial candidates to look for on Mars. (Fig. 402.)

The flight program for space biology is just getting underway. Although the trajectories were unsatisfactory, we did launch a probe and a backup last November called BIOS, the Greek word for "life," which means to us "biological investigations of space." The payload is intended to go into the inner Van Allen belt to study the lethal and hereditary effects of radiation on standard biological specimens

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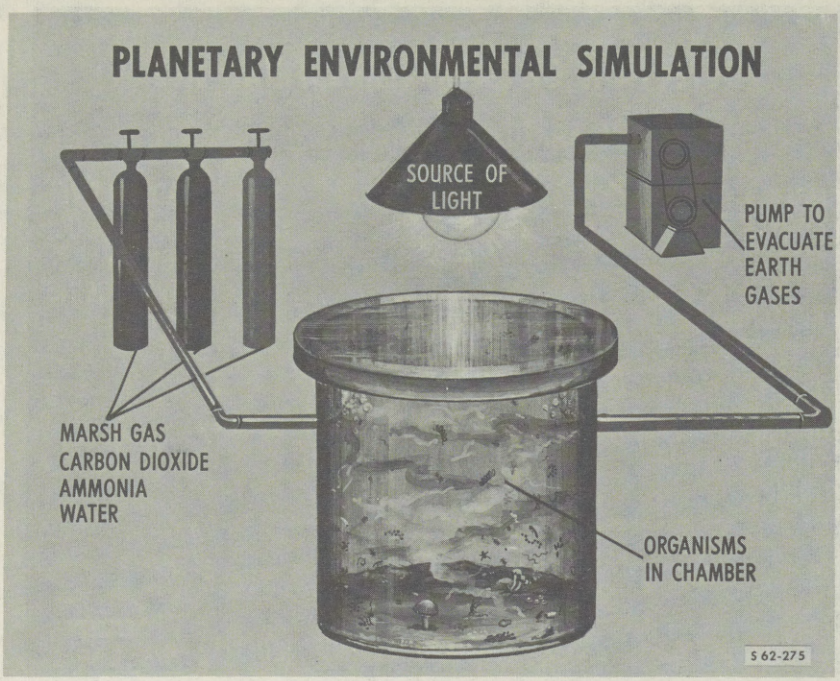

FIGURE 401

such as blood cells, barley seed, mold, bacteria, and grasshopper embryos. The trajectory also provides a certain period of weightlessness so sea urchin eggs are included to investigate the effect of zero g. on cell division and also on uncellular animals like the amoeba, and the synthesis of proteins from amino acids. The next launch will probably be over a year from now with a number of built-in improvements for the entire experiment.

Another larger experimental payload is being planned for a recoverable satellite like the Discoverer or Atlas-Mercury system which will provide prolonged periods of weightlessness for determining the effects of zero g. on a variety of biological processes including some of those already mentioned but also including photosynthesis, capillarity, fluid transport, convection, diffusion, protoplasmic streaming, growth, and geotropism. For the first time in millions of years these phenomena will be operating or will try to operate in the absence of gravity. It is here that we may possibly learn substantially new things about the nature of living processes. Furthermore, the acquired data may be pertinent to manned space flight.

Finally, we have a high altitude balloon flight scheduled for spectroscopic examination of Mars for evidence of life.

We feel strongly about this program because Sinton just a few years ago recorded an infrared spectrum that strongly suggested of life, namely, an accumulation of hydrocarbon material in the dark

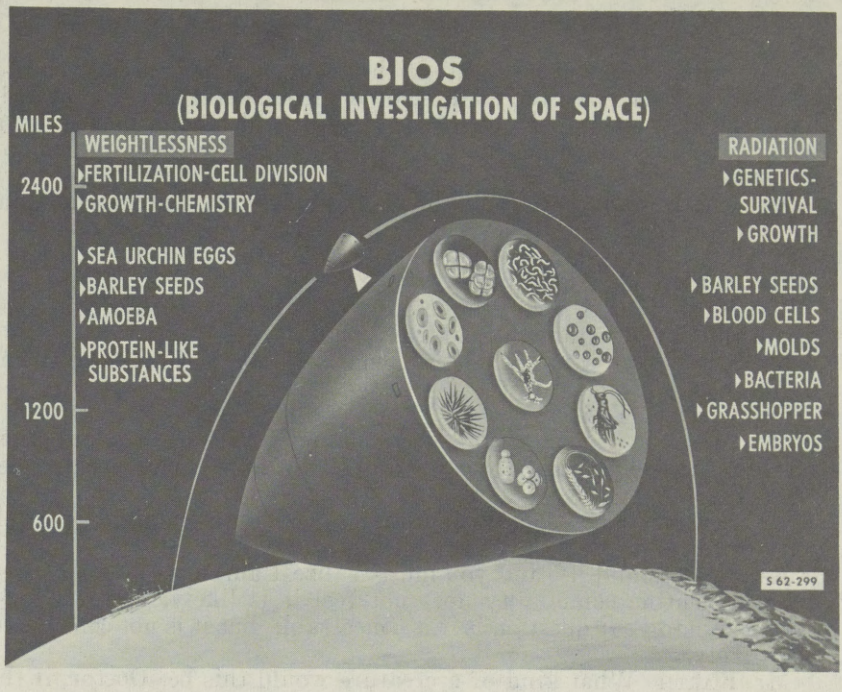

FIGURE 402

areas of Mars. Until we achieve a planetary landing, observations by means of infrared spectroscopy are the best means of searching for evidence of life on extraterrestrial bodies. Analysis of meteorites may also provide some of the evidence for which we are searching.

A newly designed instrument to be flown on a high altitude balloon platform will permit higher resolution of spectra of wave length regions of biological interest than that permitted by any previous observations through the earth's atmosphere.

Information will be obtained on the structure and composition of planetary atmospheres and surfaces, as well as on planetary organic matter. In addition to a great variety of molecules of astronomical interest on the Moon, Mars, Venus, and Jupiter, we can also observe the presence of water vapor, methane, ammonia, and carbon dioxide. A strong correlation of water vapor bond intensities with Martian seasonal variations would in itself be favorable evidence for life on Mars.

The present NASA plans call for the utilization of the Schwarzschild—that is Professor Schwarzschild of Princeton University—stratoscope II, a 36-inch telescope plus an "all wave" interferometer to be designed and developed by Dr. Ring at the University of Manchester. The latter instrument utilizes all of the available light source energy and is believed to be a superior experiment for these reasons. This NASA study of the planets from a high-altitude platform is scheduled for February 1963, and is expected to coincide with

or precede similar experiments by the U.S.S.R. in a 1963 planetary fly-by.

We feel that, if and when all of these observations on extraterrestrial life are made, as well as those on environmental effects, they will have the deepest impact on biology, philosophy, and science as a whole, and may have an effect as well on the overall betterment of mankind.

Mr. Chairman, at this point, I would like, with your permission, to ask Mr. Cortright to review the launch vehicle programs.

Mr. BASS. Mr. Chairman, before we get into that.

Mr. KARTH. Mr. Bass.

Mr. BASS. This is a very interesting discussion you have given us, in the search for extraterrestrial life, Doctor.

Am I correct in saying that the element carbon is the basic element in life as we know it?

Dr. NEWELL. Yes.

Mr. BASS. Is it conceivable some other forms of life on other planets, such as Venus, might have a form of life, with a basic element silicon?

Dr. NEWELL. It is conceivable, and considerable thought is given to this possibility.

As I understand it—and you must realize I am not a bioscientist—the bioscientific community does not feel it is likely, however. So the answer to your question is it is conceivable, but it is not considered very likely.

Mr. KARTH. What kind of a creature would this be, Doctor, if the basic element was silicon instead of carbon?

Mr. BASS. It is intriguing.

Dr. NEWELL. It is intriguing. I am sure I couldn't guess correctly. The idea, however, is that instead of carbon forming the various chains that go in to make up the complex biomolecules, silicon, because it has some of this capability of building up into long chains, as in the silicones, might be the basic element.

Mr. KARTH. Well, if this were true, would it be a form of life of higher order or lower order than we know it?

Dr. NEWELL. I couldn't give an answer to that.

Mr. BASS. Pursuing my line of inquiry a little further, a form of life based on silicon could withstand very high temperatures, for instance?

Dr. NEWELL. That is quite likely.

Mr. BASS. Such as you described we think exists?

Dr. NEWELL. That is quite likely, yes.

Mr. BASS. Is there any other basic element on which life conceivably could exist?

Dr. NEWELL. There has been some speculation sulphur might play the same role, but this is even less likely than silicon.

Mr. RANDALL. Silver?

Dr. NEWELL. Sulphur.

Mr. RANDALL. Oh, sulphur. I thought we might have a gold mine in the sky some place.

Mr. KARTH. Mr. Bass.

Mr. BASS. No, that is all I have.

Mr. KARTH. Mr. Chairman, we are delighted to have you at our subcommittee hearings.

Mr. MILLER. Thank you.

Mr. KARTH. Dr. Newell has just completed his presentation, and is now going to ask Mr. Cortright to proceed.

Mr. MILLER. I am sorry I didn't get here sooner, Mr. Chairman.

Mr. BASS. One further question, Doctor. If this kind of life does exist, will our instrumentation pick that up as well as carbon-based form of life?

Dr. NEWELL. Hopefully it will, because we will look for the products of activity, and these products should be detectable by our devices.

Mr. BASS. Thank you.

Mr. HAMMILL. Mr. Chairman, before we get into the description of the launch vehicle programs by Mr. Cortright, would it be appropriate to ask some questions about sounding rockets and scientific satellites at this point?

Mr. KARTH. I think it would be, Doctor, if you don't mind, I think now that you have wound up your portion of the program, that you expected to address yourself to, if you don't mind, maybe there are a few questions now in the minds of committee members.

Dr. NEWELL. I would be happy to.

Mr. KARTH. They may like to pose them at this point, maybe rather than later on, at which time they may well forget them.

Dr. NEWELL. I will be happy to. I might also point out Dr. Clark will address himself to the details of the sounding rocket and satellite programs, so we are at your pleasure, either way.

Mr. KARTH. Mr. Hammill has a few questions he feels would be appropriate at this time, Doctor, if you don't mind.

Mr. HAMMILL. It appears that sounding rockets and scientific satellites have many of the same objectives.

Can you explain the reasons for using both techniques?

Dr. NEWELL. Yes. The sounding rockets we define as vertically launched vehicles, which go to an altitude of no more than one Earth's radius from the surface of the Earth.

This is an arbitrary definition, but since we have to use the term quite frequently, it is worth having clearly in mind what we mean by it.

The term "sounding," was derived from previous similar use in connection with the sounding of the ocean by the mariner, and the sounding of the atmosphere by the weatherman with his balloons.

We think of the sounding rocket, then, as a vehicle that explores the atmosphere along a vertical trajectory from, say, roughly balloon altitudes, at about 20 miles, on out to no more than one Earth's radius.

The sounding rocket, therefore, is used for studies of the pressure, temperature, density, charge content, water content, chemical constituents, winds of the upper atmosphere.

It makes measurements in a region not accessible to the satellites, namely, the region below 100 miles or so, and, therefore, is needed for that purpose. The satellite cannot do that part of the job.

In addition, the sounding rocket gives us an extremely powerful way of checking out experiments that will go on satellites for longer

duration observations, or for making survey-type observations which will determine the range in which our satellite instruments must later on look when we have satellites to make these observations.

Mr. HAMMILL. If these sounding rockets are used to investigate the atmosphere, the ionosphere, and the close-in area out to one Earth's radius, do you predict that within the foreseeable future we will have investigated this area and learned sufficient about it that we will no longer need sounding rockets as part of our space sciences program?

Dr. NEWELL. I predict we will be using the sounding rocket for the foreseeable future, because of the fact that it gives us an opportunity to study in detail our own atmosphere in a way the satillite can't always do.

Secondly, because of the fact that it does provide a means of checking out equipment, and thirdly, because it does provide a very powerful means of bringing new people into the program. The sounding rocket-type experiment is of the same nature as the deep space or the satellite-type experiment as far as the overall use of rockets and so forth is concerned, but is sufficiently simpler that this is a good way to bring new people in the program.

We plan to work with universities to bring as many new experimenters into the program as we can through this technique.

Mr. HAMMILL. We are told scientific satellite projects are useful in promoting international cooperation.

How many experiments have we conducted with other countries, which countries have been involved, and which countries are going to be involved in future experiments?

Dr. NEWELL. With your permission, I would like to review this from memory, and then correct it later as far as numbers and so forth are concerned.

Mr. HAMMILL. Surely.

Dr. NEWELL. First, I should like to say that there is an overall NASA international program which extends to most of NASA's activities. I shall be addressing myself only to that portion related to space science programs. The sounding rocket has proved to be an extremely powerful way of developing a cooperative program with other countries, and I should have mentioned this in my answer to your earlier question.

We have worked with Italy in the sounding rocket area, and with Sweden, Norway, Pakistan, New Zealand, and France. We have had sounding rocket firings in Australia, as mentioned earlier, and are exploring the development of future sounding rocket programs with India and Argentina.

We are right now developing a joint sounding rocket payload for ionospheric studies with the Japanese. This one will be fired at Wallops Island. One of the most effective cooperative programs in the sounding rocket area has been with our neighbor, Canada. We have been using the Fort Churchill Rocket Range, and working jointly with them on the study of the arctic atmosphere there.

The Canadians also have brought some of their payloads to Wallops Island, and we have fired them there.

In the satellite area, the Canadians are developing a payload for the sounding of the ionosphere from above. We call this a top-side sounder, and I believe Dr. Clark will describe this at more length later.

For a long time the ionosphere has been studied from the ground by means of radio waves propagated into the upper atmosphere where they are reflected back to Earth.

Unfortunately this technique permits you to study the ionosphere only up to the level where they are reflected back. Above that, at least to this technique, the ionosphere remains unknown. But if we put a satellite above the ionosphere and look down, we can peer down to the point where the ground-based technique stops looking at the ionosphere.

The Canadians have prepared this satellite, and have borne the costs of the satellite. They have established ground stations for receiving the data from the satellite. In cooperation we are prepared to launch this satellite on a Thor-Agena vehicle, and we have prepared our own ground stations to obtain our own record of the results from the satellite. In addition, other countries, like the United Kingdom, have been invited to prepare ground stations and they are doing that. So that this has become not just a bilateral but a multilateral cooperative program.

It has been agreed among all the participants that the data from this program will be generally available. They will be made available to scientists around the world.

There is another satellite program underway, and this is with the United Kingdom.

This satellite is prepared and ready for launching in the near future. The United Kingdom has instrumented this satellite for ionospheric and related solar research.

In this case, the United Kingdom prepared the experiments, but we, that is, the Goddard Space Flight Center, prepared the satellite structure and the auxiliary equipment, such as the telemetry, the power supply and so on. Again, we are planning to provide the launching vehicle for this.

The United Kingdom is also planning a second satellite, and the initial work on that second satellite is underway. Looking forward further into the future, the United Kingdom has indicated they would like to launch a third satellite and discussions about that are underway.

Other countries have indicated an interest ——

Mr. MILLER. May I ask, where would the United Kingdom launch, or where do they propose launching it?

Dr. NEWELL. We would launch it at our range. In the case of a Delta vehicle, it would be AMR, and in the case of the Scout, at Wallops Island.

Mr. MILLER. Aren't they in the process of setting up a European cooperative arrangement to take over some of this work somewhat similar to NASA, 11 European countries will participate?

Dr. NEWELL. Yes. There are two organizations, in fact. One, a scientific organization, which plans to develop a science program, and second, a launching vehicle organization, which plans to develop a launching vehicle of European make. The two organizations, although obviously they must work together, have been developing their early plans somewhat separately, because the science organization that we will be glad to work with them in a cooperative fashion the United States and by means of sounding rockets and so on.

We have indicated—NASA has indicated—to the science organization that we will be glad to work with them in a cooperative fashion just as we have been working with Canada or the United Kingdom on cooperative satellites.

Mr. MILLER. Is this the one headed by Professor Auger?

Dr. NEWELL. Auger, yes.

Mr. MILLER. I believe several of the countries have already taken steps to approve the joint effort of European nations.

Dr. NEWELL. Yes, sir.

Mr. HAMMILL. Would it be correct to say that the United States is underwriting this cooperative scientific satellite program to a greater extent than the other countries from the standpoint of financial support?

Dr. NEWELL. Yes, it would, because we are providing the launching vehicle and much of the tracking operation and so on.

Our approach to this has been that the cooperation should be a genuine cooperation, in the sense that the other country has something substantive to contribute, but that it will not necessarily be a 50–50 cost-sharing sort of thing. Since each country pays for its own work on the project, no export of dollars is involved.

Mr. KARTH. In the final analysis, Doctor, this is a fairly economical way for scientific experimentation of the ionosphere, and beyond, is it not?

Dr. NEWELL. It is indeed.

Mr. KARTH. It is most economical?

Dr. NEWELL. It is most economical.

Mr. MILLER. It also brings into the picture some very fine scientific know-how in Europe that we can't discount, isn't that true?

Dr. NEWELL. That is quite true.

Mr. MILLER. That is one of the big items.

Mr. RANDALL. All the countries you enumerated, you made no reference to any of the Soviet satellites or any area behind the Iron Curtain, is that true? Is no effort offered to cooperate?

Dr. NEWELL. Up to this point our efforts to generate a genuine cooperative program with the Soviets have been almost fruitless. We haven't been able to go beyond an agreement to exchange information.

Mr. HAMMILL. Mr. Khrushchev recently proposed certain cooperative efforts in space. Would you estimate that the Soviet space sciences program is as broad gage as our own, and would any such cooperative effort have particular applicability to the space sciences field in your judgment?

Dr. NEWELL. I would say from my own contact with the Soviet program, and from the literature, that their science program is not as broad gage as ours, but what they do is just as high quality as ours.

I missed the last part of your question.

Mr. HAMMILL. I was wondering whether if we were to enter into some sort of cooperative agreement with the Soviets, would you guess it would have particular applicability to space sciences, as opposed to other areas of endeavor?

Dr. NEWELL. Yes, the quality of their work indicates we could gain, as well as they.

Mr. KARTH. Are there further questions?

Mr. DOWNING. What do the Soviets specialize in? You say it is not as broad gage as ours.

Dr. NEWELL. The reason I say it is not as broad gaged as ours, is that they have had a limited number of satellites directed toward solving some of the major known scientific problems.

For example, after Sputnik III, which was an excellent satellite, and well instrumented, and which made some very important measurements and discoveries, they did not continue to bear down on the problem of the ionosphere and the radiation belt particles, and so on, the way we have.

As scientists, we wonder why didn't they do this, because they were off to a good running start. This is why I say that our program seems to be broader gaged. We plan our program followup on discoveries and new information.

Mr. KARTH. Counsel has another question.

Mr. HAMMILL. To what extent is it feasible or practicable to combine scientific satellite program objectives? To put it another way, would it be more economical to approach these experiments from the standpoint of multiple payloads?

Dr. NEWELL. This is a question that much of Dr. Clark's talk will be directed toward, and I think he will bring out quite forcefully the place of multiple payloads in the program.

Mr. HAMMILL. We will defer it then until Dr. Clark speaks.

This morning we received testimony to the effect that reorientation of the Mariner "A" program to Mariner "R" as a result of the delay in Centaur has resulted in a loss of several million dollars.

What other programs have been reoriented or pushed back because of the unavailability of Centaur, and what would you estimate the losses to be?

Mr. CORTRIGHT. No other programs in the Office of Space Sciences. We are prepared to launch at a slightly later date, as I mentioned earlier, but this does not entail loss.

Mr. KARTH. How about the loss in timetable, Doctor?

Mr. CORTRIGHT. That is a loss.

Mr. KARTH. What other programs do you conceivably see losing a certain number of months or even possibly years in the timetable, or the target dates, as they were spelled out to this committee a year ago?

Mr. CORTRIGHT. The Surveyor program in NASA and the Advent program in the Department of Defense.

Mr. KARTH. Do you think the problems we have found in Centaur would also cause us to delay for a short period of time at least project Apollo?

Mr. CORTRIGHT. No, sir. The Apollo program is going to have to have certain decisions before we get Surveyor on the Moon, such as to what type of landing mode they are going to use and what landing gear. They will try to make the system, no doubt, compatible with as wide a variety of lunar surface conditions as they can design into it; and we will hope that some years before their actual flight to the Moon, at least 2 years, we will have data which will enable them to confirm, modify, and select sites appropriate to the information we gather. But they will not slow that program down.

Mr. DOWNING. May I ask a question?

Mr. KARTH. Mr. Downing.

Mr. DOWNING. Did the Russians actually land a vehicle on the Moon?

Dr. NEWELL. Yes, they have.

Mr. DOWNING. Do you know any results they obtained from this?

Dr. NEWELL. The landing is what was called a hard landing or crash landing, so the only results obtained were those measurements made as the approach was made to the Moon.

The major results concerned the particles in the neighborhood of the Moon—they found no evidence of an ionosphere of the Moon, and the magnetic field measurements made as they approached the Moon, and they found no evidence of a strong lunar magnetic field.

Mr. MILLER. Have they made that information available?

Dr. NEWELL. Yes, that has been published in the literature.

Mr. HAMMILL. I have just one more question, Mr. Chairman, if I may.

The committee is aware that NASA is not directly involved in the funding or management of the Advent program. We have heard that the Advent program has cost something in the neighborhood of twice as much as was expected originally under a development contract with General Electric.

Now, in the scientific satellite programs, have we experienced any similar overages?

Dr. NEWELL. The answer to that question is no, we have not experienced similar overages of 100 percent in the scientific satellite programs. We have, however, experienced some smaller overages during fiscal year 1962.

Mr. HAMMILL. Can you indicate the ones that have gone fairly well beyond the expected cost?

Mr. TAYLOR. I think perhaps we should supply that for the record.

Dr. NEWELL. In order to have the numbers correct, we would appreciate it if we could supply that for the record.

Mr. HAMMILL. Very well, Doctor.

(The information requested is as follows:)

While we do not have any programs that have gone fairly well beyond the expected cost, given below for example are the fiscal year 1962 increases for the Orbiting Geophysical Observatory and the Orbiting Astronomical Observatory.

	1962 budget	1962 allocation [1]	Percent
Orbiting Geophysical Observatory	$18,517	$20,700	11
Orbiting Astronomical Observatory	22,175	29,180	33

[1] R. & D. cost excluding personnel services and institutional support.

While these increases are not as large as the indicated 100 percent for Advent, we are quite concerned and are monitoring these programs extremely closely.

Dr. NEWELL. Mr. Chairman, I have been given a note here in which the committee may be interested, if I may read it.

Mr. KARTH. Yes, sir; proceed, Doctor.

Dr. NEWELL. We have had at Cape Canaveral a Delta awaiting firing for the launching of the first Orbiting Solar Observatory. The note given to me says, "Lift-off occurred at 11:06 this morning." That the firing of the first and second stages were definitely confirmed. That coast and spinup of the payload stage appeared OK. That the third stage firing has not yet been confirmed. This may be because of the horizon problem. This is a long, low trajectory. It is presumed everything is OK. The payload condition is not yet known.

Mr. KARTH. Thank you very much for the information.

Mr. MILLER. Are we over half home?

Dr. NEWELL. Over half home.

Mr. KARTH. Mr. Bass.

Mr. BASS. Did you refer to this particular one? Where is that described in the testimony you have given us?

Dr. NEWELL. This is the Orbiting Solar Observatory.

Mr. BASS. Page 28?

Mr. NICOLAIDES. This is the figure here if you can locate it in your text.

Mr. BASS. The description is on page 28?

Dr. NEWELL. Page 28. That is correct.

Mr. BASS. Thank you.

Mr. KARTH. Doctor, as it was true yesterday, we do not have permission to set while the Congress is in session. They are going in session in just 12 or 10 minutes.

I wonder, rather than getting into the vehicle phase of this testimony, if we should not defer until tomorrow, and we can start out fresh. I am sure Mr. Cortright might find this is better for us.

For the information of those from NASA who will be in attendance tomorrow, I might just call to your attention we are going to meet in the George Washington Inn, where we met yesterday, in the same room, and that the meeting will begin at 10 o'clock, the same as we met the previous days.

Is this all right, Doctor? Would you rather do it this way?

Mr. CORTRIGHT. Yes, sir.

Mr. KARTH. We would barely get into it, and I am afraid we will be interrupted by a call to the floor.

Dr. NEWELL. This is fine.

Mr. HAMMILL. May I make one announcement?

Mr. KARTH. Yes.

Mr. HAMMILL. For the benefit of the members of the committee, there will be a trip to Huntsville on Friday, March 9, which will leave Butler Airfield at 7 a.m., and will return to Washington at 6:30 p.m.

Chairman Miller has asked that we invite the members of the subcommittee who would like to go, and to inform them that they will have to furnish their own transportation to Butler, but that return transportation will be furnished.

If possible, I would like to poll the members of the subcommittee who are here who might like to attend. The trip is this Friday.

Mr. DOWNING. I will be unable to.

Mr. HAMMILL. I will check with the absent members.

(A poll was taken off the record.)

Mr. KARTH. Are there any other announcements?

Mr. HAMMILL. No.

Mr. KARTH. Fine.

The meeting is adjourned until tomorrow morning at 10 o'clock.

Thank you very much, Doctor. Your presentation was very interesting.

Dr. NEWELL. Thank you.

(Whereupon, at 11:52 a.m., the subcommittee adjourned, to reconvene at 10 a.m., Thursday, March 8, 1962, at the George Washington Inn.)

1963 NASA AUTHORIZATION

THURSDAY, MARCH 8, 1962

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON SPACE SCIENCES,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10 a.m., in room 100–B, George Washington Inn, Hon. Joseph E. Karth (chairman of the subcommittee) presiding.

Mr. KARTH. The committee will come to order.

Before we get into the launch vehicle programs, I would like to go back over some of the things that were said yesterday and try to clear up a question or two that remains in my mind, if you have no objections.

I wasn't sure that I clearly understood some of the testimony that we received, and particularly on the Mariner Project.

STATEMENT OF MR. EDGAR CORTRIGHT, DEPUTY DIRECTOR, OFFICE OF SPACE SCIENCES, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ASSISTED BY DR. HOMER E. NEWELL, DIRECTOR, OFFICE OF SPACE SCIENCES; COL. DONALD HEATON, DIRECTOR, LAUNCH VEHICLE AND PROPULSION PROGRAMS, OFFICE OF SPACE SCIENCES; MR. JOHN NICOLAIDES, DIRECTOR, PROGRAM REVIEW AND RESOURCES MANAGEMENT, OFFICE OF SPACE SCIENCES; MR. ELDON TAYLOR, RESOURCES MANAGEMENT OFFICER, OFFICE OF SPACE SCIENCES

Mr. NEWELL. Yes.

Mr. KARTH. As I went over the transcript of yesterday, I found that there were two reasons for canceling Mariner "A." One was because of the Centaur slippage, and the other was because Mariner "A" did not have a dual capability; that is, didn't have a capability for Mars and Venus.

My question at this point would be: Which of those two is most decisive?

Mr. NEWELL. Well, inasmuch as Mr. Cortright was speaking at that time.

Mr. KARTH. Mr. Cortright.

Mr. CORTRIGHT. Very definitely it was the Centaur which was most decisive in determining the cancellation. We had no qualms at all in going forward with the project with the Venus capability primarily. Does that answer your question?

Mr KARTH. Yes. The weight of the Mariner "A" was approximately 1,150 pounds; is that correct?

Mr. CORTRIGHT. Yes, sir.

Mr. KARTH. What about Mariner "B," what is the anticipated weight of that?

Mr. CORTRIGHT. Well, it is somewhat flexible, inasmuch as it is designed to carry a capsule which can weigh anywhere from 100 pounds up to several hundred pounds, depending on the ultimate capability of the Centaur launch vehicle.

The basic bus, we call it, which is the unit with all the guidance, control and power, solar panels, and so forth, will weight in the neighborhood of 1,200 pounds.

Mr. KARTH. Approximately the same as Mariner "A"?

Mr. CORTRIGHT. Yes. In fact it is very much an evolution from the Mariner "A" design.

Mr. KARTH. There was some discussion yesterday, too, about what portion of the funds we had spent on Mariner "A" were applicable to Mariner "R" or Mariner "B," and what portion of those funds we could assume we are wasting.

I noticed going over the budget that in fiscal 1961, NASA received about $13 million, slightly more than $13 million for Mariner "A," and fiscal 1962 they received slightly more than $7½ million, or a total of approximately $20.6 million. Was only $7 million of that $20.6 million spent on Mariner "A"?

Mr. CORTRIGHT. No.

Mr. KARTH. What portion of the $20.6 million was appropriated for specifically Mariner "A," which was spent on Mariner "A"?

Mr. CORTRIGHT. All of the funds indicated in the "Blue Book." We actually received more than that shown for Mariner "A" if I am not mistaken from fiscal 1962, but we did a reprograming when we switched to Mariner "R."

Mr. KARTH. Page RDO 10–14.

Mr. CORTRIGHT. We show large funds on Mariner "R" which were originally allocated to Mariner "A," but in the bookkeeping process certain contractural obligations which had already been incurred on Mariner "A," could not reasonably be shown under Mariner "R" even if the resulting hardware were applicable. So we have shown the actual obligations which were made in 1961 and 1962 on Mariner "A" even with the reprograming of funds into Mariner "R."

The fact that this is $7.6 million in 1962, and 13 in 1961 does not mean this money was wasted.

Mr. KARTH. Nor does it mean Mariner "A" was being phased out during 1962, and that the appropriation requested was only $7.6 million. You did request more than that. This probably would be a composite of what you show in the budget, a composite for "A" and "R."

Mr. CORTRIGHT. Yes, sir.

Mr. KARTH. Your total request for Mariner "A" for fiscal 1962 then was for $7.6 million plus the $13½ million for Mariner "R," is that correct?

Mr. CORTRIGHT. In 1962, Mr. Chairman, the total Mariner budget for "A" and "R" combined was approximately $31 million. I would like to ask Mr. Taylor and Mr. Nicks if that isn't close to the re-

quested appropriation during last year's appearance before this committee.

Mr. TAYLOR. Yes, it is. I do not have the actual number for fiscal 1962.

Mr. KARTH. Some of the 30 million that you are talking about, Mr. Cortright, includes the launch vehicle, does it not? I'm just talking about Mariner "R" itself. I'm not talking about any launch vehicle systems that may be connected with the program.

Quite frankly, I don't see anything near the $30 million figure you are talking about for Mariner "R" in fiscal 1962, even with the launch vehicle I see only $23.778 million. I'm referring to "RDO" in the blue book, page RDO 10–14.

Mr. CORTRIGHT. I'm on that page now.

Mr. KARTH. At the bottom of the page you will notice the total Mariner "R" figure is 23.778 million. Is this accurate?

Mr. CORTRIGHT. Yes, sir, that is accurate, including the launch vehicle and the 13.486 million for spacecraft and instruments.

Mr. KARTH. The 13½ million represents what you spent on Mariner "R" during fiscal 1962; is that correct?

Mr. CORTRIGHT. That is correct.

Mr. RANDALL. What is that figure?

Mr. CORTRIGHT. 13.486 million.

Mr. KARTH. So this budget identification, or itemization, does not indicate that you were following both programs in parallel? That is, that you were spending money on Mariner "A" at the same time as you were spending money on Mariner "R"?

Mr. CORTRIGHT. It could be misinterpreted to read that way because we carry both items, you see.

Mr. KARTH. This is what I was trying to clear up for the record.

Mr. CORTRIGHT. When we made the decision to go to Mariner "R," we canceled Mariner "A" contracts, or diverted the hardware, so they would be applicable to Mariner "R." We also immediately made a transfer of funds which we call a reprograming action. Thus we did not continue on with Mariner "A" hardware without a mission planned for it for any appreciable period of time at all.

Mr. KARTH. Did you specifically ask for funds for Mariner "R" in fiscal 1962 request?

Mr. CORTRIGHT. No, sir.

Mr. KARTH. It was all for Mariner "A"?

Mr. CORTRIGHT. That is right.

Mr. KARTH. Those funds we find on page RDO 10–14, under Mariner "R," were those funds transferred from Mariner "A," is this correct, all of them, in total?

Mr. CORTRIGHT. Yes, that is correct. I would like to clarify the statement I made a moment ago, although we will check this more carefully for the record. I think if we had last year's budget book here we would find the Mariner "A" funds requested from Congress were the sum of the 7.62 million and the 13.486 million, primarily. We did other reprograming to make the two Atlas-Agena launch vehicles available, because they had not been ordered, you see.

Mr. KARTH. Yes, I understand.

Going back 1 more year, Mr. Cortright, to fiscal year 1961, where we find the total for Mariner "A" was $13,068,000; were any of

those funds transferred into Mariner "R" or had all of those funds been spent during that fiscal year on Mariner "A"?

Mr. CORTRIGHT. Those funds had been obligated during fiscal 1961, on Mariner "A," but much of the hardware and technology resulting were applicable to Mariner "R." This is why we were unable yesterday to give you a firm number which you could define as loss—total loss. We estimated it was less than $5 million, even though there is a total $20 million shown obligated to Mariner "A."

Mr. KARTH. But out of these $13 million in fiscal 1961 that were obligated, they were in fact spent on Mariner "A," were they?

Mr. CORTRIGHT. Yes, they were. You see Mariner "A" is just——

Mr. KARTH. I was wondering whether or not any of these funds indicated in the book here in fiscal 1962 were there as a result of transfer from fiscal 1961 in the Mariner "A" program, that is the the reason for my question, but apparently they were not.

Mr. CORTRIGHT. No.

I just received a note which might help clarify this—Mariner "A" hardware contracts were completed in many cases without change of name, and yet used on Mariner "R." And so we showed the bookkeeping as a Mariner "A" obligation.

Mr. KARTH. What happens in a situation of this kind, Mr. Cortright? Regarding the 1961 funds that were obligated and spent, let us assume in some of these areas the contractor had only finished 50 percent of what he would have been expected to finish if he had gone on with the program. What happens to the additional funds that have been contracted for but in fact he has never earned?

Mr. CORTRIGHT. Well, there is a technical determination made by the Jet Propulsion Laboratory in this case as to whether or not it is in the interest of the Government to proceed and acquire that piece of hardware for either flight purposes, if it is a subsystem, or for environmental testing.

Mr. KARTH. Who makes that decision?

Mr. CORTRIGHT. That decision is made by the Jet Propulsion Laboratory and our Western Operations Office. Legally, is it made by WOO?

Mr. KARTH. Isn't it strange that every penny obligated, or justification for spending it, was apparently made by JPL and WOO, or whatever you called it, Mr. Cortright? I mean isn't there a possibility of recovering some of these funds in the program that you no longer expect to carry through to completion?

Mr. CORTRIGHT. Yes.

Mr. KARTH. Let's say only 50 percent of those funds in fact were used.

Mr. CORTRIGHT. There were contracts canceled with termination charges, and funds recovered. Your question is a good one, and I don't——

Mr. KARTH. OK. How much of those $13 million were recovered?

Mr. CORTRIGHT. You are asking how much of the 13 ended up on Mariner "R" in the next year?

Mr. KARTH. Yes.

Mr. NEWELL. Or elsewhere.

Mr. CORTRIGHT. Or elsewhere?

Mr. KARTH. Or elsewhere.

Mr. CORTRIGHT. I can't answer that today. I will have to supply that for the record.

Mr. KARTH. All right, if you would, please.

(The information requested is as follows:)

MARINER "A" FUNDING

Fiscal year 1961 funding for Mariner "A" was spent for spacecraft design and subsystem development. These contracts were complete in fiscal year 1961 and the corresponding hardware was on hand at JPL. The fiscal year 1962 funding, on the other hand, was largely for flight hardware. By September 1961, the Mariner-Centaur relationships had been reviewed, a study of the possibility of using a lighter version—Mariner "R"—had been completed, and the decision made to halt the Mariner "A" effort. During September all Mariner "A" contracts were carefully reviewed and were either (*a*) allowed to continue for use in either Mariner "R" or Mariner "B"; (*b*) modified to meet Mariner "R" requirements; or (*c*) canceled.

Although a number of Mariner "A" contracts are still being negotiated, best estimates are that the total will run $20.7 million (13.1 fiscal year 1961+7.6 fiscal year 1962) including salaries, and other support costs.

In order to determine what portion of the Mariner "A" budget is essentially unrecoverable, all Mariner "A" budget items were reviewed and those relating directly to Mariner "R" and Mariner "B" development and hardware were separated out and totaled with the following result:

	Million
Mariner "R" development	$5.6
Mariner "R" hardware	3.0
Mariner "R" total	8.6
Mariner "B" development	6.5
Mariner "B" hardware	.2
Mariner "B" total	6.7

Mariner "A" costs can therefore be grouped as follows:

		Million
Total Mariner "A" budget		$20.7
Less:		
Headquarters S. & E. and SOP	$1.5	
Mariner "R"	8.6	
Mariner "B"	6.7	
		16.8
Unrecoverable Mariner "A" funding		3.9

Mr. BERESFORD. Mr. Chairman, may I ask a question at this point?

Mr. KARTH. Yes.

Mr. BERESFORD. Are those contracts subject to renegotiation, on a cost-plus?

Mr. CORTRIGHT. Yes.

Mr. KARTH. Yesterday in answer to Mr. Randall's question on the total anticipated R. & D. cost for Surveyor, I think your answer was approximately $250 million. I think he also posed a question for Prospector. I didn't see an answer giving a figure in the testimony yesterday. Could you provide that today?

Mr. CORTRIGHT. I would like to answer those one at a time.

The cost that I gave for Surveyor was $250 million. I thought better of that figure later, and consulted with members of the staff, and we feel that a more accurate projection would be slightly less than $200 million—$180 to $200 million for the seven Surveyor shots.

Now you asked me for an estimate of the Prospector costs.

Mr. KARTH. Could you give us an estimate of that?

Mr. CORTRIGHT. I can't give you a firm projection of that, because at the moment the Prospector is conceptual in many respects, and if you would like I will review for you the conceptual nature of the project.

Mr. KARTH. No, I don't feel that is necessary.

Mr. CORTRIGHT. Basically, Mr. Chairman——

Mr. KARTH. I think this committee would like to know what their responsibilities for appropriations are going to be in the future, at least for those programs that are scheduled today, and Prospector of course is one of those programs. You must have some idea of how much this thing is going to cost. Is it so "paperish" there is no estimate on the cost of this program?

Mr. CORTRIGHT. No, sir; in the first year we have budgeted sufficient funds to carry us through what we call a "Phase 1 Engineering Design." At the end of the phase 1 design contract we will end up with an accurate mockup, a certain amount of hardware work on long-leadtime items, and a firm hardware design.

Now the costs beyond that which would begin to be incurred in fiscal year 1964, and thereafter, can vary tremendously, depending on what we determine as a result of current studies and through the phase 1 engineering.

Mr. KARTH. Yes, but for a space flight, Mr. Cortright, for example, we are estimating up to $20 billion. It might be off a few million dollars. Someone has made an estimate, but we are a long way from going to the Moon and returning, I might point out.

Mr. CORTRIGHT. The estimate I made yesterday for Prospector was for a new spacecraft, as opposed to an uprated Surveyor. This cost would be slightly more than it is costing us to do the first seven Surveyors. There is a development cost that will probably be in excess of $150 million to develop the spacecraft alone.

I would like to consult with Mr. Nicks, if I may, and see if that is a fair representation of that one.

Mr. Nicks feels that my estimate of $150 million to develop the Prospector spacecraft preparatory through three-flight units, is a reasonable estimate.

Mr. KARTH. This includes R. & D.?

Mr. CORTRIGHT. That is R. & D. Of course, as you use the spacecraft, depending on what the configuration of the launch vehicle is, the cost per shot will vary, and the number of shots you make per year in the late 1960's will influence the total cost of the program, the total investment that the Government makes.

Mr. KARTH. Do you have any anticipated cost of what each Prospector vehicle would be?

Mr. CORTRIGHT. This would vary considerably with the final configuration, because of the size spread that is being studied. I would rather answer on the basis that the Rangers, which weigh about 750 pounds, are worth about $7½ million per copy after development; and the Surveyors, which weigh 2,300 to 2,500 pounds injected with their retro rocket, and about 750 pounds of actual spacecraft on the lunar surface, will cost between $10 and $15 million per instrumented copy. Now the Prospector will cost more, but how much more depends on the configuration that evolves.

Mr. KARTH. All right, thank you.

Now, Doctor, did you want to proceed with the vehicles?

Mr. Cortright, I understand you are going to undertake this task, so if you want to proceed, you may go ahead.

Mr. CORTRIGHT. Thank you, Mr. Chairman. This section of the presentation concerns itself with the light and medium launch vehicles used by NASA, and the armed services also in some cases.

The models of these vehicles are on the table to the rear and can be discussed afterwards if you choose.

As Dr. Newell indicated in his earlier presentation, they consist of the Scout, the Delta, the Thor, Agena B, the Atlas-Agena B, and the Centaur.

These are all part of the national launch vehicle stable, which has been mutually agreed upon by the NASA and the Department of Defense, and excludes obviously the larger series of vehicles of the Saturn size which NASA is presenting to another committee.

I would like to begin with the Scout. (Fig. 403.)

The Scout vehicle shown here in a Wallops Island launching is the smallest of the basic NASA launch vehicle family. Scout is designed to provide a highly reliable, relatively inexpensive launch vehicle so that the smaller payloads may be carried in an economical manner.



FIGURE 403

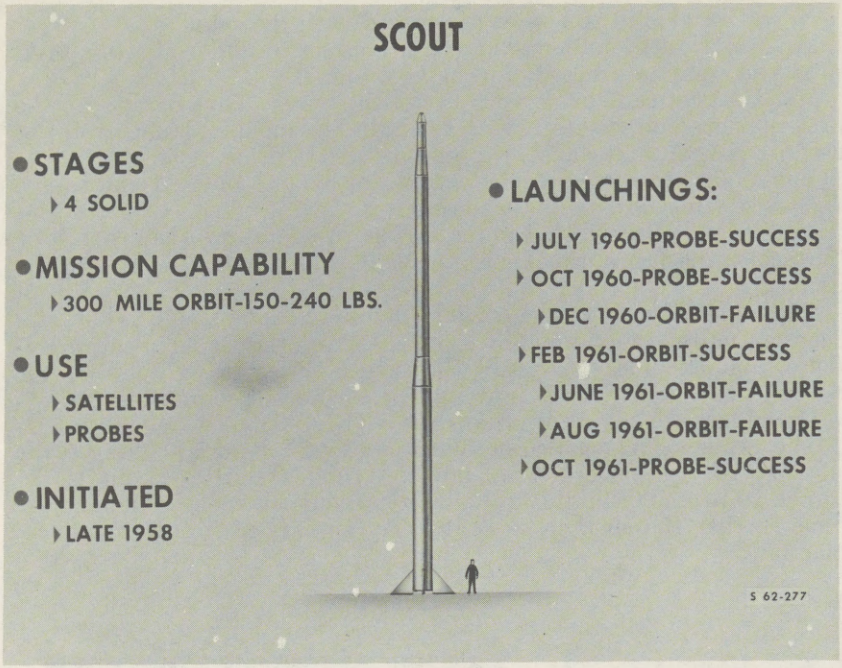

FIGURE 404

Scout is the only all-solid propellant vehicle in the basic vehicle family. Use of solid propellants in this particular application tends to reduce overall costs primarily by simplification of the ground support equipment. (Fig. 404.)

Although the smallest NASA vehicle by category, Scout is not a small item itself. It stands over 72 feet tall and has a gross weight of approximately 37,000 pounds. As shown here, Scout is capable of performing a variety of research missions, including satellite, space probe, and reentry experiments. Missions using all of these capabilities are scheduled for Scout in the future. Scout is capable of placing between 150 and 240 pounds in a 300-mile orbit. The higher weight will be available on all vehicles in late 1962 or early 1963.

This basic Scout development program consisted of eight vehicles, all of which have been launched. Of this total, five may be classified as successful from the development standpoint and three have been failures. Of the five successful development shots, three were completely successful from a mission point of view. All of the launchings regardless of success or failure have provided the necessary data return to define the vehicle problem areas and to establish proper corrective measures. (Fig. 405.)

As indicated, the Scout performance will be increased from 150 pounds in a 300-mile orbit to 240 pounds in the same orbit. This performance improvement program was initiated during fiscal year 1961 and will be substantially completed during fiscal year 1963. The

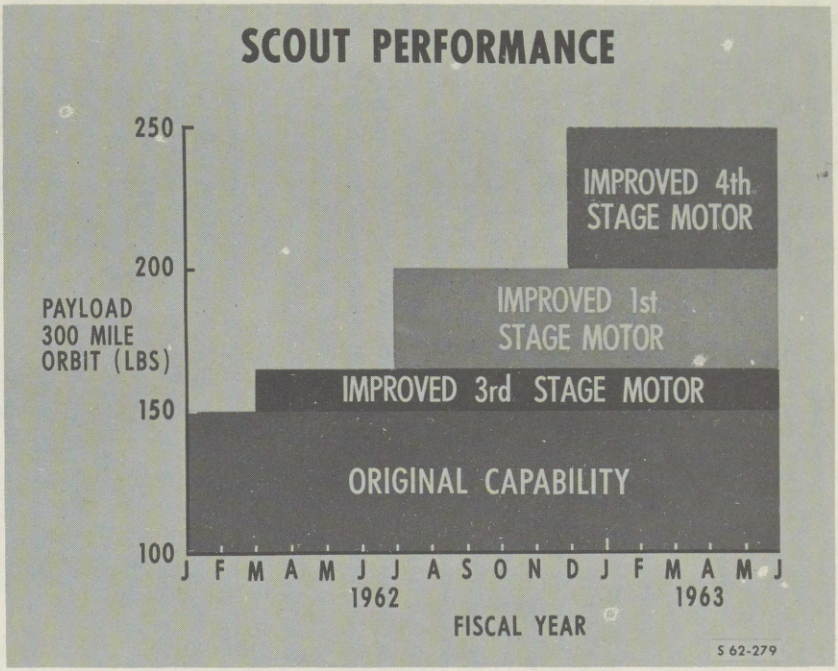

FIGURE 405

improvements hinge primarily on updating the four solid propellant motors to make them current with the state-of-the-art established by programs such as Minuteman and Polaris. In this manner, we are able to obtain the performance increase by utilizing propellants and techniques developed on other solid propellant programs which significantly reduces the cost of the Scout motor developments, obviously. The other continuing development area is to improve the overall accuracy of the vehicle system. (Fig. 406.)

As shown, Scout has a variety of missions to perform for NASA. The polar orbits will be launched from the new Scout facility at the Pacific Missile Range which will be operational in early 1962. In addition, probes for reentry heating experiments and ionosphere investigations will be launched, as well as the second U.K. international satellite.

Mr. CORTRIGHT. I would like to point out that this list of vehicles is not complete, inasmuch as it excludes the military usage of the Scout which is at least equal to the NASA usage.

Overall development of the Scout vehicle has proceeded satisfactorily. Launch results to date have been encouraging. The demand for Scout is evidenced by the 30 vehicles now on order. We feel confident that Scout will be capable of performing its mission of providing low cost, reliable transportation for a large variety of spacecraft requirements.

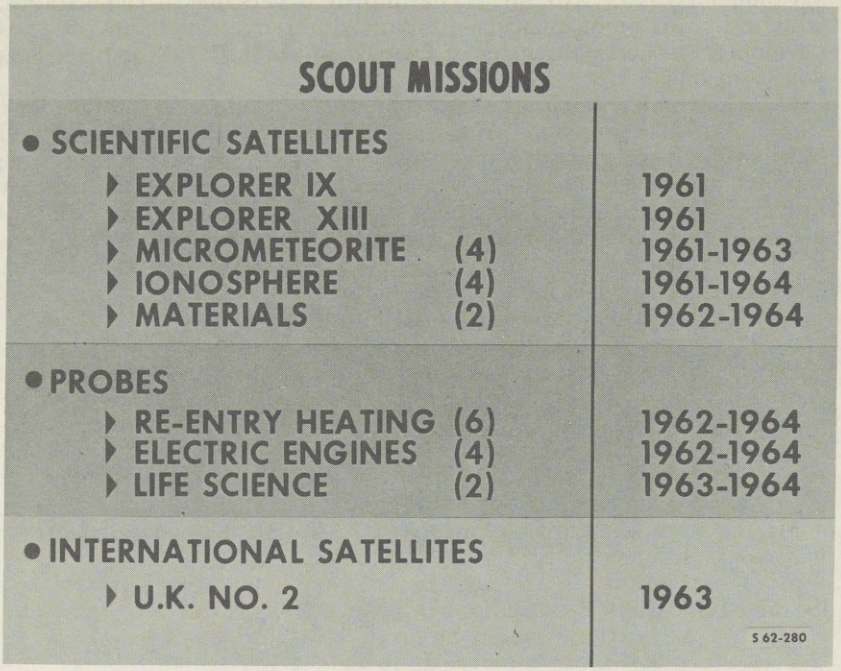

FIGURE 406

Mr. KARTH. Mr. Cortright, I think Mr. Randall has some questions at this point.

Mr. RANDALL. Who was the contractor?

Mr. CORTRIGHT. Chance-Vought Astronautics.

Mr. KARTH. How long has the Scout been under development?

Mr. CORTRIGHT. Since 1958, November or December, immediately after the creation of NASA. This was about the first vehicle project that we started.

Mr. KARTH. This was about the time you were developing Minuteman and Polaris, is that true?

Mr. CORTRIGHT. Yes.

Mr. KARTH. Was there cooperation between NASA, the Air Force, and the Navy in the development of the propellant?

Mr. CORTRIGHT. This is Colonel Heaton, who will respond.

Colonel HEATON. The Scout concept was based on the use of older, more proven hardware and propellants; whereas, the Polaris and the Minuteman required new higher performance propellants to make it a success.

Mr. CORTRIGHT. I think in answer to your question though——

Mr. KARTH. My question is whether or not NASA, the Air Force, and the Navy were all going in different directions to develop this propellant that apparently gives a higher specific impulse, or greater capability.

Colonel HEATON. No, sir. The improved versions of these stages, which Mr. Cortright mentioned, involved uses of propellants of types developed by the Department of Defense in pursuit of those programs you mentioned.

Mr. CORTRIGHT. That it was a cooperative venture is the point we would like to bring out. We worked very closely with the armed services during the development of Scout. This is why at this time we have armed service launch teams, launching at P.M.R., and NASA industry launch teams launching at Wallops Island, and a mutual use of the vehicle in about equal quantities. I would say the program in all represents a very fine example of cooperation between NASA and the armed services in vehicle development and use.

Mr. KARTH. But you are still continuing to update the Scout, aren't you?

Mr. CORTRIGHT. That is correct, because we did not want to take a chance at that time on utilizing high energy solid propellants, which had some big question marks on them. They now have been developed in the various military weapons system programs to the point where we now want to use them in the Scout. So the improvement is largely one of using the new propellants in the Scout motor cases.

Mr. HAMMILL. For what purpose will the Department of Defense utilize the Scout vehicle?

Mr. CORTRIGHT. We can provide for the committee, if you wish, a listing of the presently scheduled military uses of Scout.

Mr. HAMMILL. That would be fine. I would like to have that for the record. But would you give us an idea at this point?

Mr. CORTRIGHT. They use it for the Transit navigational satellite. I think there are some Air Force probes scheduled. I can't give you a great deal on their usage beyond that.

(The information requested is as follows:)

DOD SCOUT MISSIONS IN 30 SCOUTS ON ORDER

Navy: 2 solar radiation—orbit; 6 transit—orbit.
Air Force: 14. Approximately 50 percent orbit. Others reentry experiments. Most missions classified, the remainder have not been defined in detail.

Mr. HAMMILL. Was the research and development of the Scout funded in part by the Department of Defense?

Mr. CORTRIGHT. I don't believe it was.

Colonel HEATON. Some of the motors were. As far as the development of the vehicles, per se, it was by NASA.

Mr. CORTRIGHT. The reason the motor was, was that it was a developed motor. We were packaging it into a useful multistage vehicle.

Mr. HAMMILL. It will be used by the Department of Defense without modification, is that your understanding?

Mr. CORTRIGHT. Essentially. In fact, we have been very careful on the Scout production line to minimize the number of different configurations that come down the line. I think in the entire series of 30 Scouts, if I remember correctly, there are only 3 Scouts that have been excused from this rigid control of being virtually identical. These have special requirements on them.

Mr. KARTH. There is some speculation the new 4th stage identified as X–258, I believe, is running into serious difficulty, and that NASA may abandon it now. Do you care to comment on that, Mr. Cortright?

Mr. CORTRIGHT. This is the X–258 development, which did run into ignition problems, which persisted for a long period of time. However, the last two or three firings in the 258 development series were completely successful, and we are now in the process of evaluating whether or not we will use that as sufficient evidence to adopt this stage, or whether to test it further. We actually were prepared to proceed with a backup development had this problem not been solved. I thing there is a strong feeling that the ignition problem has been solved.

Mr. KARTH. Mr. Casey.

Mr. CASEY. I noticed in your chart you had one out of four successful orbital firings. Is that due to overloading the capacity of the vehicle, or technical difficulties?

Mr. CORTRIGHT. We had a tipoff problem during the development of the Scout, which you may have heard of, which resulted in inaccurate injection. There were corrective measures taken and flown for the first time on the last developmental Scout. The current evaluation of telemetry and tracking data is that the tipoff problem was eliminated. As for as a shot-by-shot breakdown on what the failures were caused by, I would have to supply that for the record.

Mr. CASEY. I just noticed you had two failures, one success, and then another failure, from my recollection of what your slides show. One out of four. When you just look at the chart it doesn't make a good picture.

Mr. CORTRIGHT. No, sir, except I would like to point out this is the development series of Scouts. All new vehicles when they go through this——

Mr. CASEY. I wondered whether it may be the load you had in it?

Mr. CORTRIGHT. It wasn't a loading problem. There were various problems, tipoff of which was the most annoying.

Colonel HEATON. Ignition was the other problem: Second and third stage ignition failures.

Mr. HAMMILL. Will you explain what you mean by tipoff?

Mr. RANDALL. I would be glad to have that, too.

Mr. CORTRIGHT. When a rocket goes through a staging operation, if the separation is not clean, the unfired stage gets cocked on an angle. As it spins it tends to wobble, and when it fires it ends up with an error in the velocity. We were using a separation technique which did not work perfectly.

Mr. CASEY. Have you had a successful Scout since August 1961?

Mr. CORTRIGHT. No, sir. We have not had an orbit attempt.

The last shot that we tried, which doesn't show on the slide, was in February of this year, and was a highspeed reentry probe that was not intended to orbit.

Mr. CASEY. You have not had any shots since August 1961?

Mr. CORTRIGHT. That is correct. We think we have the tipoff problem cured. Unfortunately, the last of our test series which we would have hoped would have worked perfectly so we could go into the operational phase, did experience a rare failure. However, it is a little premature for me to comment on that, because I know that they are analyzing the telemetry now to determine the exact nature of that problem.

Mr. KARTH. Who is under contract to develop the X–258 stage?

Mr. CORTRIGHT. That is Allegheny Ballistic Laboratories.

Mr. KARTH. I understand there is some consideration being given to naming a new contract, is this true?

Mr. CORTRIGHT. There were bids requested to do a backup development on the 258, and these were received and evaluated, but no action has been taken at this time.

Mr. KARTH. What seems to be the main difficulty with the fourth stage?

Mr. CORTRIGHT. Well, it was ignition, and it was not precisely determined why ignition was a problem. The 258 had a new propellant in it, a higher energy propellant. We have experimented with various types of flame holders and minor variations in the propellant to try to get this to ignite properly. The "flame holder," is part of the igniter assembly. As I said, the last two, in ground tests, ignited very well.

Mr. KARTH. How will the backup fourth stage differ from the X–258?

Mr. CORTRIGHT. I have not been a member of any of these evaluation teams. I can't comment on the proposals.

Mr. KARTH. Can you supply that for the record?

Colonel HEATON. There were three different approaches on which proposals were based and since no decision has been made to go ahead with it, with any version of a new fourth stage, no decision was made as to precisely which configuration would be adopted. However, all of the approaches are similar to X–258.

Mr. KARTH. If you decide to go ahead, actually what you are saying is that the contractor, the original contractor on X–258, didn't do a very good job, and you are scouting around looking for a new one, isn't that true?

Mr. CORTRIGHT. I would hesitate to point the finger at ABL on this development, but here is no question development has not proceeded well. However, this is a fundamental problem anyone would run into using the particular shape rocket grain and type of propellant.

Mr. KARTH. What is your answer to the question, Colonel?

Colonel HEATON. The same thing, sir. The request for proposals for an X–258 backup asked for three different approaches. One was merely to put a new propellant in the same case. The second was to have a case of the same dimensions but leaving it up to the proposers as to whether you would have precisely the same case configuration and grain configuration. And the third, allowed somewhat more latitude in shape.

Mr. BERESFORD. How much has this Scout development program slipped in schedule?

Colonel HEATON. I don't recall. I don't think I know exactly what the original target date was for completion of the program. There has been some slippage though. We can supply that if you would like, for the record.

(The information requested is as follows:)

SCOUT PERFORMANCE AND SLIPPAGE

The Scout vehicle concept was originated by the Langley Research Center in early 1958. This concept envisioned a logical expansion in the development of specific research tools, such as the sounding rockets they had been developing and launching for many years. Consequently, the original program was for

four vehicles with the possibility of an additional four. At that time it was intended that the Scout vehicle would become a research tool for use by Langley not that it would evolve into one of the workhorses in the national family of space vehicles.

The initial cost estimate for the development and launching of these eight vehicles was $10 million R. & D. Through fiscal year 1962, a total of $19 million R. & D. will be expended on Scout development. However, a number of significant increases in original program scope have contributed to the increased development funding. They are:

(*a*) New launch pad and launcher at PMR	$600,000
(*b*) Uprated 3d and 4th stage motors	2,500,000
(*c*) Uprated 1st stage motor	850,000
(*d*) Operational launch site equipment	1,000,000
(*e*) Establishment of prime vehicle contractor	2,000,000
Total	6,950,000

The remaining $2,050,000 of the $19 million R. & D. through fiscal year 1962 reflects the additional costs necessary to fund underestimation of program costs, correct defects experienced during flight test, and perform vehicle system redesign to enable delivery of a standardized vehicle to different launch ranges operating under somewhat different safety criteria and philosophies.

The establishment of a prime system contractor in September 1960 to meet the requirements placed on Scout as a national space vehicle involved a number of additional items which were not a part of the original program. These include in-plant tooling for a sustained production rate, detailed system checkout equipment in-plant to provide full system check capability prior to delivery to the launch site, initiation of reliability and failure reporting procedures, and the development of standard operating procedures. All of these reduced the amount of in-house support previously required.

The original launch date for the first Scout launch was slipped approximately 8 months. However, since that time all other launches have been on schedule except for Scout 8, launched in March 1962. The original schedule called for this launch to take place in December.

Correction of the tipoff defect discovered on Scout 6 and delays due to adverse weather postponed this launch to March 1, 1962.

Production of the 30 ordered Scouts is on schedule with a new vehicle being delivered every 14 days.

Of the 30 Scout vehicles now being produced, approximately 80 percent will be used on orbital flights. In addition to the NASA missions previously described, Scout will launch Transit and solar radiation satellites for Navy sponsored programs and a number of Air Force experiments. Launch schedules and certain details of the Air Force missions are classified.

The eight vehicles launched to date have demonstrated good performance capability. One of the major development items on the Scout vehicle was the guidance and control system. This system has operated perfectly on all eight flights. The following analysis of the eight development firings is provided:

Scout 1.—Scout 1 was launched on July 1, 1960, and carried vehicle instrumentation on a ballistic trajectory. Operation of all systems in the vehicle was fully satisfactory. The entire trajectory was not completed due to a failure in ground tracking radar which caused the range safety officer to erroneously send a signal which prevented ignition of the fourth stage. This first development flight did fully demonstrate the successful operation of all items being developed for the vehicle, including the destruct receiver. From a vehicle development standpoint, this flight is considered fully successful.

Scout 2.—Scout 2 launched in October 1960 followed same general ballistic trajectory. However, reduced vehicle instrumentation allowed a 30 pound Air Force Special Weapons Center payload to be carried. This flight was completely successful from all standpoints.

Scout 3.—Scout 3 launched in December 1960 was the first orbital attempt on Scout. Second stage ignition was not achieved and the flight was a failure. However, information was obtained which allowed redesign of the vehicle ignition system and no further failures in this system have been experienced.

Scout 4.—This launch in February 1961 was fully successful and placed the 12-foot diameter balloon air-density experiment in the prescribed orbit. This satellite, Explorer IX, has obtained a large quantity of valuable data. All vehicle and payload mission objectives were achieved.

Scout 5.—The attempted launch of the S–55 micrometeorite satellite occurred in June 1960. Ignition of the third stage motor was not achieved. This failure was due to a procedural error causing the improper installation of the igniter assembly in the third stage motor. All motor assembly procedures have been thoroughly reviewed and revised and no further failures of this nature experienced.

Scout 6.—This launch repeated the attempt to orbit the S–55 micrometeorite satellite and did achieve an orbit. On this flight, the tipoff phenomena of the Scout fourth stage was experienced to a serious degree for the first time. The orbit obtained was not that required for the mission and due to a low perigee, the orbit decayed. Satellite reentry occurred after approximately 3 days. All vehicle functions up to the fourth stage separation and including fourth stage motor burning were performed in a completely successful manner. The only discrepancy was the excessive tipoff of the fourth stage created by its separation system.

Scout 7.—This launch of the P–21 ionosphere probe in October 1961 was fully successful. Scout boosted the experiment to a higher altitude than any ionosphere experiment had achieved previously and the vehicle performed properly from all standpoints.

Scout 8.—Scout 8 launched in March 1962 was the first high-speed reentry test to measure the extreme heating conditions experienced at velocities approaching those required for manned capsule reentries. The only difficulty on this flight was the premature ignition of an additional motor carried in the payload. The four stages of Scout performed properly and the mission is considered a success. If this operation had been an orbit attempt, all indications are that a successful orbit would have been achieved.

It should be noted that on the ballistic probe and reentry flights, the entire Scout vehicle system must operate the same as on any orbit attempt. Therefore, the Scout vehicle system has performed properly in six out of eight development firings. Also, the Scout vehicle has conducted useful experiments (four) during its development period. On some vehicle developments, there are no scientific experiments of any nature conducted during the development sequence. The flights carry vehicle instrumentation only. Consequently, the Scout development program has provided not only the satisfactory development of the first all-solid propelled space vehicle, but conducted a number of useful scientific experiments at the same time.

The tipoff experienced on Scout 6 has been corrected and demonstrated satisfactorily on the Scout 8 flight. Based on this flight, the Scout vehicle is now considered capable of meeting all of its assigned mission requirements, including the large number of orbit missions which start in the spring of this year.

Mr. HAMMILL. Does the Scout have any potential for growth, insofar as its payload capabilities are concerned? Would there be any reason for uprating its performance capabilities?

Mr. CORTRIGHT. We don't anticipate any measures to uprate beyond the steps shown on the slide.

Mr. HAMMILL. In other words, we have vehicles under development or available which are capable of a higher performance range in the "stable" at the present time, is that correct?

Mr. CORTRIGHT. The next up the line is the Delta, which is highly successful, having been successful 7 out of 8 launches.

Mr. HAMMILL. I notice Delta is going to be used for a number of programs that were not anticipated as of last year. In fact wasn't Delta going to be phased out? Didn't we hear this last year?

Mr. CORTRIGHT. The original procurement was 12 Deltas; since then we have gone ahead with the procurement of 14 additional. I think this is partly attributable to the fact that it is so good. Nothing succeeds like success, and everyone wants to ride on it, so you stay flexible and adjust to a good situation when you have it. There is no other multistaged rocket of the space booster category that compares in reliability with the Delta. So your question probably is very well taken. There have been additional programs put on the Delta, just because it is a good "bird."

Mr. KARTH. What is the total R. & D. cost of Scout up to date, Mr. Cortright? Could you supply us with that?

Mr. CORTRIGHT. $19 million, approximately.

Mr. KARTH. How about Delta?

Mr. CORTRIGHT. $37 million. In all fairness, of course, the Delta had a lot of development worked into it under military programs before we decided to put it together the way we did as a space booster. For example, there was the Thor-Able. We changed the Able, in going to the Delta configuration, with some guidance and control changes plus some detailed engineering changes which we thought would improve its reliability.

Mr. KARTH. How much more do you anticipate you will need to develop Scout to a point where it will be operational?

Mr. CORTRIGHT. $4 million, in 1963, I believe, is the number we submitted. That is close to the end of it.

Mr. KARTH. What is the difference in cost between the two vehicles? That is, what is the difference between the cost of a Scout as opposed to a Delta?

Mr. CORTRIGHT. I would like to check the answer I just gave you.

The number I gave you applied to money which we would put into outside contractors to complete the development.

Mr. KARTH. What is the difference in the cost of the "bird," now—between the Scout and the Delta?

Mr. CORTRIGHT. The Scout costs about $1 million and the Delta about 2.5.

Mr. KARTH. How many Scouts are you thinking about?

Mr. CORTRIGHT. There are 30 on order with fiscal year 1962 funds.

Mr. KARTH. Thirty? How many Deltas?

Mr. CORTRIGHT. We fired 8 out of 12 and have ordered 14 more. I imagine the series will extend a little bit beyond that before we are through. I am sure it will.

Mr. HAMMILL. Mr. Cortright, can you explain why NASA has placed the small and medium vehicle development programs under the management of the Office of Space Science?

Mr. CORTRIGHT. I think so. Maybe Dr. Newell would like to answer that question.

Dr. NEWELL. Well, we have been asked to assume responsibility for vehicles of this size because we are the largest user of these vehicles.

In addition, we have asked to assume responsibility for these for the applications people, for meteorological and communications satellites.

So in summary, because we are the primary users of these vehicles.

Mr. KARTH. Pursuing the question that I have just asked; the Delta is capable of doing everything that the Scout is intended to do, is it not?

Mr. CORTRIGHT. And more.

Mr. KARTH. And more.

Wouldn't it be cheaper to develop one vehicle to do a multitude of things, including some of those things that you feel are not quite so sophisticated which Scout is today designed to do than to develop two vehicles? It appears to me if you are talking about 30 Scouts, and the cost of these after development is about a million dollars apiece, and the development itself is somewhere in the neighborhood of $24 or $25 million, it would seem to be much, much cheaper just to

go ahead and develop one "bird" and use that for a variety of purposes which you now intend to use different "birds" for.

I come out here with a figure, just doing some real quick arithmetic, and it appears to me to be much more economical to use only one. Of course, you would also free up a lot of engineers and other scientific minds to work in other areas.

Mr. CORTRIGHT. Of course, in a series of 30 launches, the difference between 1 million and 2½ million per vehicle is 45 million.

Mr. KARTH. I thought you said it was 2.3 million?

Mr. CORTRIGHT. I was corrected, sir.

Mr. KARTH. It is still cheaper.

Mr. CORTRIGHT. 2.5 is the number we will use for Delta, and that is a difference of $45 million over a series of 30 launches.

Mr. KARTH. Well, now, if you take your $24 million development cost—and, of course, we still don't have a "bird," and you add to that $30 million, which is the cost of each one, with every simple arithmetic I come up with $54 million. This does not include salaries and some of the other things. And so if we just went ahead and shot 30 Deltas, at a difference in cost of let's say $1.7 million, we have freed-up a lot of people, and we have economized, too. We have even saved money.

Mr. CORTRIGHT. If you had never developed the Scout, and fired only Deltas, you would have a very good point, and in retrospect one might say that maybe one shouldn't have developed the Scout, particularly if he knew the Delta would be this successful. But the idea behind the Scout was that this would provide a relatively simple, inexpensive vehicle that could be easily launched, even by foreign countries that might wish to participate in the space program. We could let them purchase the Scout in this country. In fact, there is an agreement between Defense and NASA to permit these countries to purchase the Scout and launch their own satellites.

Now a difference of $1.5 million per "bird" between vehicles having the same reliability would be, I think, significant. Also the ground installation is simpler.

Mr. KARTH. Well, it might be that if we searched far enough we can always justify whatever we have done. I am not trying to be unduly critical about it, but I have always felt that it was unnecessary to develop so many different kinds of vehicles, the development of costs of which are tremendous, and then find that you don't have too much difference in capability between the vehicles after you get them developed.

We are 2,000 engineers short today, I understand, or a combination of scientists and engineers. It seems to me we could in fact free-up a great deal of this talent to work on some of these programs and probably not have the crying need for the additional manpower that NASA feels they need at the moment, and at the same time we could save some money. Now it is true we probably couldn't make Scouts available for some of the foreign countries who want a real cheap "bird" after we have spent $30 or $40 million in research and development. Who knows, it might be that? If we include salaries and everything else, it is probably that now.

This is my point. I just don't feel that this is the wisest thing to do. Mr. Randall.

Mr. RANDALL. I would like to agree with the chairman, but I am several questions behind here. I would like to check this arithmetic out. I think we have something here.

Did I understand—and I would like for you to come back and check it out for us at a subsequent date—you say you have 30 Scouts on order, that is $30 million. I understood you to say you had 12 Deltas on order; is that right?

Mr. CORTRIGHT. Fourteen additional.

Mr. RANDALL. Is it 12 and 14?

Mr. CORTRIGHT. Twenty-six total.

Mr. RANDALL. That is $2.5 million a copy; isn't that right?

Mr. CORTRIGHT. That is right.

Mr. RANDALL. Now you have $39 million R. & D. cost on Delta. Is that the right figure approximately?

Mr. CORTRIGHT. To date.

Mr. RANDALL. To date, and more to come?

Mr. CORTRIGHT. $37 million with no more to come.

Mr. RANDALL. You said you had $19 million to date on Scout R. & D., and $4 million more to come?

Mr. CORTRIGHT. That is right.

Mr. RANDALL. $23 million. I think we ought to figure that arithmetic out. I didn't come out with the same figures. It is even more than the chairman suggested.

As I understand it, Mr. Cortright, the real season for this simpler vehicle, at least the only one you enumerated is, so it would be cheaper for the foreign governments to purchase, $1.7 million cheaper; is that your principal reason?

Mr. CORTRIGHT. No, sir.

Dr. NEWELL. There is an element left out in our discussion. We have been talking about the vehicle costs only. There are related costs with each of these. These are also much cheaper when you work with the Scout. When you use the Delta vehicle you are getting up into the several hundred pounds satellite category, and the total cost of the payload, then, is considerably greater than the total cost for a Scout payload.

Mr. KARTH. But all you have to do is build into the satellite the required amount of scientific experiments you want, isn't that correct?

Dr. NEWELL. No. This brings me to my next point.

There are many cases in which you want to use a vehicle for a specific orbit, specific-type trajectory, specific type of mission. It is economical to have on hand, then, an inexpensive vehicle that can take care of that for a few or small number of experiments, especially "tailored" experiments, rather than to use the more expensive, the more complicated vehicle for those special things.

Mr. KARTH. This is true, but our point is that if you include all of the R. & D., and then the cost of the vehicle itself, as opposed to the R. & D. and the cost of another vehicle, and the salaries and the expenses and everything else added up, it seems to us that NASA might give some consideration to not developing quite so many vehicles. This is our point. We may be wrong, and it would be fine if we are proved to be wrong. But I think it deserves some consideration.

Dr. NEWELL. Well, I agree——

Mr. KARTH. I might say this, Doctor, although it may be desirable to develop a relatively cheap vehicle for which you have only certain restricted objectives in mind, if you used the Delta instead of Scout, I suppose you could incorporate two or three different experiments for which you might be using two or three Scouts, and reach the same objective with only one Delta.

Dr. NEWELL. That is the crux of the matter. I agree with the point that you are trying to bring out. I think what I am saying is that when you add up the costs of these special missions, then it turns out to be more economical to use the Scout. I think we can draw up the figures to show this for you.

Mr. KARTH. I would appreciate it if you would, and I would like to have all the costs of the Scout, of course, included, not just the R. & D.

Dr. NEWELL. Right.

Mr. KARTH. Including all of the R. & D. costs of the Scout, and then the anticipated costs of each one of the 30 vehicles, because I understand you are intending to purchase 30 vehicles after the vehicle becomes operational?

Dr. NEWELL. Right. These 30 vehicles have been ordered.

Mr. KARTH. Then we will have a pretty good idea of what the cost of this program is going to be. Then we will take a look at it and try to evaluate it to see how it compares with Delta's objectives.

Perhaps the answer will be as you indicated. It appears to me right now there is some question.

(The information requested is as follows:)

SCOUT COSTS (COMPARED WITH DELTA)

SCOUT DEVELOPMENT COST

(*a*) The total development cost of Scout through fiscal year 1962 is about $30 million. This includes procurement and launching of nine vehicles. The breakdown is as follows:

Research and development	$19,000,000
Salaries and expenses and support of plant	9,000,000
PMR launch site [1]	400,000
Total	28,400,000

[1] Other PMR costs included in R. & D. as detailed previously.

(*b*) This total has been rounded to $30 million to conservatively cover any discrepancies due to accounting system changes which have occurred.

COST COMPARISON

(*a*) Assuming that the 30 missions now assigned to Scout had been assigned to Delta the cost would be:

30 Delta vehicles at $2,500,000 each	$75,000,000
In-house support	5,000,000
Addition of new launch facility	5,000,000
Total	85,000,000
30 fiscal year 1962 Scout vehicles at $1,000,000 each	30,000,000
In-house support	5,000,000
Total	35,000,000

SUMMARY

30 fiscal year 1962 Scout vehicles complete	$35,000,000
Scout development	30,000,000
Total	65,000,000
30 Delta vehicles to fulfill Scout missions	85,000,000

The above information demonstrates that all Scout development costs have been amortized and a $20 million saving obtained during the first year of operational Scout use. Continued savings will accrue at the rate of $15 million for each 10 vehicles. Present Scout usage estimates indicate this saving will be approximately $30 million per year for the next 3 years.

It should be noted that the majority of missions now assigned to Scout require unique orbits. Consequently, they are not amenable to combinations into a larger class of payload.

In addition to the development and operation of the Scout vehicle, there have been a significant number of research projects performed in conjunction with the program by the Langley Research Center. These include specific body bending flight tests, noise tests, ionization effect tests, etc. In fact, as of this time, Langley Research Center personnel, based on their work with the Scout development, have published a total of 31 technical reports and papers on a wide variety of subjects, all of which are of scientific importance. These subjects range from flight body bending and noise measurements to photographing the ionization effect of peroxide steam on a solid motor exhaust plume. A substantial portion of the S. & E. and support of plant which has been charged to Scout in the past and will be charged to Scout in the future is devoted to this type of effort at Langley.

In summary, Scout will start operational use this spring. During the first procurement year Scout's development costs are being amortized and a saving of $20 million obtained. The savings will continue in the future, which appears to fully justify the development of a small vehicle to handle the unique mission requirements which are not compatible with the larger experiment collections in the heavier payload categories.

Mr. CORTRIGHT. Mr. Chairman?

Mr. KARTH. Yes.

Mr. CORTRIGHT. I would like to comment on Mr. Randall's use of the numbers I gave. I am not sure you did this properly, Mr. Randall.

If you launched 30 vehicles at Scout costs as opposed to buying Deltas and doing the same missions, there is a saving of $45 million.

Now, if you subtract from that the development cost of the Scout, which is in the neighborhood of $20 to $25 million, there is a net saving to the Government, on paper at least, of $20 million. It wasn't a net loss. I was afraid you had added those to come out with a net loss.

Mr. RANDALL. Well, are you suggesting, Mr. Cortright, the $39 million figure then is not accurate for the Delta, that part of the development on Scout is reflected in Delta? Is that your point?

Mr. CORTRIGHT. No, sir. The point is that if you were to now go out and decide you wanted to launch 30 satellites, and you could choose between the Scout and the Delta, the Scouts would total $30 million and the Delta would total $75 million.

Mr. RANDALL. $65 million.

Mr. CORTRIGHT. $75 million.

Mr. RANDALL. $75 million, yes.

Mr. CORTRIGHT. So there is $45 million excess cost by virtue of——

Mr. KARTH. You haven't included salaries or expenses of all the utilization of——

Mr. CORTRIGHT. Those numbers I just gave were essentially correct. Even if you consider what it cost to develop the Scout in the first place there is still a net saving.

Mr. KARTH. Even if you come out to zero, it seems to me you are ahead.

Mr. CORTRIGHT. Sticking with one "bird."

Mr. KARTH. If you are sticking with one "bird," I think this thing would become a little better bird.

Mr. RANDALL. The capability, Mr. Chairman, they said the capabilities here are greater.

Mr. KARTH. The point is perhaps you could even include two or three experiments in the Delta vehicle that you would have to shoot an individual Scout bird to accomplish the same end.

Mr. CORTRIGHT. That is a very interesting point you bring up. There is no question about that.

Mr. KARTH. Then you also free up some of the scientific talent that is needed. Certainly, it is not being wasted, but it is not being used, in my opinion, as efficiently as it could be used, if they were concentrating on less vehicles, each one with the same objective, probably building the experiments into little larger satellites and accomplishing two or three objectives at the same time. That is just a thought I have had for several years. It seems to me NASA should take a good look at it.

Mr. CASEY. Did you get anything out of your three failures? You just have "failure" down there. Did you get anything out of it?

Mr. CORTRIGHT. There is engineering information, but we don't particularly——

Mr. CASEY. Information with reference to the vehicle?

Mr. CORTRIGHT. Why it failed. We didn't get scientific information out of the shots. We were developing a launch vehicle, and whenever you get a failure, of course, you find out why it failed, and you try to avoid that the next time. Therefore, rather than use an expression that is used too often "a partial success," we just called them failures. That doesn't mean we didn't learn anything.

Mr. CASEY. Were these shots just to test the vehicle?

Mr. CORTRIGHT. They probably carried a payload also.

Colonel HEATON. One was an atmospheric density experiment, and one carried a micrometeoroid payload. We carried payloads along, because we were able to, and hoped for a gain from that score.

Mr. CASEY. Then, frankly, the vehicle has not yet been satisfactorily developed for the orbital shots, has it?

Mr. CORTRIGHT. I think it is a fair statement to say that even at the end of the test series of eight, there is not enough history developed on orbital attempts to say that the vehicle is qualified completely for orbital injection. There is only one success.

Mr. CASEY. You only made four orbital attempts; isn't that right?

Mr. CORTRIGHT. Let me check.

Mr. CASEY. You only had one success?

Mr. CORTRIGHT. One success.

Mr. CASEY. One success and three failures?

Mr. CORTRIGHT. That is right, one success and three failures on orbital attempts. The other four flights were all probes. The probes were successful with the partial failure of the last one.

Mr. CASEY. As a probe vehicle, you are satisfied with it right now, but as an orbital vehicle you are not?

Mr. CORTRIGHT. I would hesitate to say that, although there is great logic in your point. We have not proven with one success, obviously, that this is a satisfactory vehicle for orbital injection.

I think we are very close—very close. The tipoff problem was the one that worried us the most and we think we solved that in the last launching.

Dr. NEWELL. I think one might state at this stage we think we now have solved all the problems that have to be solved to make this an orbital vehicle.

The next orbital attempt will be the proof of the pudding.

Mr. CASEY. When do you plan on doing that?

Colonel HEATON. The next one will be a Department of Defense shot, as I recall. I don't have that information here, but it will be a Department of Defense firing, orbital firing this spring.

Mr. CORTRIGHT. The actual month, I guess, is classified.

Colonel HEATON. That is right.

Mr. HAMMILL. Mr. Chairman?

Mr. KARTH. Mr. Hammill.

Mr. HAMMILL. Is it possible, Mr. Cortright, or Dr. Newell, that Scout is intended to become a sort of "workhorse" vehicle, and therefore the 30 that are now on order represent just the first orders, and that perhaps before we are finished, Scout will be used for 100 or 150 such launches, in which case the lower cost of the vehicle per copy would be realized and would represent a real saving?

Dr. NEWELL. This is a correct statement. It is intended that the the Scout be a "workhorse" for many types of mission, including the individual type that I mentioned, where you can't package together a lot of different experiments because the different ones have different orbital requirements, different timing requirements, different trajectory requirements in their relationship to the Sun's position, and so forth.

I might point out the Navy has reviewed the question of cost of launching vehicles, and has moved—I believe this is correct, and Mr. Nicolaides can review this for me—from the Delta type vehicle to the Scout vehicle because of the economy in doing this.

I still feel if we go through the figures, we will show you that the Scout vehicle for the uses to which it will be put will save you money.

Mr. KARTH. Well, I would be very interested in seeing that. Don't forget to include all of the launch facilities and everything else that goes with it, because you see the "bird" is only one small portion of the total cost of that operation. All of the facilities NASA must build, for example, to test this thing, and the many other things that have to go into it, and this includes construction, and we are talking about launching facilities, as I said before, and you know better than I how much is involved in actually flying a type vehicle.

Dr. NEWELL. Right.

Mr. KARTH. I thought when you talked about 30 vehicles you were talking about the sum total that you felt you would need. I might just say this, Doctor: I suppose we could build 10 other vehicles because there are so many experiments we would like to make, but I

don't know if our resources will allow us to be this generous, you see, in our inquisitiveness to explore space and all of the scientific unknowns we would like to explore. This is going to be a costly program as it is. It seems to me maybe someplace along the line we should be thinking about doing the things that we really feel have got to be done first, and then if there is some left over later on maybe we can get into some of these other areas, all of which we would like to do.

Dr. NEWELL. Yes.

Mr. KARTH. I am sure the military feels the same way. They would like to build 4,000 B–70 bombers, and what-have-you. This is all good, except there are some people who disagree. They feel this is rather extravagant and maybe we shouldn't embark upon this program at this time because missiles might be taking the place of the need for a B–70. I just cite this as an example. There is a whole spectrum of examples I suppose if we sat down and thought about them and discussed them we could come up with about the same conclusion.

Mr. CASEY. Mr. Chairman, I wanted to follow up something here.

All you have here is the tally of the shots you have completed; isn't that right, these eight Scout shots?

How many shots has the Defense Department made of the Scout?

Colonel HEATON. I don't have the total number. They have so far all been probe-type shots.

Mr. CASEY. But they are planning an orbital shot?

Colonel HEATON. That is right.

Mr. CASEY. This spring. Do you all sit in on that so you can see how it operates and get the benefit of that shot?

Colonel HEATON. Absolutely.

Mr. KARTH. Do you have to make your own to find out?

Colonel HEATON. Absolutely. This is a completely integrated program, logistically, and from the standpoint of launch information that stems from a particular launching being fed back to the program office in NASA, the manager of the overall Scout program, and of course back to the contractor. I have never seen such an integrated program as the Scout in the launch vehicle business.

Mr. CASEY. Do you think this shot will show you have solved your prior problem? You think you have solved your prior problems on this tipoff and others?

Mr. CORTRIGHT. We think we have. We have yet to put a payload into orbit with the developed Scout to prove it.

Mr. CASEY. This orbital shot that you label as a success, didn't have a payload on it?

Mr. CORTRIGHT. Yes; it had a payload. It had the 12-foot sphere, atmospheric density experiment.

Dr. NEWELL. We got some really startling results in that in the matter of air densities. Scientifically that was a very good one.

Mr. CASEY. I wondered why you said you have yet to put a payload in it.

Mr. CORTRIGHT. Subsequent to that shot we had failures. We need, as you pointed out yourself, much better reliability to take advantage of this $1½ million difference between Scout and Delta launches. The

30 shots, as Mr. Hammill pointed out, represents only the fiscal year 1962 procurement. Beyond that if the Scout is working well, there will be additional usage with this saving of at least $1,500,000 per launch.

Dr. NEWELL. Just on the rocket?

Mr. CORTRIGHT. Just on the rocket.

Dr. NEWELL. There is more saving than that.

Mr. CORTRIGHT. There is more saving, when you consider the launching, which is more simple with the Scout than the Delta.

Mr. RANDALL. Coming back the other way, maybe we should cut down on the Delta if the Scout is such a useful vehicle?

Dr. NEWELL. No.

Mr. RANDALL. You were talking a moment ago about upgrading the Scout, increasing its potential, reaching a point near the Delta; is that right?

Dr. NEWELL. The Delta is a vehicle that can do things that the Scout cannot do. In outlining the "stable" of vehicles that we ought to have, you go from one of a certain capability to another that has more capability to another that has more, and so on. So you range from the Scout—we might go even back further and drop down to balloons because we actually use balloons for some of our experimenting, because they are more economical, because you can do the job with them. You pick up with sounding rockets. Then the Scout vehicle. You go to the Delta, you go on to the Agena-type vehicles, on to the Centaur, and so on. You use for a given job the thing which is most economical.

Now, in developing this "stable" of vehicles, we had in mind that we certainly did not want to try to develop everything that one could think of to develop.

Mr. RANDALL. That is a good point, Doctor. All you are speaking of there is the optimum, you are talking about the best. If that is what is desirable, what is most desirable, I don't think we are going to be able to approve an authorization of everything that is desirable. It is very fine for you gentlemen in science to speak thusly.

Mr. KARTH. That is your responsibility.

Mr. RANDALL. That is your responsibility. We have to go back and explain this to our people. The people in my district are not too happy about this cost.

Dr. NEWELL. Understandably, every piece of these costs must be looked at very carefully. It has been our judgment that the total "stable" of vehicles you need to do the job most economically and effectively has included the Scout. We will be happy to review this again for you and show you what our reasoning is based on.

Mr. HAMMILL. Mr. Chairman?

Mr. KARTH. Mr. Hammill.

Mr. HAMMILL. On that point, Dr. Newell, we understood the Delta was being phased out.

Now, in spite of the additional orders that have been placed for the Delta vehicle recently, is it intended now that Delta will become a permanent member of the Nation's launch vehicle family, as is the case with Scout, or not? And if not, why not?

Dr. NEWELL. In the history behind the Delta, there has been this matter of judgment that has entered in and some of those who have

been reviewing the "stable" of vehicles felt that we could afford, in the job we have to do, to jump from the Scout-type capability to the Agena-type capability, and that we did not need a Delta-type vehicle in between.

Others, just as vigorously have felt that we did need the Delta in between, and in fact the Space Science Board of the National Academy of Sciences has made quite a point of the fact that we did need the Delta-type vehicle. It has been my feeling that we have needed the Delta-type vehicle.

So I have recommended and supported including the Delta among our stable of vehicles for a long time to come.

Mr. HAMMILL. But the decision has not yet been reached?

Dr. NEWELL. I think the decision has, yes.

Mr. HAMMILL. I see.

Dr. NEWELL. Yes.

Mr. KARTH. Let's don't let the Science Foundation run the space program, Doctor. Keep your eye on that.

Dr. NEWELL. I didn't hear that.

Mr. KARTH. Don't let the Science Foundation run the space program for you.

Dr. NEWELL. This is the National Academy of Sciences.

Mr. CORTRIGHT. Mr. Chairman, I would like the record to show a fact which I think is important on where we agree completely, and that is that the national stable of launch vehicles should be kept to a minimum of different vehicles. The point you bring out today is a good one, and one which has to be looked at. But we have already, with the Department of Defense, selected from literally dozens of proposed configurations and tried to hold fast to a few configurations which will cover the spectrum of needs. This is why we say we have a "stable" of launch vehicles to use with the Department of Defense.

Mr. KARTH. It might be, Mr. Cortright, that we just disagree on what the basic needs are.

Mr. CORTRIGHT. Yes, sir.

Mr. HAMMILL. Have you been able to obtain agreement with the Department of Defense on this "stable"?

Mr. CORTRIGHT. Yes; we have, in all cases. I mentioned before, above, the 30 Scouts already ordered, they have ordered about half of them.

Mr. KARTH. I understand, too, the Department of Defense has not turned down too many opportunities to develop a new vehicle, or to continue with the ones they got. I don't say this in a critical sense. It is certainly their job to provide for the defense of this Nation, and they like to do it in as sophisticated and all-inclusive manner as they can, but I even understood from various articles I have read, and things I have heard, they would like to take over the entire space program, Doctor. This is not unusual, I suppose. Maybe NASA would like to take over a certain portion of the military space program, I don't know. But I just point out desire on one hand and basic requirement on another might be quite a substantial distance apart.

If you want to continue, Mr. Cortright, I kind of lost the place where you were.

Mr. CORTRIGHT. We are beginning with Delta. (Fig. 407.)

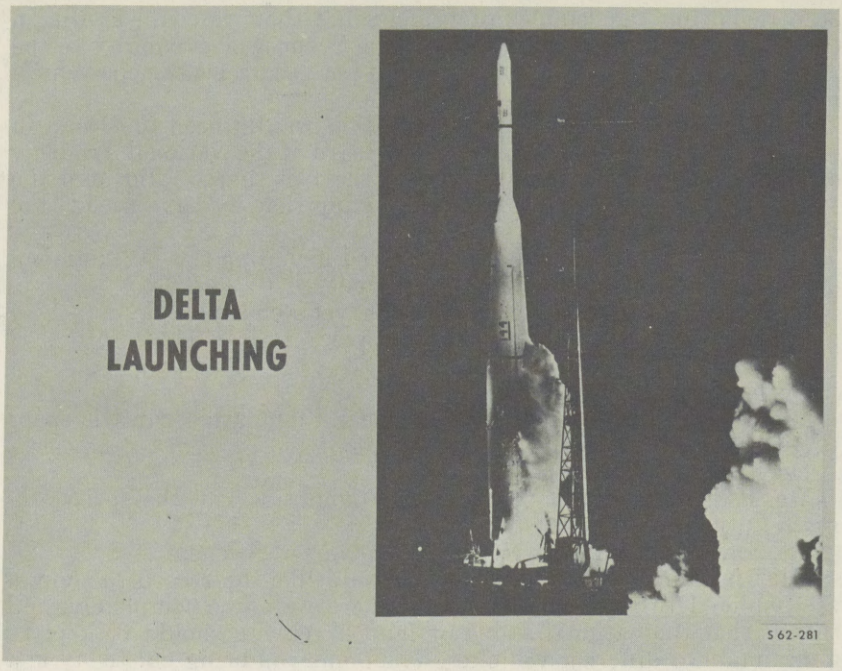

FIGURE 407

The Delta launch vehicle shown here in a launching from Cape Canaveral, was designed to provide a reliable interim vehicle for medium payload satellites and small space probes until newer vehicles such as Scout and Thor-Agena become fully operational. Delta fits between Scout and Thor Agena B in performance capabilities. (Fig. 408.)

Delta is a 90-foot three-stage vehicle using a modified Thor as a first stage. The second stage is a modified and improved second stage from the Vanguard and Thor-Able programs, and the third stage is a spin-stabilized solid-propelled stage also derived from Vanguard and Thor-Able.

It is actually the 248 about which we have been talking.

Delta thus uses proven stages, modified only as required to achieve higher reliability and perform the assigned missions.

Delta has about three times the payload capability of Scout, being able to place 500-pound satellites in low earth orbits and launch 60-pound space probes. It is being used for a wide variety of satellites and probes.

Six Deltas have been launched.

This list is not complete on the slide.

An upper stage malfunction caused a failure of the first flight, but the next five launchings were all highly successful. Delta 2 placed Echo 1 in a high circular orbit and Delta 3 launched Tiros II into its planned orbit. Delta 4 achieved a difficult, highly eccentric orbit for Explorer X, a scientific spacecraft for measuring magnetic and plasma

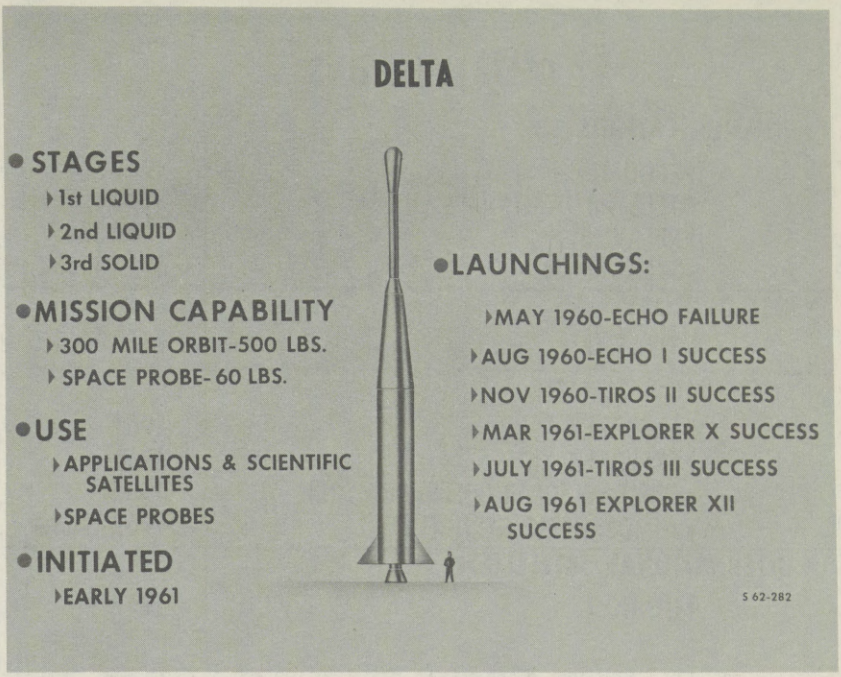

FIGURE 408

fields in interplanetary space. Delta 5 was again successful in orbiting the third meteorological satellite, Tiros III, and Delta 6 placed Explorer XII, a satellite for measuring energetic particles and fields, into its planned eccentric orbit. Seven launched Tiros IV, and yesterday Delta 8 placed the Orbiting Solar Observatory into an orbit, I am glad to say. (Fig. 409.)

Although the original Delta program included only 12 vehicles, the relatively low cost and high reliability demonstrated to date has resulted in additional payload assignments and the procurement of 14 additional vehicles. Delta will carry a number of additional Tiros meteorological satellites, and has been designated as the launch vehicle for Telstar, the experimental commercial communications satellite, as well as NASA's first two active communications satellites, Relay and Syncom. In addition, a number of scientific satellites have been assigned to this proven vehicle including the first international satellite, the United Kingdom's No. 1.

The next group of launch vehicles consisting of Thor-Agena B, Atlas-Agena B, and Atlas-Centaur, provides a range of mission capabilities intermediate between those of the lighter weight vehicles just described and the heavyweight Saturn vehicles to be presented later.

Mr. KARTH. Could I interrupt you here?

Mr. CORTRIGHT. Certainly.

Mr. KARTH. What kind of duplication are we getting into in this satellite communications field, for example, between Advent and the

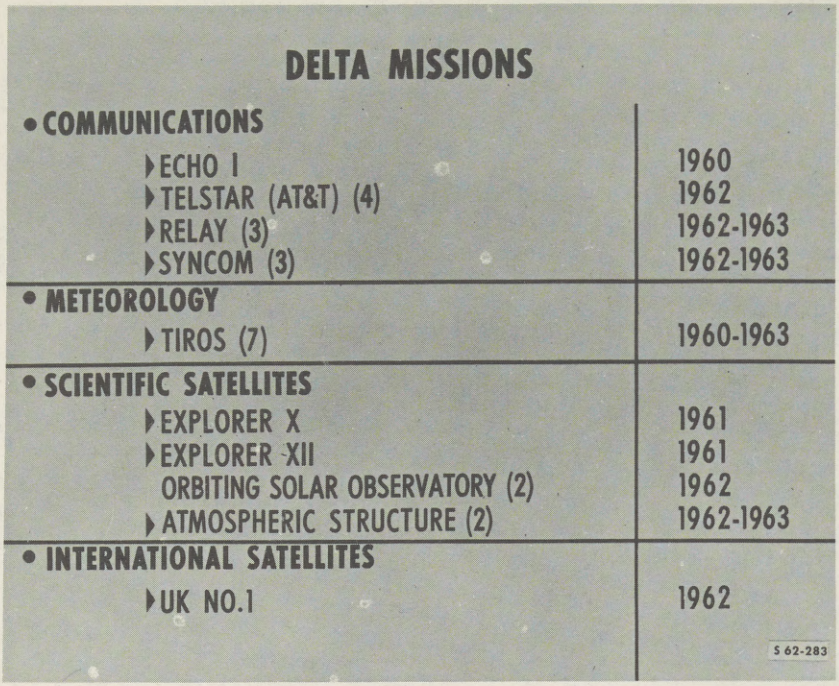

FIGURE 409

commercial satellite communications effort participated in by private industry, the whole scope of communications satellites?

What are we doing in this field, and why are we doing it, and how does it conform with some of these other communications satellites programs that are "in the mill," both from the defense standpoint and from a purely business standpoint, those outside of both NASA and the Department of Defense?

Mr. CORTRIGHT. With your permission, Mr. Chairman, I would like to disqualify myself as not competent to answer that question, inasmuch as NASA has presented extensive testimony to another subcommittee on this very subject.

Mr. KARTH. On this subject of why they are involved in the satellite communications business?

Mr. CORTRIGHT. They presented a complete story.

Mr. KARTH. Or whether or not they support the President's proposal as it applies to commercial communications satellities?

Dr. NEWELL. The reason is we really don't know the answer. We should disqualify ourselves on the basis of not being enough in this, of watching it only from the side. It is in another office.

Mr. RANDALL. That would be Subcommittee No. 4, wouldn't it?

Mr. KARTH. Then address yourself to this question. What is NASA doing in the communications satellite business? What do you expect to do? How much is it going to cost? How do you propose to use the results, whatever they might be? Are you going to have an inhouse NASA capability? Is it going to be turned over to com-

mercial users, or what is your program on it? Maybe we could discuss that for awhile?

Mr. NICOLAIDES. I am sorry we are not able to answer that question. That falls under the Office of Applications, which is the concern of another subcommittee. We simply don't have the facts, sir, nor are we responsible to have them, sir.

Mr. KARTH. This question may have been asked by another subcommittee, and I am not going to get into a jurisdictional scrap with them. Still, I want you to supply the answer or have those who are responsible to supply the answer, so it will be a part of the record.

Dr. NEWELL. We will be glad to do that.

(The information requested is as follows:)

COMMUNICATIONS SATELLITE

Question: What kind of duplication are we getting into in this satellite communications field? For example, with Advent, with the commercial satellite communications effort participated in by private industry, for example, the whole scope of communications satellites. What are we doing in this field and why are we doing it, and how does it conform with some of these other communications satellite programs that are in the mill, both from the defense standpoint and from a purely business standpoint, those outside of both NASA and DOD?

Answer: NASA activity is not considered to be a duplication of that carried on by either the military or the commercial organizations. The military effort is directed to the establishment of a communications satellite capability with the special characteristics required to provide a service of a secure nature which is resistant to jamming; neither the commercial projects nor the NASA's efforts are directed to these special requirements.

The NASA 24-hour satellite effort is an alternate attack on the problem of injecting a communication satellite in a 24-hour synchronous orbit and is trying to accomplish this with a less complicated satellite than is contemplated for Advent.

NASA's effort on low altitude active satellite development is directed toward examining transponders at other frequencies and with different electronic characteristics than those studied by industry.

NASA is using both DOD and commercial ground station developments in the support of its satellite system studies.

Question: What is NASA doing in the communications satellite business? What do you expect to do? How much is it going to cost? How do you propose to use the results whatever they might be? Are you going to have an inhouse NASA capability? Is it going to be turned over to commercial users, or what is your program on it?

Answer: NASA is conducting communications satellite development as a part of its legislative responsibility to "plan, direct, and conduct aeronautical and space activities; to provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

As indicated in Mr. Stoller's testimony, NASA expects to continue its development efforts so as to assist in the establishment of an operational communications satellite system at the earliest possible date. It will probably continue the support and development of such a system after its establishment.

NASA's fiscal year 1961, 1962, and 1963 costs for the communications satellite systems are estimated as follows:

Fiscal year 1961	$33,833,000
Fiscal year 1962	48,477,000
Fiscal year 1963	85,377,000

The results of this program will be published in the technical literature and will be disseminated to all those concerned with the development of the communications satellite system. NASA inhouse research and development in support of the communication satellite system will be made available to whatever entity is established by the Congress for the direction of an operational satellite system. All details and technical information developed in our program will be made generally available.

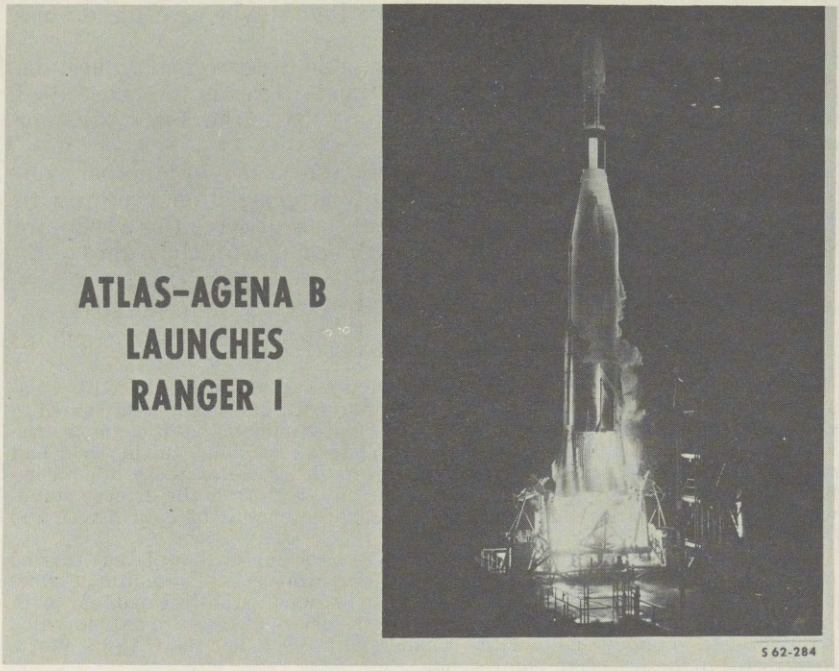

FIGURE 410

Mr. CORTRIGHT. Should I continue, Mr. Chairman?

Mr. KARTH. Yes.

Mr. CORTRIGHT. Slide. (Fig. 410.)

The Agena vehicle is shown here with an Atlas first stage in its first NASA launching from Cape Canaveral. It was developed by the Air Force as a second-stage booster for use with the first-stage Atlas and Thor boosters in their Discoverer and Midas programs.

Early in 1960, NASA decided to use the Thor-Agena B and Atlas-Agena B launch vehicles to fulfill its own requirements in this weight class rather than to develop similar vehicles in parallel.

This, of course, is in the spirit of the points you have been making, Mr. Chairman, and other members of the committee. The Agena, by the way, is from here on up [indicating]—the Atlas terminates at this point [pointing].

Mr. KARTH. We have no research and development in these vehicles at all, do we, Mr. Cortright?

Mr. CORTRIGHT. No, sir. In the procurement of our Agena we made a minor modification to the Air Force Agena, inasmuch as we required a clean parting plane built so we could bolt various types of payload onto the front end; whereas, their vehicles were integral throughout. This added flexibility, and is a procedure which they are now going to follow.

By this means, the costs of duplicate development were saved and both agencies expect to benefit in the areas of increased reliability at

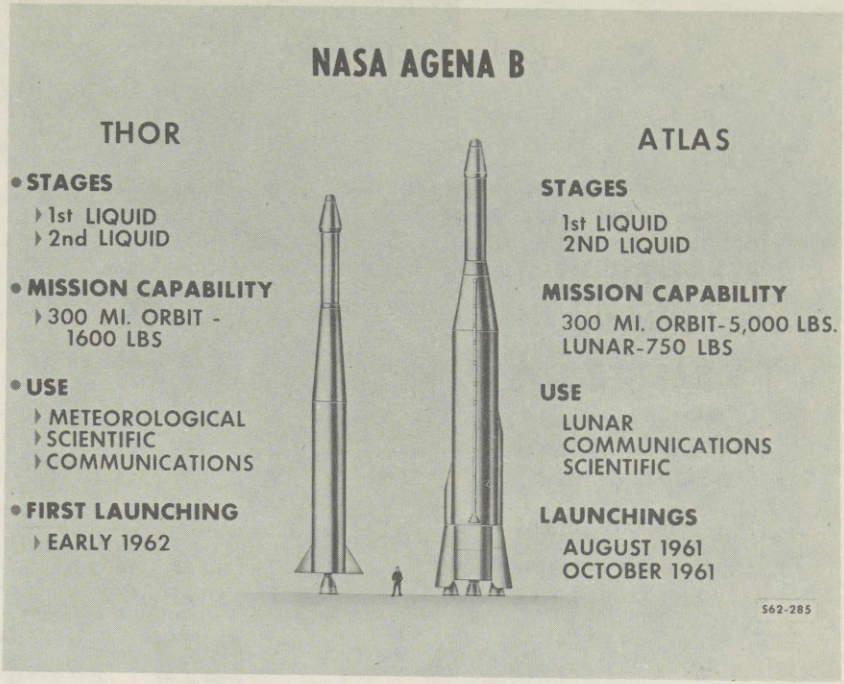

FIGURE 411

lower unit costs due to the increased number of launchings. (Fig. 411.)

The Thor-Agena B, shown in the left of this chart consists of the Thor IRBM first stage and the Agena B second stage. Liquid oxygen (lox) and kerosene (RP–1) are used as propellants in the Thor. Unsymmetrical demethylhydrazine (UDMH) and inhibited red fuming nitric acid (IRFNA) are the Agena B propellants. The Thor-Agena B is capable of placing about a 1,600-pound payload into a 300-mile orbit and will be employed by NASA for launching meteorological, communications, and scientific satellites starting in early 1962.

The same Agena B stage is shown on the right side of the chart with an Atlas ICBM first stage booster. This Atlas utilizes the same propellants as Thor and, when combined with the Agena B, is capable of launching 5,000 pounds into a 300-mile orbit or a 750-pound payload on a trajectory to the Moon. NASA will employ the Atlas-Agena B for launching lunar missions, communications, and scientific satellites.

In addition, as we mentioned the other day—Dr. Newell mentioned it—we are now using Atlas-Agena B for the Mariner "R" missions this year.

Out of a total of 47 successfully orbited space satellites launched in the U.S. space programs, 24, or over one-half, utilized the Agena vehicle in a variety of missions. NASA launched two Agena vehicles in late 1961 in lunar spacecraft tests, both using the Atlas first stage. Both missions were only partially successful in that the Agena failed

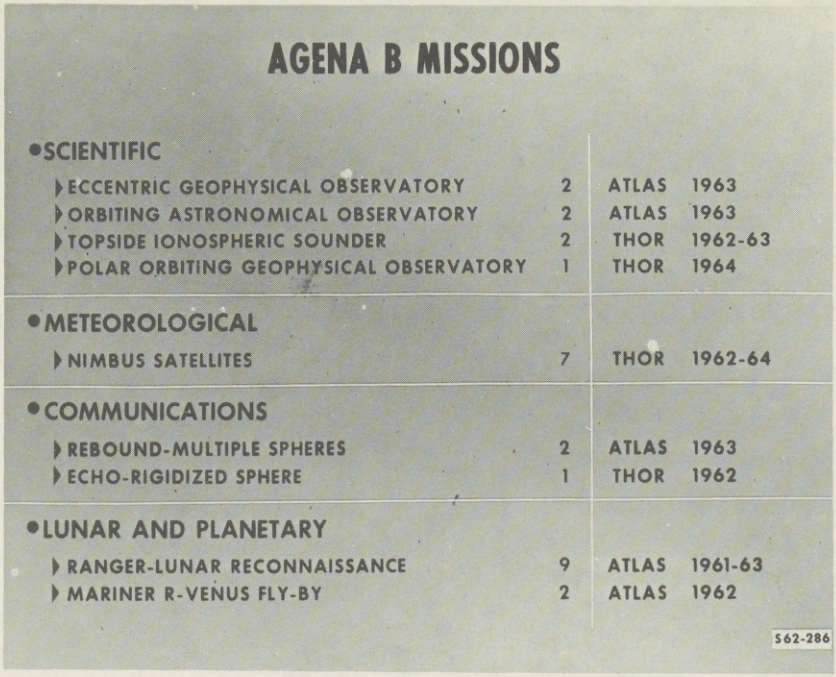

FIGURE 412

to place the spacecraft in its final prescribed trajectory. Corrective action has been taken to prevent recurrence of these failures in the next lunar launch early in 1962.

Unfortunately, though the Agena stage performed very well, the Atlas experienced a rare guidance failure resulting in a 23,000-mile miss of the Moon with Ranger III. I am sure you are all familiar with that fact. (Fig. 412.)

During the next few years, the Atlas- and Thor-Agena B vehicles are expected to be the workhorses in the NASA launch vehicle program. Until the Centaur and the Saturn become operational, the Atlas-Agena B will be used for the NASA heavy duty missions. This chart reflects the 28 presently planned missions for NASA Atlas- and Thor-Agena B launched vehicle programs, including the two lunar tests conducted in late 1961. The payloads include lunar and planetary missions, meteorological and communications satellites, and a variety of scientific satellites. Additional applications are currently in the planning phase, and it is anticipated that NASA will use the Agena vehicle into the 1970 time period. Atlas-Agena launches will be conducted primarily at the Atlantic Missile Range and the Thor-Agena launches will be from the Pacific Missile Range.

Mr. KARTH. Are there any questions?

Mr. HAMMILL. That last statement, is there any special reason for that?

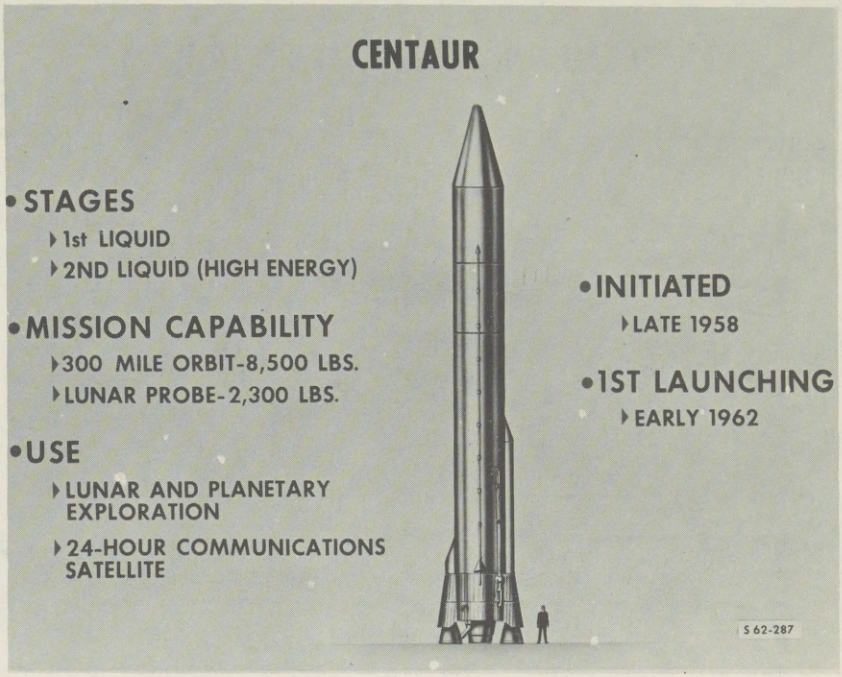

FIGURE 413

Mr. CORTRIGHT. Yes. The Pacific Missile Range missions, in general, are those which attempt to get a polar orbit which you can't do from the Atlantic Missile Range without overflying friendly countries.

The Thor-Agena is an adequate launch vehicle for such programs as Nimbus and Pogo, or polar orbiting geophysical observatory. That is essentially the answer to the question.

Mr. HAMMILL. The Atlantic Missile Range is used for what?

Mr. CORTRIGHT. Lunar and planetary missions and orbiting geophysical observatory.

Mr. HAMMILL. The overflight problem does not exist?

Mr. CORTRIGHT. We fly right down the range. (Fig. 413.)

The objective of Project Centaur is to provide a general purpose launch vehicle of high performance and reliability for Earth satellite, lunar, and planetary exploration missions of the National Aeronautics and Space Administration and the Department of Defense. Centaur will be the first free-world rocket vehicle to utilize high energy liquid hydrogen as fuel and, as such, will provide much of the basic knowledge required for the design of the upper stages of the Saturn and Nova rocket vehicles, and for the design of the Rover nuclear propulsion system, all of which will use liquid hydrogen. In addition, Centaur vehicles will carry ion and arc jet electrical propulsion systems for flight tests, the Advent military communications satellites, and the Mariner probes intended for the Nation's exploration of the planets

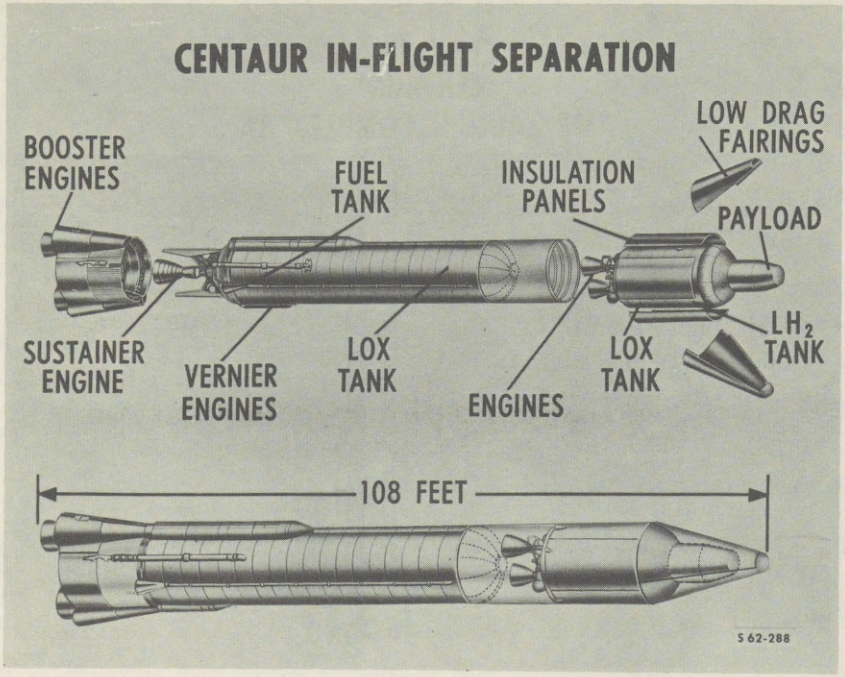

FIGURE 414

Venus and Mars. In direct support of the manned lunar landing objective, Centaur will also provide a vital function as a vehicle for preliminary unmanned exploration of the Moon's surface (Project Surveyor). It is expected that other military and civilian missions in space will use the Centaur in the future.

This chart shows a drawing of the Centaur vehicle. It is composed of two stages: a modified Atlas ICBM as first stage, using liquid oxygen and kerosene as propellants; and the Centaur second stage, using liquid oxygen and liquid hydrogen as propellants. The vehicle's payload carrying capacity fills the gap between the Atlas-Agena B and Saturn C–1 launch vehicles. Centaur can carry 8,500 pounds into a low Earth orbit, or approximately 2,300 pounds on a flight to the Moon. The project was begun in late 1958 and we will launch the first developmental vehicle early in 1962, a little over 3 years from date of contract. The 10-vehicle development flight program is scheduled for completion by late 1963, whereupon Centaur will begin extensive service as an operational space mission launch vehicle. (Fig. 414.)

This chart shows the Centaur vehicle in an exploded view permitting identification of its parts. The Centaur second-stage engines are being developed by Pratt & Whitney Aircraft Corp. at West Palm

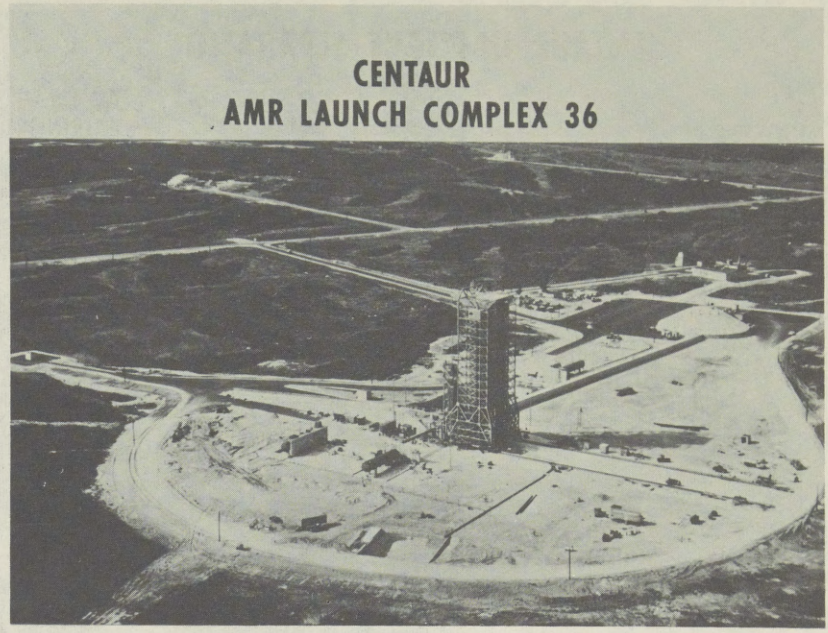

FIGURE 415

Beach, Fla. Each engine delivers 15,000 pounds of thrust when operating. The Centaur second-stage vehicle and the Atlas booster are produced by General Dynamics/Astronautics at San Diego, Calif.

Mr. CORTRIGHT. I will point out a few features which you may or may not be familiar with and which are not in the text.

This, of course, is the first stage of the Atlas which separates and the Atlas continues on sustainer. Upon separation of the Centaur stage, insulation panels are jettisoned. These are necessary on the ground and in the atmosphere to keep the hydrogen from boiling away, but they are things you want to get rid of as soon as you can so you don't have to boost that load to higher velocity.

Now we can continue to a photograph of the Centaur launch complex 36. (Fig. 415.)

This photograph shows the Centaur launch complex No. 36–A at Cape Canaveral. An additional launch pad, No. 36–B, which will utilize the same blockhouse, will be constructed at the intersection of these two roads in the upper left. The first Centaur launch from the second launch pad is scheduled for late 1963. (Fig. 416.)

This photograph shows the first flight Centaur second stage suspended in the complex 36 service tower prior to mating with the Atlas booster. (Fig. 417.)

CENTAUR STAGE AT AMR LAUNCH PAD

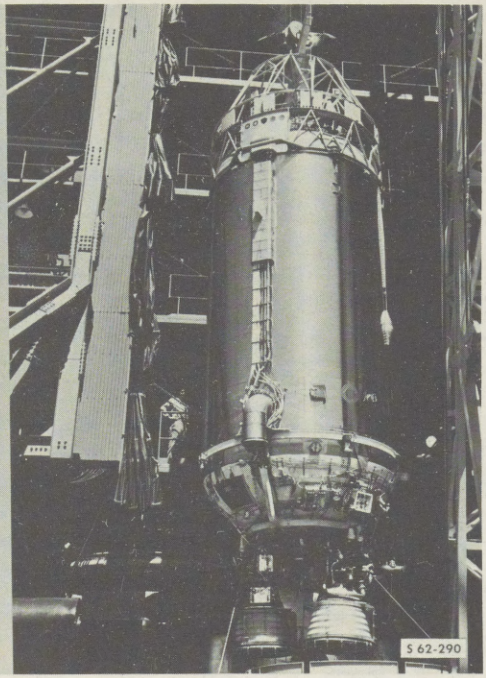

FIGURE 416

Here is the complete first-flight article erected on pad 36–A, after the service tower has been removed. The remaining structure is the umbilical tower with its utility connections to the vehicle. Preparations for first launch are currently underway. (Fig. 418.)

Here is a single Centaur hydrogen engine mounted in the altitude test facility at the Lewis Research Center, Cleveland, Ohio. In this facility, the engine is being tested at a simulated altitude of 100,000 feet to determine its operating characteristics under the vacuum conditions of space. (Fig. 419.)

Tests are currently underway at this test stand at West Palm Beach wherein two Centaur engines are operated simultaneously to insure no difficulty in flight due to their interaction. It was here in November 1960 that we experienced our first engine explosion due to ignition failure. A number of recent runs such as the one shown here have given assurance that the Centaur ignition problem has been solved. The engine is now qualified for flight. The multitude of preparations consuming the last 3 years will soon be subjected to the acid test.

For the future, there are several significant areas demanding our attention. Protecting the very cold liquid hydrogen in the Centaur tank from boiling away during flights in space continues to be a critical problem in the Centaur development program. In addition, we in-

CENTAUR ON LAUNCH PAD FOR FIRST FLIGHT

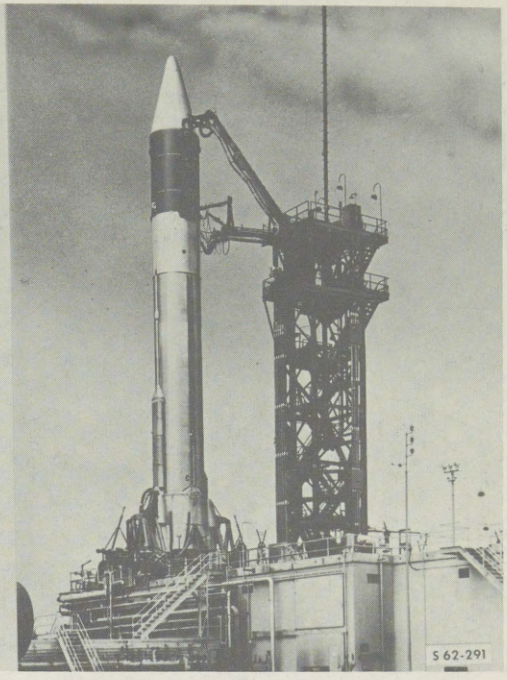

FIGURE 417

tend to proceed with a product improvement program which will increase the weight-carrying capability of the vehicle and thus make it increasingly useful for space missions in the future. (Fig. 420.)

The program which has been unfolded requires considerable tracking and data acquisition coverage. These will be explained in some detail in a presentation by Mr. Buckley in another subcommittee. More than a dozen minitrack stations and three deep-space tracking stations contribute to meeting this requirement of the space science program. (Fig. 421.)

The necessity for multiple station coverage may be more readily grasped in this chart which graphically shows the variety of satellite orbits and spacecraft trajectories. When it is realized that not only do we have several vehicles with which we must simultaneously communicate to retrieve scientific data, but we also have these vehicles in different positions along their respective orbits while the Earth is rotating on its axis, it is seen that the tracking and data retrieval problem is indeed a global one.

Although the more spectacular part of our program is embraced in space-flight missions, there is considerable Earth-based effort to test components, simulate environments, and otherwise guide our program. Such facilities are required to insure a knowledgeable execution of

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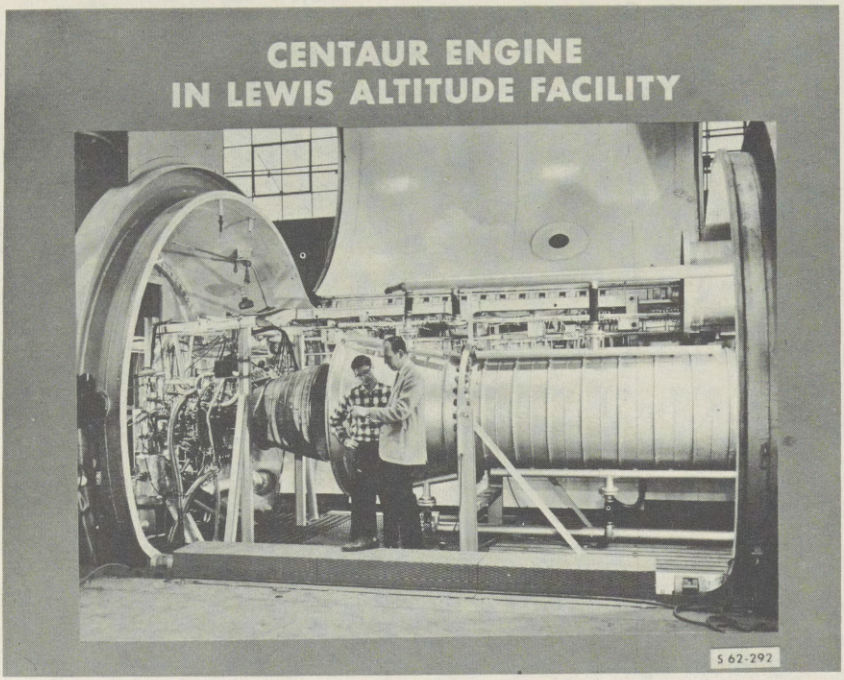

FIGURE 418

the resultant flight program, and include facilities for simulation of the space environment, vibration environment, planetary atmospheres, and the celestial sphere. Another type of Earth-based facility is the data and command center which permits scientists to view experimental progress in essentially real time and command appropriate sequencing as results of the experiment unfold.

The NASA science program is an all-inclusive program. In addition to a competent staff of civil servants, it draws upon the best talents it can find anywhere in the world. These experts come from the scientific community, universities, industry, other Government agencies, and (through international cooperation) from other countries. This wide participation is an essential ingredient of success in our space program.

Mr. CORTRIGHT. And at a later date, Mr. Chairman, we would like to insert for the record a tabulation of the participation of various scientists in this country and around the world in this program.

Mr. KARTH. All right, any time you find it convenient, we would like very much to have it.

Dr. NEWELL. Thank you.

Mr. KARTH. I would like to say this, Mr. Cortright and Dr. Newell, I think we will adjourn for the day. It may be that the member's

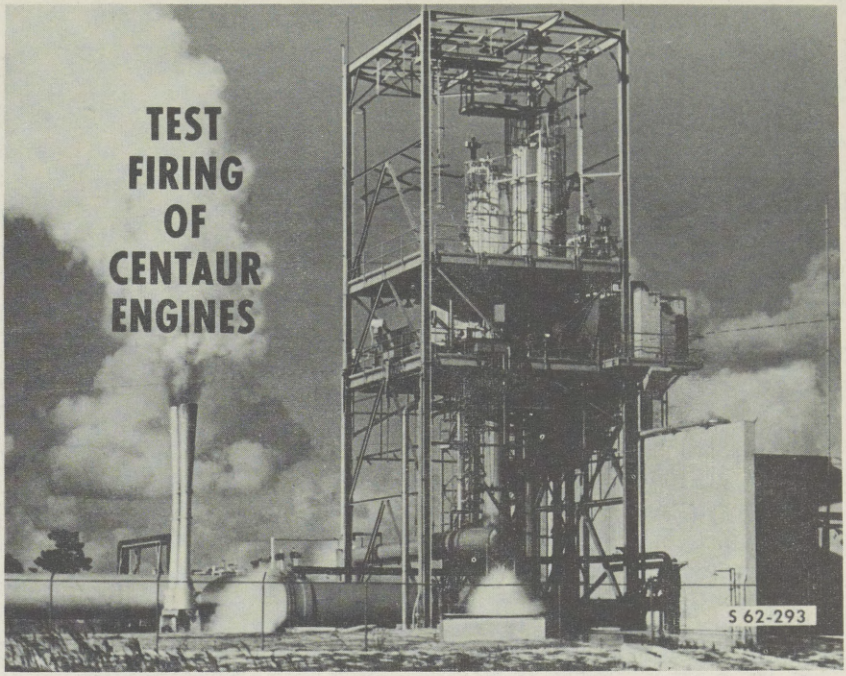

FIGURE 419

interest in the Centaur thing would take an hour or so. It is now almost 10 minutes to 12.

So if there are no objections from members of the committee, we will just leave this whole Centaur thing until next week, and adjourn for the day.

Dr. NEWELL. All right.

Mr. CORTRIGHT. May I ask a question, Mr. Chairman?

Mr. KARTH. Yes.

Mr. CORTRIGHT. We had planned with Mr. Frank Hammill that the launch vehicle presentation would come after additional details on the science, both the geophysics and astronomy and lunar and planetary.

If we are going to devote extended discussion on the Centaur, perhaps you would like to hear this presentation on launch vehicles in detail, rather than the broad-brush treatment I have given it. Do you have a preference, sir?

Mr. KARTH. I have no preference. Maybe the committee would have. I certainly don't have.

Mr. CORTRIGHT. Suppose we work out these details with Mr. Hammill, then?



FIGURE 420

Mr. KARTH. That is fine. The only reason I say we shouldn't get into the Centaur thing today is because we only have 10 minutes really, and it might take only 10 but it might also take an hour.

There is no sense in getting started in it, as we will have to get into it later on anyway.

Mr. Hammill has a question or two he would like to ask before we adjourn.

Mr. HAMMILL. On a couple of occasions during your testimony, the United Kingdom scientific satellite No. 1 was described as the first international satellite. I wonder if you would tell the committee what is involved in that experiment.

Dr. NEWELL. The United Kingdom No. 1 satellite, which will be reviewed in more detail by Mr. Clark later, is a satellite in which the experiments have been prepared by British scientists.

It is in the general area of ionospheric physics, although it includes solar physics as well.

In the preparation of this satellite the Goddard Space Flight Center has been the manager, and they have prepared the structure, provided the utilities, that is, the power supply, and the temperature control and so on—and made arrangements for the telemetry ground recording, and so forth, although the United Kingdom also will participate in the ground recording, of course.

The United Kingdom is paying for all of the experimental equipment, hardware, and so forth, that it is responsible for, namely, the sensors, the experiments themselves—and we are paying for all that

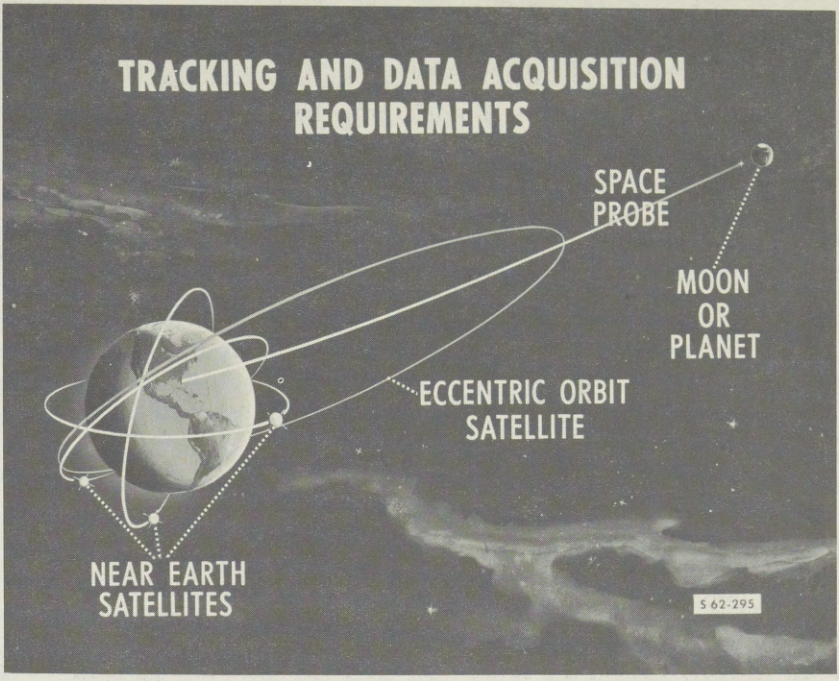

FIGURE 421

we have assumed technical responsibility for, namely, the structure and the vehicle and the necessary installations in the ground stations.

Mr. HAMMILL. What I was really interested in was whether or not this particular experiment duplicates anything that we have already done, or have programed for the future.

Dr. NEWELL. This is a very good question. We have taken the point of view that in our international cooperative projects the experiments that are performed should be substantive experiments that contribute to advancing the scientific field, and in discussing the experiments with the United Kingdom that should go into this satellite and into later ones, we have had as one objective to arrive at a set of experiments that fit very nicely into the total program, including our own domestic experiments.

Mr. HAMMILL. I see. Referring now to the scientific satellites programs, and the lunar and planetary exploration programs, are there other Government agencies involved in any of these experiments? If so, what are their functions, and how is their work funded? Perhaps that is an awfully broad question.

Dr. NEWELL. That is a portamento type question. Let me start out by saying, yes, there are other Government agencies involved in our program. Some of the involvement is as experimenters. For example, the Naval Research Laboratory scientists under Herb Friedman is involved in the Orbiting Solar Observatory program.

In the next satellite, in this program, they will have a major experiment in the "pointed" portion of the satellite.

There is participation on the part of scientists in the Bureau of Standards Central Radio Propagation Laboratory, again in the scientific experiments.

There are other cases that we may review for you, and I'll be glad to assemble a list of them—I don't pull them right out of the air at the moment.

Other Government laboratories are also participating in other aspects, for example. I might mention the Applied Physics Laboratory, which although it is not another Government laboratory, has been closely associated with the Bureau of Weapons program, and they are working with us in the development of an ionosphere satellite. So if you were to include that as essentially a Government laboratory, that would be another example—of their participation.

The Air Force, of course, has an extensive group of scientists very knowledgeable and experienced in fields related to the atmosphere and space science, and their scientists also paritcipate with us. For example, Hinteregger, of the Air Force Cambridge Research Center, which has a new name now that I have forgotten, is participating with us in our solar research, and has served as consultant to us in our planning functions.

Mr. HAMMILL. If you would review the question later on, and submit an answer for the record, I think that it might be of interest to the committee.

Mr. HAMMILL. One final question, if I may, Mr. Chairman.

What are the criteria that are used in selecting universities which work with NASA on the space science programs, and has there been any indication that the work has tended to concentrate in a small group of such universities? Finally, how much money is involved annually in such university contracts?

(The information requested is as follows:)

The attached tabulation of scientists participating in the scientific satellite and lunar and planetary program is compiled in a manner to indicate the agency where the scientist is located. This tabulation also gives information on other Government agencies involved in these experiments. It will be noted that there is no tendency for the work to concentrate in a small group. Individual scientists on the several institutional staffs are given NASA funds for their research on the basis of (*a*) the scientific merit of the research, and (*b*) the importance of the research in the space science program. During calendar year 1961 universities were supported by the scientific satellite and lunar and planetary programs in the amount of $10.8 million.

Participants in Office of Space Sciences programs

Country	Experimenter	Mission
Canada	Rose, D.C	Swept frequency topside sounder.
Do	Brown, R. K	Do.
Do	Chapman, J. H	Do.
France	Blamont, J. E	Sounding rockets (4), laboratory studies.
Great Britain	Boyd, R. L. F	International ionosphere satellite (UK No. 1) (3).
Do	Elliott, H	International ionosphere satellite (UK No. 1).
Do	Frith, R	International ionosphere satellite (UK No. 2).
Do	Jennison, R. C	Do.
Do	Quenby, J. J	International ionosphere satellite (UK No. 1).
Do	Savers, J	Do.
Do	Smith, F. G	International ionosphere satellite (UK No. 2).
Do	Stewart, H. K	Do.
Do	Willmore, A. P	International ionosphere satellite (UK No. 1) (3).
Do	Norman, K	International ionosphere satellite (UK No. 1).
New Zealand	Titheridge, J. E	Ionosphere beacon satellite (2).

Participants in Office of Space Sciences programs—Continued

	Location	Experimenter	Mission
NONPROFIT			
Armour Research Foundation.	Illinois	Hawrylewicz, E. J.	Biosciences (ground-based studies).
Carnegie Institute of Washington, D.C.	Washington, D.C.	Clark, S. P.	Surveyor (2).
Mellon Institute	Pennsylvania	Cohen, A.	Advanced studies.
Do	do	Massalski, T.	Do.
National Academy of Sciences.	Washington, D.C.	Jacobius, A.	Biosciences.
Do	do	Lapp, C. J.	Do.
National Academy of Sciences and National Research Council.	do	Trytten, M. H.	Do.
San Diego Science Foundation.	California	Dietz, R.	Advanced studies.
Stanford Research Institute	do	Lyon, R.	Do.
Armour Research Foundation.	Illinois	Davies, W.	Do.
INDUSTRY			
Advanced Kinetics Laboratory.	California	Waniek, R.	Do.
Aeronutronic (Ford)	do	Kay, Robert	Biosciences (ground-based studies).
Do	do	Walwick, Earle	Do.
General Atomics Corp	do	Schmitt, R.	Advanced studies.
Lockheed Aircraft Co	do	Fischer, P. C.	Sounding rockets (2).
Do	do	Hanson, W.	Do.
Do	do	Johnson, F.	Theoretical studies in atmospheric physics.
Do	do	McKibben, D.	Sounding rockets (1).
Do	do	Von Kenschitzki, C.	Theoretical studies.
Northrop Corp	do	Lindberg, R. G.	Biosciences (ground-based studies).
Do	do	Mitchell, D. R.	Do.
Rand Corp	do	Cunningham, R. W.	Theoretical studies.
Do	do	Kahle, A.	Do.
Do	do	Kern, J. W.	Do.
Do	do	Schilling, G.	Advanced studies.
Do	do	Stebbins, D.	Theoretical studies.
Do	do	Sugiura, M.	Do.
Do	do	Vestine, E. H.	Do.
Solid State Radiation Corp	do	Friedland, S.	Advanced studies.
Space Technology Laboratory.	do	Farley, T. A.	Analysis and interpretation of Explorer VI and Pioneer V data.
Do	do	Graves, C.	Advanced studies.
Do	do	Rosen, A.	Analysis and interpretation of Explorer VI and Pioneer V data.
Do	do	Smith, E.	Advanced studies.
Do	do	Saunders, N. L.	Analysis and interpretation of Explorer VI and Pioneer V data.
Ball Bros. Research Corp.	Colorado	Dolder, F.	OSO pointing control.
Electronic Communications, Inc.	Maryland	Cohn, M.	Research on instrumentation.
Do	do	Eikenberg, A.	Do.
Do	do	Packard, R.	Do.
Do	do	Wiltse, J.	Do.
American Science & Engineering, Inc.	Massachusetts	Harmon, N. F.	Orbiting astronomical observatory.
Geophysics Corp. of America.	do	Manring, E. R.	Sounding rockets (16).
Do	do	Marmo, F. F.	Laboratory studies.
Do	do	Smith, L. G.	Sounding rockets (14), laboratory studies.
American Science & Engineering, Inc.	do	Giacconi, R.	Orbiting astronomical observatory.
National Research Corp	do	Goldblith, S. A.	Biosciences (ground-based studies).
Do	do	Keller, W. H.	Do.
General Mills	Minnesota	Anderson, A. A.	Do.
Do	do	Green	Do.
Do	do	Jones, S. P.	Do.
International Telephone & Telegraph.	New Jersey	Blanchard, R.	Advanced studies.
Airborne Instrument Laboratories.	New York	Barna, G.	Fixed frequency topside sounder.
Do	do	Offutt, Warren B.	Do.
General Electric	do	Dickey, R.	Advanced studies.
Wilmot Castle Corp	do	Bruch, C.	Biosciences (space probe sterilization).

Participants in Office of Space Sciences programs—Continued

	Location	Experimenter	Mission
Melpar	Virginia	Blei, Ira	Biosciences (ground-based studies).
Resources Research, Inc.	Washington, D.C.	Levin, Gilbert V.	Do.
GOVERNMENT AGENCY			
Atomic Energy Commission (Argonne).	Illinois	Gordon, S.	Do.
AEC (Argonne)	do	Shen, J.	Do.
Air Force Cambridge Research Institute.	Massachusetts	Sagalyn, Rita C.	Eccentric orbiting geophysical observatory.
Air Force Air Research and Development Command, Andrews.	Maryland	Kelly, H. R.	Engineering support for modifying 2 X–15 airplanes.
U.S. Army (Fort Detrick)	do	Phillips, Charles (Dr.)	Biosciences (spacecraft sterilization).
Army Rocket and Guided Missile Agency.	Alabama	Copeland, J.	Mariner R (2) and Mariner B (2).
U.S. Geological Survey	Washington, D.C.	Adler, I.	Surveyor (2).
Do	California	Shoemaker, E. M.	Ranger (7), Surveyor (2), advanced studies.
National Bureau of Standards.	Washington, D.C.	Branscombe, L. M.	Fixed frequency topside sounder, sounding rockets (2), research on radiometric standards for extreme UV.
Do	do	Kessler, K. G.	Research on instrumentation.
Do	Colorado	Knecht, R. W.	Fixed and swept frequency topside sounders; sounding rockets (2).
Do	do	Lincoln, V.	Research in solar monitoring.
Do	do	Little, C. G.	Ionosphere beacon (2).
Do	do	Roach, F.	Advanced studies.
Do	do	Shapely A. H.	Research in solar monitoring.
Do	do	Van Zandt, T. E.	Fixed and swept frequency topside sounders; sounding rockets (2).
Do	do	Wright, J. W.	Analysis of ionograms.
U.S. Naval Ordnance Test Station.	California	McBride, W.	Research on instrumentation.
National Research Laboratory.	Washington, D.C.	Chubb, T. A.	Ranger (2), eccentric orbiting geophysical observatory, and orbiting solar observatory.
Do	do	Friedman, H.	Sounding rockets (2).
Do	do	Kolb, A. C.	Research.
Do	do	Kreplin, R. W.	Ranger (2).
Do	do	Purcell, D.	Orbiting solar observatory (2).
Do	do	Tousey, R.	Orbiting solar observatory (5).
U.S. Navy (School of Aviation Medicine).	Florida	Beischer, D. E.	Biosciences.
Smithsonian Astrophysical Observatory.	Massachusetts	Davis, R.	Sounding rockets (2) OAO.
Do	do	Jacchia, L.	Air density-drag measurement satellite, theoretical studies.
Do	do	Whipple, F. L.	Orbiting astronomical observatory, sounding rocket, theoretical studies.
Smithsonian Institution	Washington, D.C.	Diegman, S. L.	Biosciences.
NASA	do	Coleman, Paul J., Jr.	Mariner R (2).
Do	do	Horowitz, Richard	Atmospheric structure satellite (2).
Do	do	Sonett, Charles P.	Mariner R (2).
Ames	California	Bader, Michael	Energetic particles satellite (2), orbiting geophysical observatory.
Do	do	Robinson, G. G.	Orbiting solar observatory.
Do	do	Young, Richard (Dr.)	Biosciences.
Goddard Space Flight Center.	Maryland	Alexander, Wesley M.	Micrometeoroid satellite (2), ionosphere direct measurement satellite, Mariner R (2), Ranger (2), orbiting solar observatory, orbiting geophysical observatory, and 2 sounding rockets.
Do	do	Behring, William E.	Orbiting solar observatory (2), sounding rockets (4).
Do	do	Berg, O. E.	Sounding rockets (2).
Do	do	Boggess, A.	Do.
Do	do	Bourdeau, R.	Sounding rockets (2), ionosphere direct measurement satellite.
Do	do	Bryant, Duncan	Energetic particles satelites (2).
Do	do	Cline, T. L.	Eccentric orbiting geophysical observatory.

Participants in Office of Space Sciences programs—Continued

	Location	Experimenter	Mission
Goddard Space Flight Center—Continued	Maryland	Davis, L. R	Energetic particles satellites (2).
Do	do	Donley, John L	Ionosphere direct measurement satellite.
Do	do	Donn, B	Sounding rockets.
Do	do	Fichtel, C	Do.
Do	do	Frost, Kenneth J	Orbiting solar observatory (2).
Do	do	Guss, D	Sounding rockets.
Do	do	Hallam, K. L	Orbiting solar observatory (2) and eccentric orbiting geophysical observatory.
Do	do	Hauser, W	Sounding rockets (2).
Do	do	Heppner, J. P	Magnetic field probe (2), orbiting geophysical observatory and Ranger (2).
Do	do	Hess, W	Orbiting solar observatory.
Do	do	Jackson, John E	Electron density profile probe (2).
Do	do	Kane, Joseph A	Ionosphere direct measurement satellite and sounding rockets (2).
Do	do	Kupperian, J	Sounding rockets (9).
Do	do	Lindsay, J.C	Sounding rocket.
Do	do	Longenecker, G. W	Energetic particles satellite (2).
Do	do	Martin, F. T	Sounding rocket (8).
Do	do	McCracken, C	Orbiting solar observatory and orbiting geophysical observatory.
Do	do	McDonald, Frank B	Energetic particles satellite (2), orbiting geophysical observatory and IMP.
Do	do	Milligan, J. E	Orbiting astronomical observatory (2).
Do	do	Neunert, W. M	Orbiting solar observatory.
Do	do	Nordberg, W	Sounding rockets (11).
Do	do	Ogilvie, K	Sounding rockets (8), vac-sorb pump sampler.
Do	do	Powell, R. S	Orbiting solar observatory.
Do	do	Reber, C	Atmospheric structure satellite.
Do	do	Russell, S	Fixed frequency topside sounder.
Do	do	Scearce, C. S	Magnetic field probe (2).
Do	do	Schaefer, David H	Energetic particles satellite (2).
Do	do	Secretan, L	Micrometeoroid satellite (2).
Do	do	Serbu, Gideon P	Ionosphere direct measurement satellite.
Do	do	Skillman, T. L	Magnetic field probe (2).
Do	do	Spencer, Nelson	Atmospheric structure satellite, sounding rockets (5), eccentric orbiting geophysical observatory.
Do	do	Stolarik, J. D	Ranger (2).
Do	do	Taylor, H	Sounding rockets (4), orbiting geophysical observatory.
Do	do	Whale, H. A	Electron density profile probe (2), sounding rocket.
Do	do	White, W. A	Orbiting solar observatory (3).
Do	do	Wolff, C. L	Do.
Jet Propulsion Laboratory	California	Anderson, H. R	Mariner R (2), Surveyor (2), and Ranger (2).
Do	do	Brown, Walter E., Jr	Sounding Rocket and Ranger (3).
Do	do	Bull, H. P	Ranger (2).
Do	do	Dolbies, E	Ranger (7).
Do	do	Heacock, R	Do.
Do	do	Jones, D. E	Mariner R (2).
Do	do	Kaplan, L	Do.
Do	do	La Porte, B. D	Ranger (2).
Do	do	Metzger, A	Ranger (3).
Do	do	Neugebauer, G	Mariner R (2).
Do	do	Neugebauer, Marcia	Mariner R (2), Ranger (2).
Do	do	Smith, E. J	Mariner R (2), Mariner B (2), EGO (2).
Do	do	Snyder, C. W	Mariner R (2), Ranger (2).
Langley Research Center	Virginia	Bressette, W. E	Air density-drag measurement satellite.
Do	do	Coffee, Claude W., Jr.	Air density-drag measurement satellite (3).
Do	do	D'Aiutolo, C. T	Micrometeoroid satellite (2).
Do	do	Hopko, W. N	Sounding rockets (2).
Do	do	Hord, R	Sounding rockets (5).
Do	do	Kinard, W. H	Sounding rockets (2).
Do	do	Murrow, H. N	Sounding rockets (approximately 200).

Participants in Office of Space Sciences programs—Continued

	Location	Experimenter	Mission
Langley Research Center—Continued	Virginia	O'Sullivan, W. J., Jr.	Air density-drag measurement satellite.
Do	do	Tolefson, H. B.	Sounding rockets (approximately 200).
Lewis Research Center	Ohio	Conger, C. C.	Micrometeoroid satellite.
Do	do	Davidson, E. H.	Micrometeoroid satellite (2).
Do	do	Potter, A. E.	Sounding rockets (4).
Marshall Space Flight Center.	Alabama	Holderer, O.	Saturn (3).
Do	do	Taiani, A.	Sounding rockets (approximately 200).
Do	do	Vaughan, W. W.	Sounding rockets (approximately 200), Saturn (3).
UNIVERSITY			
University of Alaska	Alaska	Akasofu, S.	Theoretical magnetodynamic studies.
Do	do	Chapman, S.	Do.
University of Arizona	Arizona	Kuiper, G. R.	Ranger (7), Surveyor (2), advanced studies.
Do	do	Meinel, A.	Lunar and planetary advanced studies.
Do	do	Wykoff, R.	Research on soft X-rays.
University of Arkansas	Arkansas	Testerman, M.	Laboratory studies.
Boston University	Massachusetts	Hawkins, G.	Advanced studies.
University of California, Berkeley.	California	Anderson, K. A.	Eccentric orbiting geophysical observatory, Surveyor (2), IMP.
Do	do	Bloom, L.	Orbiting solar observatory.
Do	do	Calvin, M.	Biosciences (ground-based studies).
Do	do	Elberg, S.	Do.
Do	do	Sagan, C.	Mariner R (2), biosciences, high-altitude balloon.
Do	do	Scher, S.	Biosciences (ground-based studies).
Do	do	Schroder, C. A.	OSO.
Do	do	Silver, S.	Biosciences (ground-based studies).
Do	do	Tobias, C.	Do.
University of California, Los Alamos.	do	Anderson, E.	Ranger (3).
Do	do	Van Dilla, M.	Do.
University of California, Los Angeles.	do	Kennedy, G. C.	Surveyor (2).
Do	do	MacDonald, G.	Advanced studies.
University of California, San Diego.	do	Arnold, J.	Do.
Do	do	Arrhenius, G.	Surveyor (2), advanced studies.
Do	do	Goldberg, E.	Do.
Do	do	McIlwain, C.	Trapped radiation studies.
Do	do	Suess, H.	Advanced studies.
Do	do	Urey, H. C.	Ranger (7), advanced studies.
University of California, Santa Barbara.	do	Walker, W. C.	Research.
California Institute of Technology.	do	Benioff, H.	Advanced studies.
Do	do	Brown, H.	Surveyor (2), advanced studies.
Do	do	Davis, L., Jr.	Mariner R (2), advanced studies.
Do	do	Neher, H. V.	Mariner R (2), Surveyor (2), Ranger (2).
Do	do	Press, F.	Ranger (3), Surveyor (2), advanced studies.
University of Chicago	Illinois	Fan, C. Y.	Ranger (2), IMP.
Do	do	Meyer, P.	Do.
Do	do	Parker, E.	Advanced studies.
Do	do	Simpson, J. A.	Eccentric orbiting geophysical observatory, Ranger (2), IMP.
Do	do	Turkevich, A.	Advanced studies.
University of Colorado	Colorado	Athey, G.	Research.
Do	do	Rense, W. A.	Orbiting solar observatory, sounding rockets (2).
Do	do	Todd, E.	Orbiting solar observatory.
Do	do	Warwick, C.	Research (2 projects).
Do	do	Zirin, H.	Research.
Columbia University	New York	Cassidy, W.	Advanced studies.
Do	do	Ewing, M.	Ranger (3), advanced studies.
Cornell University	do	Gold, T.	Theoretical studies, advanced studies.
Do	do	Mitchell, T.	Theoretical studies.

Participants in Office of Space Sciences programs—Continued

	Location	Experimenter	Mission
Detroit University	Michigan	Szutka, A	Biosciences (ground-based studies).
Dudley Observatory	New York	Hemenway, C. L	Laboratory studies.
Florida State University	Florida	Barrow, C	Advance studies.
Do	do	De Busk, A. G	Biosciences (ground-based studies).
Do	do	Fox, S	Biosciences (ground-based studies) institute.
Do	do	Metz, C	Biosciences (ground-based studies).
Georgia Tech	Georgia	Davis, E. L	Theoretical studies.
Do	do	Edwards, H	Laboratory studies.
Harvard University	Massachusetts	Goldberg, L	Orbiting solar observatory.
Do	do	Liller, W	Orbiting solar observatory, sounding rockets (2).
Do	do	Lilley, A. E	Mariner R (2), ground-based research.
Do	do	Menzel, D	Advanced studies.
University of Hawaii	Hawaii	McAllister, H	Research on instrumentation.
Do	do	Steiger, R	Advanced studies.
Houston University	Texas	Lovelock J	Surveyor (2), advanced studies.
University of Illinois	Illinois	Swenson, G. W	Ionosphere beacon satellites (2).
Do	do	Wyatt	Eccentric orbiting geophysical observatory.
Do	do	Yeh, K. C	Ionosphere beacon satellites (2).
State University of Iowa	Iowa	Crandall, C. D	Eccentric orbiting geophysical observatory.
Do	do	Frank, L. A	Do.
Do	do	Maehlum, B	Eccentric orbiting geophysical observatory: Mariner R (2), Mariner B(2), Ranger (2).
Do	do	O'Brien, B. J	Energetic particles satellites (2).
Do	do	Rosser, W. G. V	Eccentric orbiting geophysical observatory: Mariner R(2), Mariner B(2), Ranger (2).
Do	do	Thissel, J. D	Eccentric orbiting geophysical observatory.
Do	do	Van Allen, J. A	Eccentric orbiting geophysical observatory: Mariner R(2), Ranger (2).
Johns Hopkins University	Maryland	Fastie, W	Sounding rocket.
Mankato State College	Minnesota	Tillinghast, E	Biosciences (ground-based studies).
University of Maryland	Maryland	Opik, E	Theoretical studies.
Do	do	Singer, F. S	Do.
Do	do	Tidman, D	Theoretical studies in plasma physics.
Massachusetts Institute of Technology.	Massachusetts	Barrett, A	Mariner R(2).
Do	do	Bieman, K	Biosciences (ground-based studies).
Do	do	Bridge, H. S	Eccentric orbiting geophysical observatory, Mariner B(2).
Do	do	Clark, G. W	Gamma ray astronomy satellite.
Do	do	Kraushaar, W. L	Do.
Do	do	Pinson, W	Advanced studies.
Do	do	Reintjes, J	Do.
Do	do	Rossi, B	Do.
University of Michigan	Michigan	Brace, L. H	Sounding rockets (6).
Do	do	Carignan, G. R	Sounding rockets (3).
Do	do	Estry, H. E	Sounding rocket.
Do	do	Haddock, F. T	Eccentric orbiting geophysical, sounding rocket, advanced studies.
Do	do	Hogarth, J	Sounding rockets (4).
Do	do	Hogey, W. R	Sounding rockets (3).
Do	do	Jones, L. U	Sounding rockets (6).
Do	do	Kuiper, J	Sounding rocket.
Do	do	Lindsay, W	Sounding rocket, EGO.
Do	do	Schaefer, E	Sounding rockets (6).
Do	do	Shulte, H	Sounding rocket.
Do	do	Siegel, K	Advanced studies.
Do	do	Walsh, D	Sounding rocket, EGO.
University of Minnesota	Minnesota	Brown, A	Biosciences (ground-based) studies).
Do	do	Gast, P	Advanced studies.
Do	do	Ney, E. P	Sounding rockets (8), orbiting solar observatory (2).
Do	do	Peterson, L	Orbiting solar observatory.
Do	do	Winckler, J. R	Orbiting solar observatory, orbiting geophysical observatory.

Participants in Office of Space Sciences programs—Continued

	Location	Experimenter	Mission
University of New Hampshire.	New Hampshire	Cahill, L. J., Jr.	Energetic particles satellites (2), sounding rockets (6).
University of New Mexico	New Mexico	Leavitt, C. P.	Orbiting solar observatory.
Do	do	Moore, R.	Advanced studies.
New Mexico State University.	do	Tombaugh, C.	Do.
New York University	New York	Beiser, A.	Theoretical studies.
Do	do	Taylor, H. Austin	Laboratory studies.
University of North Carolina.	North Carolina	Dal Matier, E. D.	Do.
Ohio State University	Ohio	Tice, T.	Advanced studies, research on instrumentation.
Oklahoma State University	Oklahoma	Cooper, O. L.	Sounding rockets (2).
Do	do	Todd, F. C.	Laboratory studies.
Pennsylvania State	Pennsylvania	Bowhill, S. A.	IQSY studies.
Do	do	Nisbet	Sounding rockets (3).
Do	do	Pollard, E.	Biosciences (ground-based studies).
Do	do	Ross, W. J.	Ionosphere beacon satellite (2).
Do	do	Waynick, A. H.	Sounding rockets.
Princeton University	New Jersey	Hess, H.	Surveyor (2), advanced studies.
Do	do	Rogerson, J.	Sounding rockets (2).
Do	do	Schwarzschild, W.	Advanced studies, orbiting astronomical observatory.
Do	do	Spitzer, L.	Orbiting astronomical observatory, ground-based research.
Rensselaer Polytechnic Institute.	New York	Greenberg, M.	Research.
Do	do	Harteck, Paul	Laboratory studies.
University of Rochester	do	Blakney, R.	Research on instrumentation.
Do	do	Fazio, G.	Orbiting solar observatory.
Do	do	Hafner, E. M.	Research.
Do	do	Savedoff, M.	Orbiting solar observatory.
Do	do	Stewart, H.	Research on instrumentation.
University of Southern California.	California	Weissler, G.	Advanced studies.
St. John's University	New York	Milford, S. N.	Research on interstellar gas.
Stanford University	California	Bloise, S.	Biosciences (2) ground-based studies.
Do	do	Bracewell, R. N.	Sounding rockets (2), EGO, ionosphere beacon satellite, theoretical studies, VLF studies.
Do	do	DeMendonca, F.	Do.
Do	do	Garriott, O. K.	Do.
Do	do	Helliwell, R. A.	Do.
Do	do	Lederberg, J.	Biosciences (2), ground-based studies.
Do	do	Pattee, E.	Do.
Do	do	Peterson, A. N.	Sounding rockets (2), EGO, ionosphere beacon satellite, theoretical studies, VLF studies.
Do	do	Villard, O. G.	Do.
Temple University	Pennsylvania	Bohn, S. L.	Laboratory studies.
University of Texas	Texas	Ingerson, F. E.	Surveyor (2).
Do	do	Montgomery, P.	Biosciences, ground-based studies.
Do	do	Straiton, A.	Advanced studies.
University of Wisconsin	Wisconsin	Bless, R.	Orbiting astronomical observatory, sounding rocket, X-15.
Do	do	Code, A. D.	Do.
Do	do	Houk, T.	Do.
Yale University	Connecticut	Brouwer, D.	Research.
Do	do	Lipsky, S. R.	Surveyor (2), advanced studies.
Do	do	Morowitz, H.	Biosciences, ground-based studies.
Do	do	Oster, L.	Theoretical astrophysics studies.
Do	do	Vishniac, W.	Biosciences (2), ground-based studies.
Do	do	Wildt, R.	Research.

Dr. NEWELL. That is a very good question and one that touches upon an important element of our program.

I think it deserves a fairly careful and rather longer answer than we could give before 12 o'clock.

Mr. KARTH. Why don't you prepare it, Dr. Newell, and we will go into it at the next meeting or any subsequent meeting you feel appropriate?

Dr. NEWELL. Fine.

Mr. HAMMILL. Perhaps Dr. Clark can answer this question in connection with his presentation.

Dr. NEWELL. All right.

Mr. HAMMILL. That is all I have, sir.

Mr. RANDALL. There are a lot of details I can come to later. I won't take the time now.

I may not be able to be here next week, Mr. Chairman. Are most of the audience here today Air Force staff, or what is the complex of it?

Mr. KARTH. I think most of these people are from NASA.

Mr. RANDALL. They are your backup men, is that it?

Mr. CORTRIGHT. Some of them.

Dr. NEWELL. These include our key people, and some of the men who are responsible for program management.

Mr. KARTH. I think the first day, Mr. Randall, when you were absent for the first hour or so, these people were introduced to the committee. Most of them are with the NASA organization and working in this field.

Mr. RANDALL. All right.

Mr. KARTH. This portion of NASA's program is concluded.

Thank you very much, Mr. Cortright and Dr. Newell.

We will meet at 10 o'clock on next Tuesday.

Mr. HAMMILL. Next week we will be in a smaller room across the hall, room 100–A. We will prepare the room and have it set up for you.

Mr. KARTH. Very well. The committee is adjourned until next Tuesday.

(Whereupon, at 11:58 a.m., the subcommittee adjourned, to reconvene at 10 a.m., Tuesday, March 13, 1962, in room 100–A, George Washington Inn.)

1963 NASA AUTHORIZATION

TUESDAY, MARCH 13, 1962

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON SPACE SCIENCES,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10 a.m., in room 100–A, George Washington Inn, Hon. Joseph E. Karth, chairman of the subcommittee, presiding.

Mr. KARTH. The subcommittee will be in order. Doctor Newell, how would you like to proceed this morning?

Dr. NEWELL. Mr. Chairman, if we may, we would like to have Dr. Clark go into more detail on the geophysics and astonomy programs.

Mr. KARTH. Yes, sir. Dr. Clark is Director of the Geophysics and Astronomy Programs.

STATEMENTS OF DR. JOHN CLARK, DIRECTOR, GEOPHYSICS AND ASTRONOMY PROGRAMS, AND MR. ORAN NICKS, DIRECTOR, LUNAR AND PLANETARY PROGRAMS, OFFICE OF SPACE SCIENCES, NASA; ASSISTED BY DR. HOMER E. NEWELL, DIRECTOR, OFFICE OF SPACE SCIENCES; MR. EDGAR CORTRIGHT, DEPUTY DIRECTOR, OFFICE OF SPACE SCIENCES; MR. JESSE J. MITCHELL, CHIEF OF FLIGHT SYSTEMS, GEOPHYSICS AND ASTRONOMY PROGRAMS; MR. ELDON TAYLOR, RESOURCES MANAGEMENT OFFICER, OFFICE OF SPACE SCIENCES

Dr. CLARK. Thank you, Mr. Chairman, and members of the subcommittee.

Dr. Newell and Mr. Cortright have discussed with you the broad outlines of our program in space sciences, including the scientific disciplines that I will discuss today, namely, geophysics, solar investigations, and astronomy.

I would like to go into more detail on the more important aspects of our projects activities. I shall begin with a very brief comment on the philosophical basis of our approach, then discuss the sounding rocket program, next the Explorer type small scientific satellite program, and finally the large satellite observatory program. In a scientific discipline sense we shall be going first through the geophysics program, then the solar investigations program, and finally the astronomy program.

As you recall from last week's testimony, the geophysics and astronomy portion of the NASA space science program is concerned with the Earth as a planet; the relationships between the Sun and

the Earth, that is, the nature of the control exerted by the Sun over events in the Earth's atmosphere; and the nature and history of the universe, particularly our galaxy, and more particularly our solar system.

These are the scientific objectives. Beyond this, we have a very strong responsibility to support applications programs, both civilian and military, by providing environmental data which they will need to prosecute their programs effectively and efficiently.

We have learned by experience, and we feel very strongly, that the most effective way to support these applied programs is by proceeding with a space research program which has the best balance scientifically. Only in this way can we uncover facts and phenomena of nature which may be of the utmost importance to these applications programs, but which, before their discovery were not even recognized as areas of special promise or difficulty.

I think one of the most obvious examples of this sort of thing is that of the radiation belt which, aside from some very modest theoretical speculation prior to their discovery by Van Allen, would not have been considered by any responsible scientist or engineer as a serious space flight problem. Yet, these belts have turned out to be a very serious problem for man in that region of space.

Solar outbursts are in the same category. We had thought that solar outbursts were rare, because we rarely saw solar cosmic ray outbursts at the earth's surface. Now we know that solar protons are probably the greatest hazard to manned flights higher in altitude than Mercury.

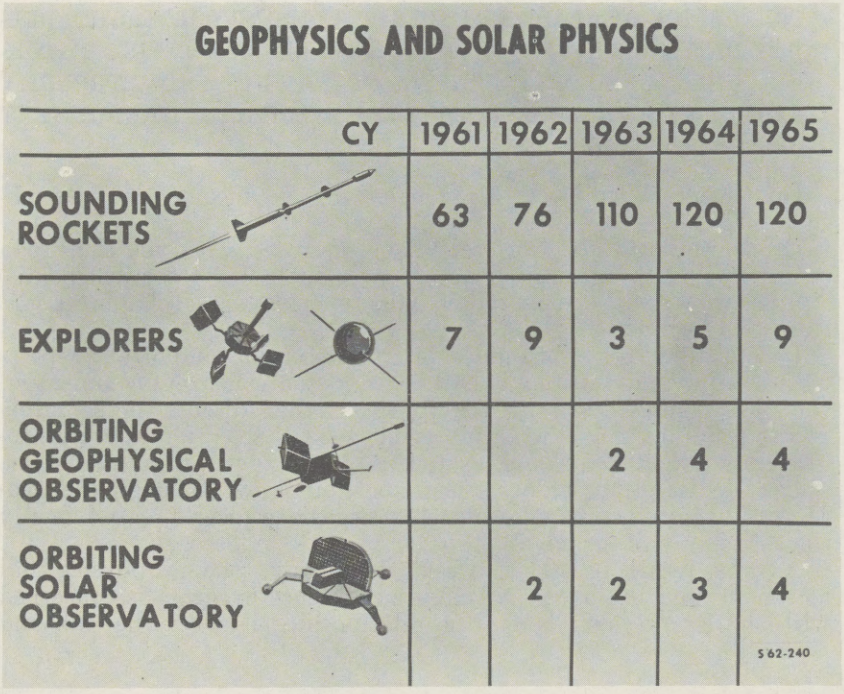

FIGURE 422

Let us turn to figure 422, the NASA geophysics and solar physics projected flight schedule through 1965. Note the first line which has to do with sounding rockets. You see that we are launching approximately 100 sounding rockets per year. What are the types of sounding rockets we are using, and why are we using them?

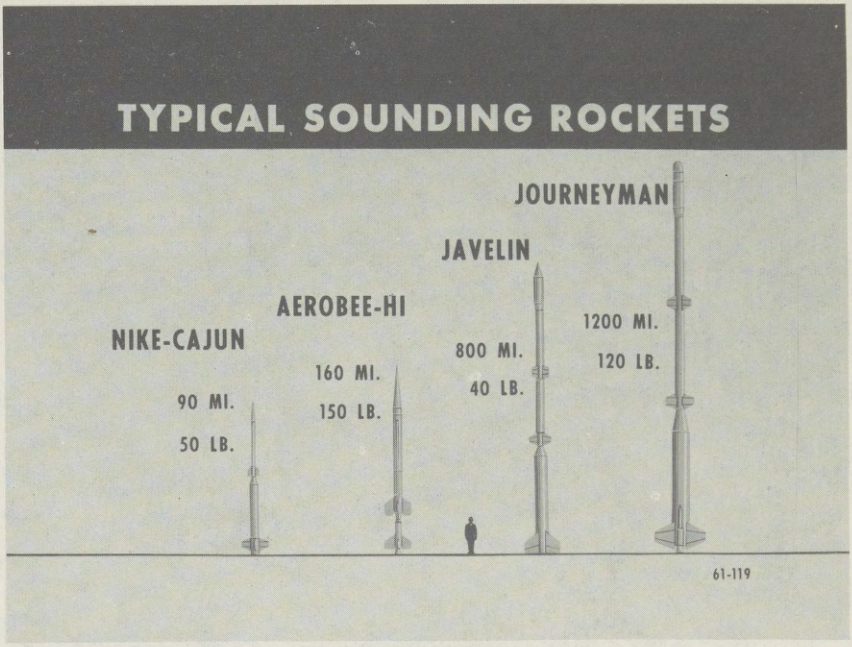

FIGURE 423

Figure 423 shows four of the standard sounding rockets. Some of you may recall this chart from last year's presentation to the Congress. This is because the sounding rockets are still the same, and for the most part they will continue to be the same over a period of some years.

They are well developed and very reliable. The success encountered with these rockets is much better than 50 percent, which in most space flight programs is considered to be a fairly respectable record.

You see that the altitude capability varies from 90 miles for the Nike-Cajun, to 1,200 miles for the Journeyman. These are all solid rockets with the exception of the Aerobee-Hi.

Solid rockets are useful primarily in geophysical investigations where we wish to react very quickly. If there is a solar outburst, then we like to get a rocket into the air rapidly. Solids are ideally suited to this type of operation because they can be launched on very short notice.

On the other hand, astronomers are fond of the Aerobee-Hi, because being liquid propelled it gives the vehicle a more gentle ride

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and is capable of carrying the relatively sophisticated pointing controls that we are now using for astronomical observations very effectively.

Mr. KARTH. What is the maximum capability of the Scout, Doctor?

Dr. CLARK. As a low altitude probe, it is 400 pounds, isn't it?

Mr. MITCHELL. Yes, and it depends on the altitude. The Scout electron density profile probe carries a payload of nearly 100 pounds to an altitude of 5,000 miles.

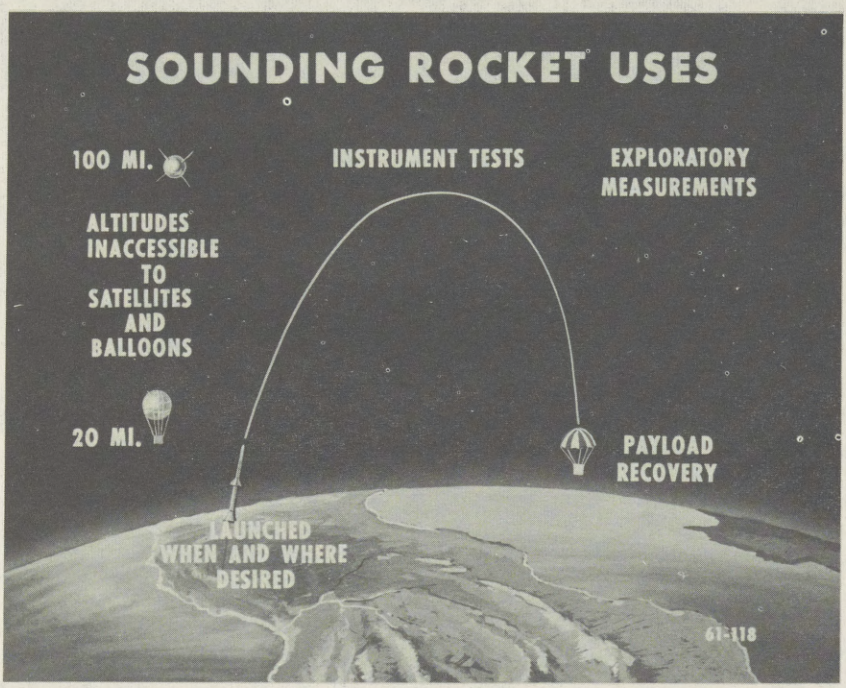

FIGURE 424

Dr. CLARK. Now, why are so many sounding rockets required? Figure 424 answers this question. You will recall that balloons have a maximum altitude capability of about 20 miles, and satellites have a minimum altitude capability of 100 miles, below which satellites of average density will spiral into the earth's atmosphere and burn up very quickly. So, at present, sounding rockets are the only vehicles which can give us data in this very important transition region between the upper and lower atmosphere.

Sounding rockets also provide a very inexpensive means to test equipment which is destined for flights in satellites, or for making exploratory measurements to determine ranges of sensitivity and similar information which is needed for subsequent satellite use. Also, it is obvious that payload recovery from sounding rockets is much easier than from satellites. The sounding rocket is a very flexible, relatively inexpensive tool which has costs measured in a few thousands or tens of thousands of dollars, as compared to the millions of dollars which are involved in satellite operations.

We feel that there is a continuing requirement for sounding rockets, and that this is only one phase of the NASA space science program philosophy which involves ground based measurements, balloon and aircraft measurements, sounding rocket measurements, geoprobe measurements, satellite measurements, and finally space probe measurements. The idea throughout is to use the cheapest tool which can meet the scientific requirements.

Now, let us return to the satellites in figure 422. We see that more of the relatively small Explorer type satellites will be launched per year than any other type, on a continuing basis. Next year the Orbiting Geophysical Observatory project will commence at the rate of two per year. The Orbiting Solar Observatory has already started

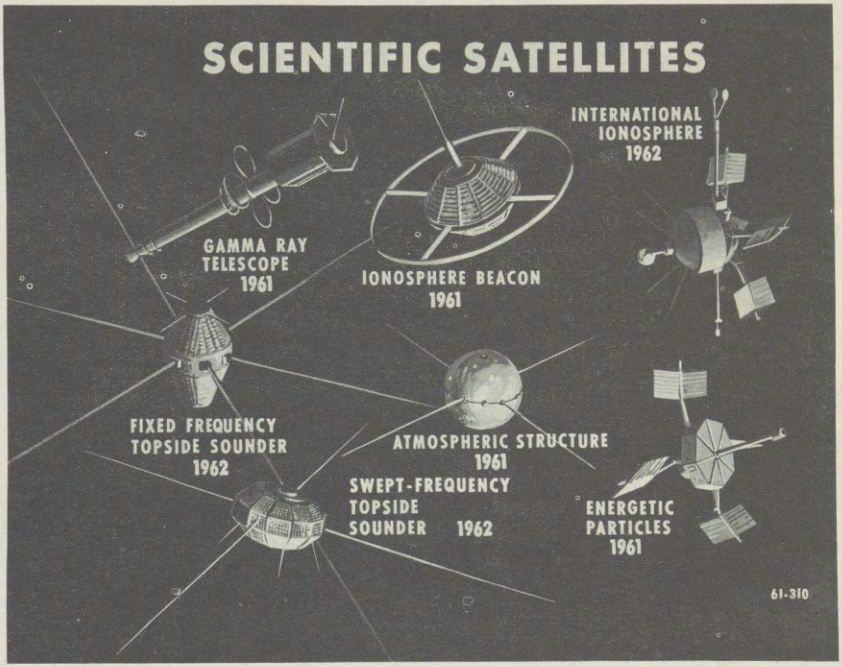

FIGURE 425

this year, again at the rate of two per year.

Now, what are these Explorer satellites? Figure 425 is another chart from last year's presentation to Congress, deliberately selected because it indicates something which is rather important about these small scientific satellites. It shows seven very different satellites with almost no family resemblance. Four of these were scheduled for launch in 1961, and three of them in 1962.

Now, what has happened to this schedule? One of these, the Atmospheric Structure Satellite, has been delayed and is scheduled for launch in 1962. Another, the Ionosphere Beacon Satellite, met with a series of misfortunes. We attempted two launches of this satellite in 1961 using the new obsolete Juno II launching vehicle. In

both of these we encountered a failure of the launch vehicle, so that the objectives of that spacecraft were not achieved.

On the other hand, the Gamma Ray Telescope was launched last year with outstanding success; Dr. Newell has already given you many of the details on what we learned from that satellite. The same thing is true of the Energetic Particles Satellite in which outstanding results were achieved. A second launch of this satellite is programed later this year in order to get new data over the continuing solar cycle.

Now, what of the three satellites that were scheduled a year ago for launch in 1962? I am happy to report that these are still scheduled for launch well before the end of this year. As a matter of fact, they are all scheduled for launch no later than the third quarter of 1962. This points up the fact that we have now had enough experience with these small scientific satellites to schedule them with assurance of success, on time, and at relatively low cost. When we decide that something should be done using this class of satellites, the probability is very high that it can be done.

Mr. KARTH. Do you think for the record you could name those satellites, Doctor?

Dr. CLARK. Yes, sir. The Gamma Ray Telescope was Explorer XI, and the Energetic Particles Satellite was Explorer XII. For 1962 we have the Fixed Frequency Topside Sounder, the Swept Frequency Topside Sounder, and the International Ionosphere Satellite.

Many of the experiments that were started in individual satellites we have found possible to continue in an integrated form, the idea being that it is scientifically necessary to coordinate data between various types of experiments if one wants to understand cross-discipline relationships. It is also more economical to launch experiments together when they have the same general orbital requirements, because advantage can be taken of common stabilization systems, common guidance and control systems, common data recovery systems, and so forth.

Figure 426 shows this integrated Orbiting Geophysical Observatory which is scheduled for launch next year.

The specifications for this satellite require that the total spacecraft weigh 900 pounds including all subsystems and structure, of which 150 pounds is for the experiments. We are using the term "experiments" in a rather restrictive sense here. We essentially furnish a space in which a standard box containing the experiment can be placed; this box may then be considered as an apartment in which all of the utilities, that is, power, heat, and so forth, are furnished. There are, of course, leads going back to the telemetry system to get the data back to the ground. The observatory is stabilized. There are programers to turn the experiments on and off at the proper time.

This standardized concept has the additional advantage that we are able to add experiments close to the launch date. Thus, if a new experiment has recently been performed which gives us data which must be followed up quickly, we are able to do so by replacing an older experiment by the new experiment. Hopefully, when this series of satellites become operational we can react up to within a month or so of the flight, by such a procedure.

Mr. KARTH. The satellite that was launched last week, Doctor, is it functioning at its optimum?

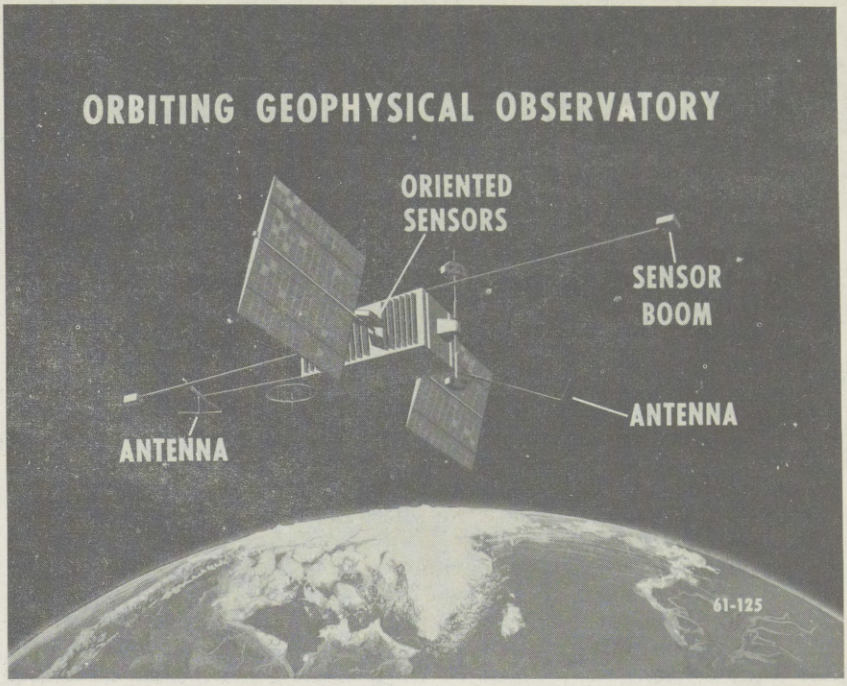

FIGURE 426

Dr. CLARK. The one launched last week was an Orbiting Solar Observatory. It is functioning; it is working exceedingly well, and we are very much gratified.

The booms that you see on the Geophysical Observatory are primarily for isolation of those experiments which interfere with, or may be jammed by other experiments. For example, the magnetic field sensors are always very sensitive to magnetic materials in the rest of the satellite.

There are various types of antennas, some having very broad patterns so that their signals may be received over wide areas of the Earth, and others which provide a narrow beam for the transmission of relatively wider bandwidth data.

There are experiments on the bottom surface which are always pointing at the Earth, and experiments on the top surface which always point away from the Earth. There are experiments in the solar paddles which always point at the Sun, and there are sensors which always point away from the Sun. There are even two orbital plane packages which rotate so that these packages are always in the plane of the orbit thus, the experiments point ahead toward that part of the atmosphere which has not been affected by the passage of the spacecraft.

This observatory represents a very advanced concept, and again the logical question is, what has happened in the past year?

A year ago we had just signed a letter contract with the prime contractor, S.T.L., and at that time set up the schedule for the first

launch of the Eccentric Geophysical Observatory in 1963. This schedule has been adhered to, and EGO is still scheduled for launch about a year from now.

Mr. KARTH. What is the estimated cost per vehicle, Doctor?

Mr. TAYLOR. Well, of course, we have to go through the development phase, which we would estimate at approximately $138 million, including salaries, support, spacecraft, and launch vehicles.

Dr. CLARK. This is for the first how many vehicles?

Mr. TAYLOR. For the first five flights of the development phase.

Dr. CLARK. And then what is the cost per vehicle?

Mr. TAYLOR. A repeat cost we estimate at around $15 million including experiments.

Dr. CLARK. Does that answer the question?

Mr. KARTH. Yes.

Dr. CLARK. There are many other factors that I can point out here, but I think we should move along.

I would like to take up at this time the question which you asked last week about our selection of experiments, because OGO is a vehicle which has the capability of accommodating up to 50 individual experiments, so the question of how we select these is certainly very pertinent.

First of all, let me cite some examples from the complete list of table I of 20 experiments which have been selected for the first observatory scheduled for launch next year. Professor Van Allen at the State University of Iowa has a Geiger-Mueller tube experiment for the study of energetic particles. In the same general area, Professor Winkler at the University of Minnesota, Dr. Bridge at MIT, and Professor Simpson at Chicago University are also participating.

TABLE I.—*Experiments for First Eccentric Orbiting Geophysical Observatory*

Experimenter	Location	Experiment title	Experiment description
Dr. Kinsey A. Anderson	University of California, Berkeley	Solar Cosmic Ray	Scintillation type detector to measure solar cosmic ray fluxes in the range from 2 to 90 Mev.
Dr. Thomas L. Cline	GSFC	Low-Energy Positron and Gamma Ray	Double gamma ray spectrometer to measure positrons (0 to 3 Mev.) and to monitor solar photon bursts.
Dr. Edward W. Hones, Jr	Institute for Defense Analysis		
Mr. Leo R. Davis	GSFC	Scintillation Counter Study of Trapped Protons and Electrons.	Ion-electron scintillation detector to study trapped electrons with directional energy flux, 10 Kev. $<E<$ 100 Kev. and the directional intensity of protons (120 Kev. $<E$ 4.5 $<$ Mev.).
Dr. Duncan A. Bryant	National Academy of Sciences Fellow, GSFC.	Determination of the Charge and Energy Spectra of the Primary Cosmic Radiation.	Cosmic ray telescope to study the charge and energy spectra of primary cosmic radiation.
Dr. Frank B. McDonald	GSFC		
Dr. C.Y. Fan	University of Chicago	Study of Low Energy Galactic Cosmic Radiation Flux.	Charged particle telescopes to investigate low-energy galactic cosmic radiation, to study energetic particle fluxes of protons above 0.2 Mev. and other nuclei at higher energies, and examine possibility for measuring isotopic abundances using solid state detector techniques.
Dr. Peter Meyer	do		
Dr. John A. Simpson	do		
Mr. L. A. Frank	State University of Iowa	Study of the Electron Component of the Outer Radiation Zone.	7 Geiger-Mueller tubes to measure the omnidirectional intensities of electrons of energies exceeding 40 Kev., 120 Kev., and 1.5 Mev.
Dr. James A. Van Allen	do		
Mr. Roger L. Arnoldy	University of Minnesota	Electron Spectrometer and Ionization Chamber Studies of Trapped Radiation and Cosmic Radiation.	Spectrometer to measure electron energy up to 4 Mev. Ionization chamber and Geiger counters to monitor galactic cosmic radiation and continually monitor the Earth's trapped radiation (electron energy from 20 Kev. to 20 Mev.).
Dr. John R. Winckler	do		
Dr. Robert E. Holzer	UCLA	Investigation of Magnetic Field Fluctuations.	Triaxial search coil magnetometer to investigate magnetic field fluctuations in the frequency range 0.01 to 1,000 cycles per second.
Dr. Edward J. Smith	JPL		
Dr. James P. Heppner	GSFC	Comprehensive Magnetic Field Measurements.	Fluxgate and rubidium-vapor magnetometer to measure magnitude and direction of magnetic fields, to measure accurately the magnetic field vector over range 1 to 100 gammas to accuracy $\leq$1 gamma.
Dr. Michel Bader	Ames Research Center	Investigation of Plasma Proton Component.	Plasma probe to measure proton concentrations ranging from 10^{-2} to 10^{-4} particles per cubic centimeter as a function of proton energy in the range 0.2 to 20 Kev.
Dr. A. Bonetti	MIT	Study of Plasma Protons and Electrons	Faraday-cup plasma probes to measure proton flux, proton energy spectrum, direction of flux, temporal and spatial variations of these quantities in the energy range from 10 Ev. to 10 Kev.
Dr. Herbert Bridge	MIT		
Dr. A. J. Lazarus	MIT		
Dr. B. Rossi	MIT		
Dr. F. Scherb	MIT		
Mrs. Rita Sagalyn	AFCRL	Spherical Electrostatic Analyzer	Spherical electrostatic analyzer to measure the concentration and energy distribution of charged particles. Energy distributions of these particles over range 0 to 1.0 Kev. for densities of positively and negatively charged particles with concentrations in the range 10 to 5×10^6 per cubic centimeter.
Mr. M. Smiddy	AFCRL		
Mr. Eldon C. Whipple	CSFC	Planar Ion and Electron Trap	Planar ion and electron trap to obtain the densities and energy distributions of charged particles of both polarities in the low-energy or thermal range. Energies measured and concentrations are about the same as Sagalyn's experiments. The 2 experiments are complimentary.

TABLE I.—*Experiments for First Eccentric Orbiting Geophysical Observatory*—Continued

Experimenter	Location	Experiment title	Experiment description
Dr. Robert A. Helliwell Mr. Louis H. Rorden	Stanford University Stanford Research Institute	VLF Noise and Propagation	Antenna and electronics to study radio noise and related propagation phenomena at low and very low frequencies (200 to 100,000 cycles per second).
Prof. Fred T. Haddock	University of Michigan	Radio Astronomy Experiment	Record and measure radio noise incident upon an electrically short dipole in the frequency bands 2 to 4 megacycles and 0.2 to 0.4 megacycles; primarily to measure the dynamic radio spectra of solar bursts.
Dr. H. J. A. Chivers Mr. R. S. Lawrence	CRPL CRPL	Radio Beacon	Transmitter to radiate linearly polarized signals toward Earth to measure number of electrons beneath the satellite. Frequencies in the range of 40 to 360 megacycles will be transmitted.
Mr. Harry A. Taylor	GSFC	Ion Mass Spectrometer	Radio frequency ion spectrometer to obtain a direct measurement of positive ion composition in the mass range 1 to 50 AMU.
Mr. Wesley M. Alexander Mr. Curtis W. McCracken	GSFC GSFC	Interplanetary Dust	Detector to measure the vectorial velocity distribution of dust particles with dimensions of about 0.5 to 5 microns, determine the cumulative mass distribution, observe the fluctuations in velocity and mass distribution and spatial density, effect of geocentric distance.
Dr. Philip Mange	NRL	Lyman-Alpha Scattering	Detectors to determine the contribution of geocorona and interplanetary medium to the Lyman-Alpha glow in the night sky.
Dr. Kenneth L. Hallam Dr. Charles L. Wolff Prof. S. P. Wyatt	GSFC GSFC University of Illinois Observatory	Gegenschein Photometry	Equipment to determine the cause and spatial extent of the Gegenschein. Pictures will be taken in the green, ultraviolet, and infrared regions.

In the area of magnetic fields, Dr. Heppner at the Goddard Space Flight Center of NASA, has a very sophisticated magnetometer experiment. Dr. Lawrence, at the Central Radio Propagation Laboratory of the Bureau of Standards, has an ionosphere radio propagation experiment.

This gives you a feel for the diverse scientific areas and the broad participation which is involved. As you will note, it includes participants from the university community, from the NASA complex including the Jet Propulsion Laboratory, and from other Government laboratories, including the Department of Defense and other agencies. The affiliation of the experimenter was not one of the selection criteria which were used. These criteria had to do only with the scientific excellence and technological feasibility of the experiment. Overall, there are eight experiments from universities, eight experiments from NASA laboratories, predominantly Goddard Space Flight Center, and four experiments from other Government laboratories.

Mr. KARTH. Were any other agencies of the Government participating from a financial standpoint, Doctor, or is this being totally funded by NASA?

Dr. CLARK. The situation varies depending upon the laboratory. Most of the other Government laboratories which participate do so financially only to the extent of bearing a portion of their internal overhead charges. In all cases, NASA bears the direct cost. The Air Force Cambridge Research Laboratory, for example, is charging us primarily for the components which they are purchasing, while absorbing a good bit of their salaries and miscellaneous expenses in their own budget.

Mr. KARTH. What do you estimate this total cost to be, outside of NASA?

Dr. CLARK. This is rather difficult to estimate. I don't think that it is a substantial percentage of the overall cost because the individual experiments run in the neighborhood of perhaps $200,000 to $400,000 apiece to a university or NASA laboratory where we are paying the entire expense.

In other words, we are being helped to the extent of only a fraction of this individual experiment cost by only 4 of the 20 participating experimenters.

Mr. KARTH. Well, whatever other outside financial participation there might be, is that relegated exclusively to salaries?

Dr. CLARK. Ordinarily, yes.

Mr. KARTH. As far as vehicle expenses, component parts, there is no outside participation.

Dr. CLARK. That is correct. NASA pays for all components. I don't think the outside participation, though, would amount to more than several hundred thousand dollars, so it is not a major factor. Does that answer the question?

Mr. KARTH. I think that is sufficient.

Dr. CLARK. Now, many of these experiments are related to figure 427 because they are in the subject area of energetic particles. This chart shows the energy of the various types of energetic particles about which we have been talking, such as solar protons, from 1 electron volt all the way to a million million electron volts. On the other vertical axis is plotted the flux, an index of the number of particles which will penetrate a unit surface per second in space. Here we

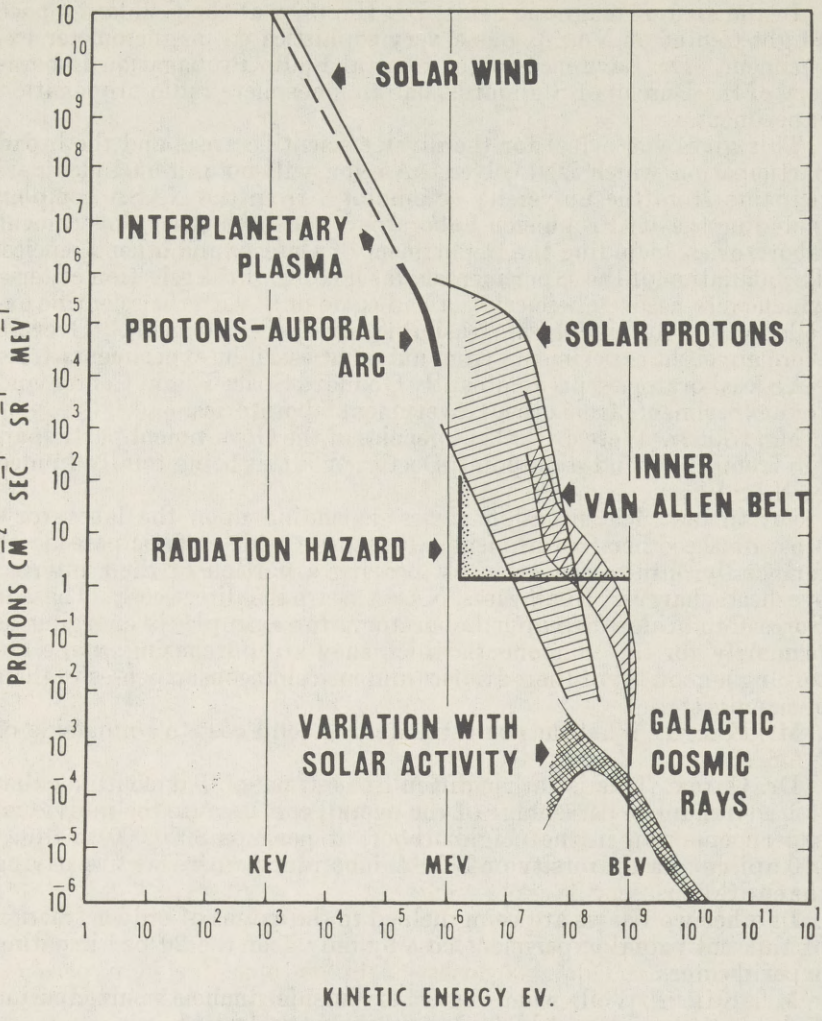

FIGURE 427

plot a great many of the geophysical and solar phenomena which are important to us. At the top, at the low-energy end, we see the solar wind. These particles are in the kilovolt energy range, a particle energy which can be stopped or shielded even by a very thin sheet of paper.

Then as you move to the megavolt—or million electron volt—range, there are energetic particles which produce the northern and southern lights, or auroras. Next we have two particle types which have different origins, but very similar energies, that is, solar protons and the inner Van Allen belt particles, in the neighborhood of 10 to 100 Mev. energy. At higher energies and even lower densities of flux, we have the primary cosmic rays which originate outside of the solar system, which go on to exceedingly high energies but with exceedingly low-numbers of particles.

The lowest energy shown in figure 427 is only one-millionth of the level which we have in its center, which, in turn, is only one-millionth of the maximum level shown, so the chart covers a very wide range of phenomena indeed.

Now, it is interesting to note which of these particles produces a radiation hazard. There is a vertical line which bounds the radiation hazard region on the left, which indicates that particles less than a little over 1 Mev. can be readily shielded out by means of the flight suit or capsule walls. The horizontal line which bounds the radiation hazard region on the bottom indicates that a minimum number of penetrating particles per second is required in order to constitute an appreciable radiation hazard. The only particles that fall in this area of the chart are the inner Van Allen belt particles and the solar protons, which is the reason why so much effort has been spent investigating these particles.

The Eccentric Geophysical Observatory has experiments which cover this entire spectrum all the way from the thermal particles, 1 electron volt, to primary cosmic radiation. We should be able to get a very good indication from these experiments of the total energetic particle spectrum function of time.

Speaking of the time variation, on figure 427 where it is a very broad band, as with solar protons, this indicates a strong variation in time; where the band is relatively narrow, this indicates relatively stable phenomena to the best of our present knowledge. Probably a year from now we will be coming back with a chart of this type which will look rather different, based upon information which we have gotten in the meantime.

Mr. KARTH. Have contracts already been let for the Apollo project?

Dr. NEWELL. Yes.

Mr. KARTH. Now, with regard to some of the things you are going to be learning in 1963 when these geophysical observatories are put into orbit. Might it not be too late to incorporate into the manned space flight program some of the things that you will find out as a result of your scientific experiments?

Dr. CLARK. This is always a difficult question to answer, Mr. Karth. I think the proper answer is that we try to keep a balanced program by, on the one hand, doing a variety of things, some of which experience tells us will turn out to have been very important to manned space flight, but not which. On the other hand, we try to be just as responsive as we possibly can to the already known needs of the manned space flight program.

Now, of course, we work very closely with the manned space flight program people, not only in planning our long-range program for the future, but also in modifying our existing program when certain aspects become considerably more significant than others, as is the radiation hazard. In this area, Explorers X and XII have already given us much of the information on figure 427.

This is an important reason why we are launching another Explorer XII type satellite this year, and why we are trying to be consistently responsive to this type of problem. You will recall that the sun is a highly valuable source of radiation, and we want to get information before it reaches its lowest ebb prior to building back up at the time Apollo will be flying.

Mr. KARTH. Well, my question, of course, was primarily directed at those aspects of the experiments applicable to the manned space flight program. I wonder whether or not your scientific discoveries could be incorporated into the Apollo project, or any one of the manned space flight programs?

I understand, of course, there will be certain scientific information which we will receive which will have no significance insofar as manned space flight is concerned. It will just be pure scientific data that will be worth the effort no matter what we do on the manned flight program.

Dr. CLARK. Yes.

Mr. KARTH. What about those portions of these experiments that will have an effect on the manned program, or are designed to answer questions for the manned flight program? Will we have those answers soon enough to incorporate into projects which have already been assigned a project?

Dr. CLARK. Yes; those areas of research now known to be important to manned space flight have been so phased that the data will be available in time to incorporate into the Apollo project.

Mr. KARTH. Requirements for shielding and things of that type. Shielding might be required to be heavier than we now assume, because of the Van Allen belt and so on.

Dr. CLARK. That is correct. You will recall the two means of protection that Apollo has, either shielding from solar outbursts, or predicting them far enough ahead to take cover. Both aspects are being investigated as parts of the geophysics and solar investigations programs.

Now, how are the scientific experiments and experimenters selected? The Space Sciences Steering Committee, chaired by Dr. Newell, is the group within NASA which makes the final decision as to what experiments fly on each and every scientific payload.

The recommendations are made by the chairmen of the various subcommittees of the Space Sciences Steering Committee in half a dozen scientific areas. These recommendations are reviewed by myself as the cognizant director of the geophysics and astronomy programs.

Mr. KARTH. May I interrupt here.

What constitutes the membership of the Space Sciences Steering Committee?

Dr. CLARK. There is Dr. Newell and Mr. Cortright, Mr. Nicks and myself, Mr. Mitchell and Dr. Sonett, and Dr. Reynolds. We all have line responsibility for the space sciences program.

In the selection of experiments for the first EGO there were four of the subcommittees that were involved. The subcommittees draw on some 50 of the outstanding scientists in the country, largely from the university community. They are chaired by NASA headquarters scientists, and include outstanding NASA and other Government experts.

About a year ago the subcommittees went over all of the experiments which had been proposed for EGO. They had several categories. There was a category of unacceptable experiments, and a category of experiments which were proven but were tending to become obsolescent in the light of new knowledge. There were new experiments which looked very promising indeed and should be prosecuted further.

but were not yet at a technologically feasible state. Finally, there were category I experiments which looked good scientifically, good technologically, and could be recommended without qualification.

We funded about 25 experiments, the best of these in category I, so that the individual proposers could spend some months developing their detailed plans for experiments. Then we had a 2-day meeting in which each of the experimenters had about a half hour to describe what they were doing, why and how they were doing it, and to answer questions from the NASA staff, our subcommittee consultants, and from each other.

It amounted to a graduate school thesis defense in which each of these men who believed in their work were required to defend it before a jury of their peers. Following the meeting, the four subcommittee chairmen involved got together and made their recommendations for the experiments in each area. They were able to come up with a unanimous recommendation which was subsequently endorsed by the space sciences steering committee. We feel this is the most advanced and significant payload in our entire geophysics program.

Figure 428 introduces the solar program. This is the Orbiting Solar Observatory which was just placed into orbit and is working so well.

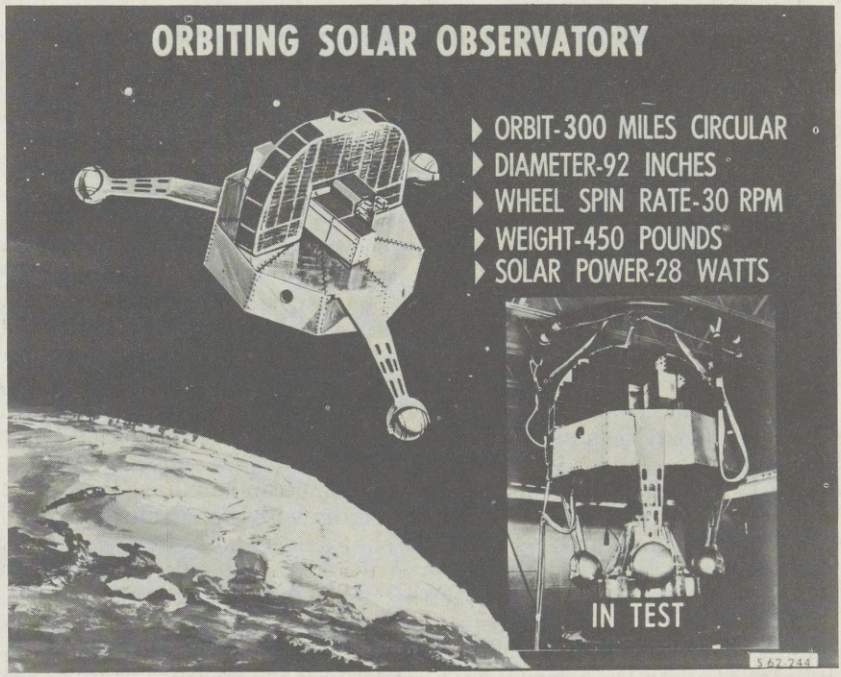

FIGURE 428

The intended orbit was nominally 350 statute miles circular. The actual orbit that was achieved was 340 miles perigee and 370 miles apogee, which is exceedingly good.

The diameter of the spacecraft is 92 inches, which is the diameter of the circle in which the arms will spin. The wheel is spinning at the rate of 30 revolutions per minute.

This is the heaviest satellite that we have yet launched in the U.S. scientific satellite program, weighing 450 pounds, and it also has the largest power capability of 28 watts, derived from the solar cells. This is a very interesting satellite conceptually.

The large nine-sided wheel or table, including the protruding arms with the gas bottles on the ends, is continuously spinning at one revolution every 2 seconds. This provides gyroscopic stabilization for the wheel, which is oriented so that the plane of its spin includes the Sun.

The oriented section, including the pointed experiments in the long cases and the sail with the solar cells, is then driven electrically in the opposite direction just fast enough so that it remains stationary in space and points at the Sun.

When, as will happen, the spin axis of the satellite starts to deviate gradually from the normal position, gas is blown out of one of the two top jets, causing the orientation to change in such a way that the pointed experiments again are pointed directly at the Sun.

There is also a fine electrical mechanism which permits these experiments to point up and down over several degrees. Early results indicate that the accuracy of pointing is the order of 2 minutes of arc, as planned. Two minutes of arc is equivalent to mounting a telescope in Baltimore and distinguishing between two objects on the order of 200 feet apart here in Washington. It is quite precise, but as you will see later, not nearly as precise as is required for astronomical purposes.

Mr. KARTH. What are the development costs for the solar observatory?

Mr. TAYLOR. We essentially have the two kinds here, the present Delta size and then in the future the Agena size. We estimate that the Delta spacecraft will run us around $60 million total for four flights.

Mr. KARTH. This includes the four vehicles?

Mr. TAYLOR. No, sir; this does not include the Delta vehicles. These run approximately $2½ million each.

Dr. CLARK. The experiments that are being run here have to do with the portion of the electromagnetic spectrum which we cannot see from the surface of the Earth. Figure 429 shows the gamut of the spectrum, from gamma rays through X-rays, ultraviolet, visible, infrared, to the radio spectrum. We can see through our atmosphere into space only in two "windows" in the visible and part of the radio wavelengths. All of the dark portions are regions in which we need satellites to get above the atmosphere in order to make measurements of the most interesting phenomena.

I would like to call your attention to the gamma and X-ray region where we know from rocket measurements that we will encounter considerable variation, depending on the activity of the Sun and particularly of the solar corona, which is studied best in the ultraviolet. The experiments are designed to take advantage of this.

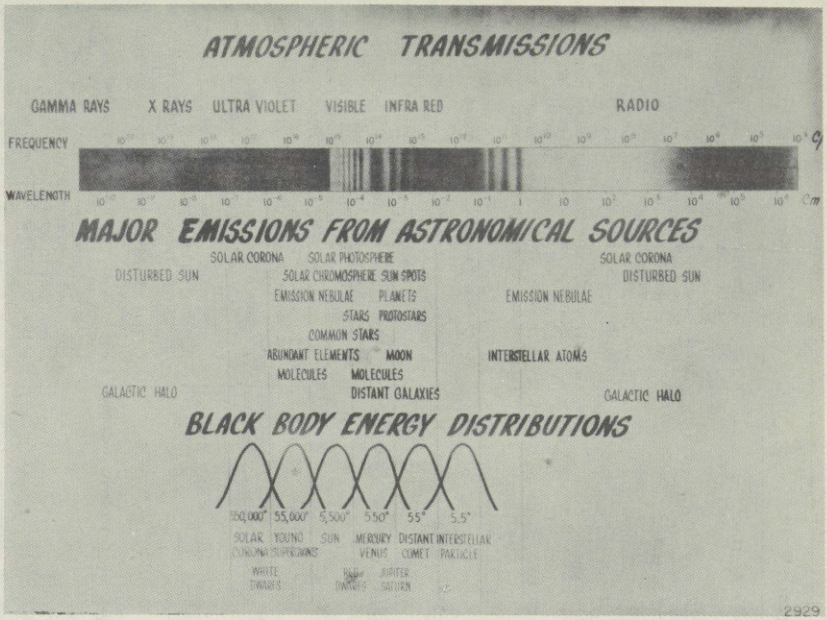

FIGURE 429

The principal experiment, the sweeping X-ray spectrometer, covers from 10 to 400 Angstroms, the very important region of the spectrum for solar corona studies.

There are also monitoring experiments which cover one range in the harder X-ray region, from 2 to 8 Angstroms, and two complementary gamma ray units, each covering a factor of about 10 in wavelength. Over a period of time these experiments will give us a much better idea of how much radiation exists in these various wavelengths, and how rapidly the radiation changes.

This is an area where our present ignorance is so total that it will be very difficult to determine which future experiments should be emphasized; until we have seen the data from OSO–I.

There are also on the wheel a somewhat larger number of experiments, eight altogether, which include an experiment in the visible region of the spectrum, to determine the variation in the solar constant from above the atmosphere, and a monitoring experiment in the ultraviolet just below the wavelength where the opacity of the atmosphere takes hold.

Again I will not go through all of the experiments in detail, but I would like permission to insert the total list on the record, as table II.

Mr. KARTH. Please do.

TABLE II.—*Experiments for the 1st Orbiting Solar Observatory, OSO I*

Experimenter	Location	Experiment title	Experiment description
Dr. William Behring	GSFC	Solar X-ray (10 to 400 Angstroms)	X-ray spectrometer to measure intensity of solar radiation as function of wavelength over the region 10 to 400 Angstroms.
Dr. Werner Neupert	GSFC		
Kenneth Frost	GSFC	0.51 Mev. Gamma Ray Monitor	Scintillator and photomultiplier to measure the 0.51 Mev. radiation from the Sun.
William White	GSFC		
Kenneth Frost	GSFC	20 to 100 Kev. X-ray Monitor	Thin crystal scintillator to measure 20 to 100 Kev. X-ray emissions from the Sun.
William White	GSFC		
Kenneth Frost	GSFC	1 to 8 Angstrom X-ray Monitor	2 ion chambers to measure solar X-ray flux in the 1 to 8 Angstrom region.
William White	GSFC		
Robert Young	GSFC		
Merle Alexander	GSFC	Dust Particle Experiment	A photomultiplier tube and microphone combination to measure influx rate, momenta, and kinetic energies of dust particles.
Curtis McCracken	GSFC		
Dr. Kenneth Hallam	GSFC	3800 to 4800 Angstrom Solar Radiation Experiment.	A photodiode with filter to measure variations solar flux as small as 0.1 percent.
Harold Murphy	GSFC		
William White	GSFC		
Dr. Kenneth Hallam	GSFC	1100 to 1250 Angstrom Solar Ultraviolet Experment.	An ion chamber to measure intensity of solar ultraviolet radiation in the region of Lyman-Alpha.
Robert Young	GSFC		
William White	GSFC		
William White	GSFC	0.2 Mev. to 1.5 Mev. Solar Gamma Ray Experiment.	2 scintillators backed by 2 photomultipliers, 1 set shielded and 1 unshielded, to detect gamma rays in the 0.2 Mev. to 1.5 Mev. range.
Kenneth Frost	GSFC		
Dr. Kenneth Hallam	GSFC		
Dr. John Winkler	University of Minnesota	50 Kev. to 3 Mev. Solar Gamma Ray Experiment.	A "Compton Telescope" consisting of a number of scintillators, photomultipliers, shields, and special electronic circuitry to measure intensity and direction properties of gamma rays between 50 Kev. to 3 Mev. of energy.
Dr. L. E. Peterson	do		
Dr. Wilmont Hess	University of California; now with GSFC	Neutron Monitor Experiment	Moderated boron trifluoride detector to measure neutron flux from the Earth and the Sun.
Dr. S. Bloom	University of California	Lower Van Allen Belt Studies	A scintillator detector and electronic circuitry to distinguish between proton and electron radiation.
Dr. M. Savedoff	University of Rochester	100 Mev. to 500 Mev. Gamma Ray Experiment.	An instrument consisting of a lead sheet, a plastic cylinder (Cerendov cylinder), a photomultiplier tube, and an anticoincidence scintillator to detect high energy gamma rays originating from the Sun and other regions of the sky.
G. Fazio	do		
G. G. Robinson	ARC	Emissivity Stability of Surfaces in a Space Environment.	7 test surfaces coated with various temperature control materials are placed in thermally isolated mountings and the temperature is measured as a function of time by means of thermistors in order to evaluate the stability of the test surfaces in the space environment.

Dr. CLARK. Mr. Taylor remarked that even as we have the first Orbiting Solar Observatory in orbit, we are making plans for a follow-on observatory, and the question arises as to why, since this is so successful, we are considering making any changes.

The problem is that what we wanted to do in 1959 was to get something in orbit that could make preliminary measurements just as soon as possible. You will recall that all of the 1962 geophysics and astronomy flight projects were conceived and started 2 to 3 years ago.

It takes this sort of time to get a worthwhile experiment into orbit, and experience has shown that the results we get control future experiments, so it is important to have both an ongoing program as well as a future program. The inadequacies of the present Orbiting Solar Observatory are pointed out in figure 430.

FOLLOW-ON SOLAR OBSERVATORY

- LONG OPTICAL PATHS
- ACCURATE POINTING
- SCAN CAPABILITY
- HIGH DATA STORAGE CAPACITY
- MAXIMUM UTILIZATION OF PAYLOAD CAPACITY

FIGURE 430

The present observatory does not provide a sufficiently long optical path length, nor does it point accurately enough to make a high-definition scan over the solar surface to determine how the output of each element varies. The present observatory measures the total integrated light from the entire solar disk. Also, it does not have the capability of an offset scan, in the outermost regions of the corona, which in space we should be able to see quite a way from the surface of the Sun. Even with a weight of 450 pounds, we do not have a sufficiently high data storage capacity to do any sort of detailed solar scanning.

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Then there is the requirement for maximum utilization of payload capacity. In order to get gyroscopic stabilization, the bulk of the payload weight cannot be continuously pointed at the Sun because it must be used for stabilization, so something like a third or less of the total payload weight can be pointed at the Sun, whereas in the follow-on observatory the entire payload will be pointed at the Sun by other means.

Mr. KARTH. What is the launch vehicle for the followon solar observatory?

Dr. CLARK. Tentatively, the Atlas-Agena. I say tentatively because we are involved in a study of these problems now, and the final decision concerning the follow-on observatory specifications will depend upon the information in the various competing proposals.

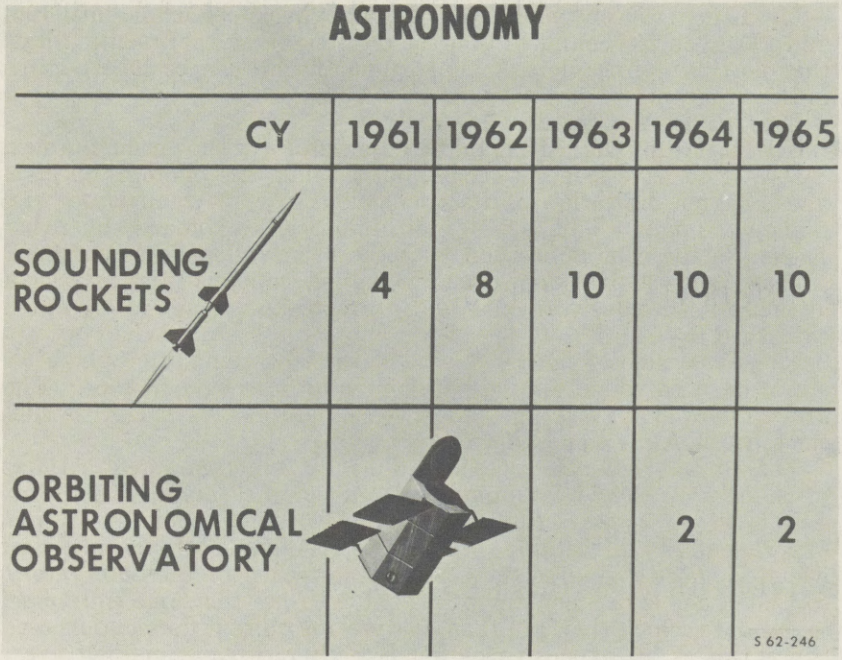

FIGURE 431

Let us then turn to the astronomy program. Figure 431 is the flight program as presented in Dr. Newell's testimony. The numbers of sounding rockets are considerably less for astronomy than they are in geophysics, because in geophysics we must take measurements at many locations over the Earth be ow satellite altitudes, but in astronomy all we need is to observe above the obscuring atmosphere in both the Northern and Southern Hemispheres.

For the most part, then, astronomy sounding rockets are used principally to test and calibrate experiments intended for use in satellites over much longer periods of time.

The heart of our astronomy program is the Orbiting Astronomical Observatory. We are planning two OAO launch attempts per year in calendar 1964 and 1965.

Mr. KARTH. Are any of the results of that experiment planned to be used in the manned space flight program?

Dr. CLARK. They will not be as obviously applicable as those of the geophysics and solar programs to early phases of Apollo. However, the Orbiting Astronomical Observatory will be used for some astronomical observations of the planets, so that we will get much better information on their nature, particularly that of Mars and Venus, primarily spectroscopically. It may well turn out that this will be very important information to future manned planetary exploration.

I say it may well be important because this is information that we simply don't have now. We will have to wait until we see its nature. I would say that we will be able to answer this question better several years hence.

Mr. KARTH. Even though your flights will not be made until 1964 and 1965, you feel confident that the results of the experiment, at least that portion applicable to manned lunar flight, can be incorporated in the program?

Dr. CLARK. Yes, we do.

The nature of the astronomical observatory is shown on the next chart. You have seen the model, but I think this photograph gives you a better indication of its tremendous size in comparison with that of the man. This is a 10-foot high satellite launched by Atlas-Agena, in the orbital position with the solar cell paddles unfolded. The top cover is provided so that if the telescope inadvertently looks at the Sun, the cover can close and prevent any damage to the optics contained inside.

The remainder of figure 432 indicates the sort of atmosphere obscuration with which ground-based observatories have to cope. Figure 429 showed in a more quantitative manner those wavelengths which come through the atmosphere.

The initial OAO objectives are primarily to obtain a detailed map of the sky in ultraviolet light and to develop a standard space observatory. It appears that in some OAO experiments the original experimenters will be able to complete their observations in a time which is short compared with the total lifetime of the observatory, so that other experimenters will be able to use the same equipment to get data which they can then analyze for quite different purposes. Since this is an expensive national facility, we are making every effort, in cooperation with the astronomical community through the Astronomy Subcommittee of the Space Sciences Steering Committee, to select experiments which will have maximum impact on astronomical and astrophysical theories, and to develop techniques for making maximum use, not only of this spacecraft as a mounting for other standard types of experiments, but also to use the experimental equipment itself for as many different experiments as possible.

Mr. KARTH. What is the estimated cost of this program?

Mr. TAYLOR. Well, again including the salaries, and the launch vehicle, for complete development for three flights, we estimate around $184 million.

Dr. NEWELL. That includes the vehicle, Mr. Chairman.

Mr. KARTH. Yes; I understand.

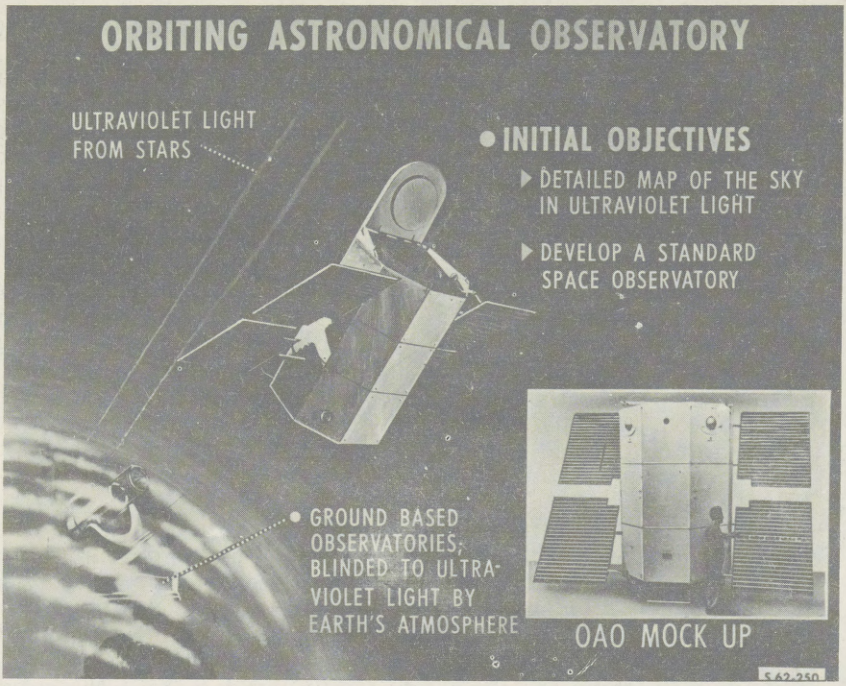

FIGURE 432

It was quite surprising, wasn't it, Doctor, that Colonel Glenn reported the stars looked pretty much the same during his orbital flight as they do on a nice clear night from the desert?

Dr. CLARK. Well, calculations show that the optical absorption of the window through which he was looking was just about the same as that of the entire atmosphere, so this is something which——

Mr. KARTH. Say that once more.

Dr. CLARK. The absorption of visible light in the window through which he was looking is just about the same as the atmosphere through which we are looking. He did have the advantage of being above levels at which scintillation or twinkling would occur.

Mr. KARTH. The instruments in these experiments will have the same drawback, won't they?

Dr. CLARK. No, sir. These will be directly exposed. Special techniques will be used so that the windows will be transparent to light of the wavelength under investigation.

For example, in this solar observatory X-ray spectrometer, the slit is in a vacuum, so that the X-radiation can go straight through the slit, bounce off the grating, and into the detector. The whole instrument is evacuated so that there is no absorption. The photons, or individual packets, of X-radiation then hit the first electrode of the photomultiplier detector tube, where electrons are knocked loose, to be collected by the next electrode in the chain. The entire assembly is operated in the vacuum of space, without windows, to take advantage of the unusual circumstances of the environment. This is the general type of approach that is being used in all of the experiments.

Mr. KARTH. Did the flight of Colonel Glenn change your mind as to the worth of this program?

Dr. CLARK. No; the one really unexpected thing Colonel Glenn came back with had to do with the luminescent particles. Since this is something clearly associated with the spacecraft or its launch vehicle, and not with outer space as such, we feel that the estimates that we have made of the worth of the solar and astronomical observatories has essentially been justified by the information that he came back with, rather than conversely.

OAO EXPERIMENTS

SPACECRAFT	INSTITUTION	EXPERIMENT	POINTING ACCURACY	EXPOSURE TIME
I	SAO	UV MAPS	5′	2 MIN
I	U. of WISCONSIN	UV PHOTOMETRY	5′	1 MIN
II	GSFC	MODERATE DISPERSION UV SPECTROMETRY	1′	40 MIN
III	PRINCETON U.	HIGH DISPERSION UV SPECTROMETRY	0.″1	12 HR

FIGURE 433

Figure 433 is a list of the experiments on the first three Orbiting Astronomical Observatories. The first spacecraft carries a double experiment, one looking out each end of the telescope tube. The Smithsonian Astrophysical Observatory is interested in mapping the sky in the ultraviolet. We use a 2-minute exposure time at each setting of the pointing controls with an accuracy of 5 minutes of arc, which is no more severe a requirement than that for the first Orbiting Solar Observatory.

The other experiment on the first OAO, by the University of Wisconsin, is ultraviolet photometry, to obtain somewhat more quantitative information as to the intensity of the ultraviolet radiation from various stars.

The second OAO will carry a Goddard Space Flight Center experiment in which more detailed information will be acquired concerning the ultraviolet flux by putting it through a spectrometer to determine the intensity of the ultraviolet radiation within each pass band of the spectrometer. Since there will be a smaller amount of light when the spectrum is sliced into smaller pieces, the spectrograph will have to maintain its pointing for a longer period of time, 40 minutes. About five times the pointing accuracy of the earlier experiments is also required, to reduce the effect of background illumination.

These experiments have been graduated in their technological requirements so that as the capability of the spacecraft improves, we can use experiments of higher definition.

The experiment in the third OAO utilizes the full design capability of pointing accuracy. This is the Princeton University high dispersion ultraviolet spectrometry in which the spectrum is divided into even smaller segments so that we can study astrophysical processes in more detail. Here we need to point the instrument at a given star to a tenth of a second of arc. This is the ultimate accuracy of the system as now envisioned, and you will recall Dr. Newell's analogy in which a telescope in Baltimore under these conditions can distinguish between the right and left eyes of an individual, and study their color and texture. This pointing accuracy is required for a 12-hour period, which will require many orbits.

This is a very difficult job, but one which will pay tremendous rewards to astronomers. The OAO will probably make possible some of the great advances in the science of astronomy during this century, by opening up the entire spectrum to which earthbound observers have heretofore been blind.

Mr. DOWNING. What is the total cost of this project?

Dr. CLARK. The experiments, spacecraft, launch vehicle, the whole thing?

Mr. TAYLOR. Approximately $184 million.

Dr. CLARK. You gave the number of observatories earlier?

Mr. TAYLOR. Yes, sir; three observatories.

ASTRONOMICAL SATELLITE REQUIREMENTS

- LARGE APERTURE OPTICS
- STRUCTURAL STABILITY
- HIGH POINTING ACCURACY AND STABILITY
- FLEXIBLE POINTING TO KNOWN LOCATION
- 400 - 500 MILE EQUATORIAL ORBIT
- TV DATA TRANSMISSION

FIGURE 434

Dr. CLARK. The requirements of this type of satellite observatory are summarized in figure 434. Very large aperture optics are needed, to collect a lot of light to minimize the exposure time. Excellent structural stability is required over a wide range of temperature and loading in order to maintain the alinement of the large aperture optics.

You all realize what a tremendous job it was to build a hundred-inch telescope on the ground. Well, we are using a 36-inch telescope in this satellite. We need, of course, very high pointing accuracy and

stability because we need to confine each observation to a very small part of the sky, in order to minimize the background illumination and work down to as faint a source as we possibly can.

We need flexible pointing to known locations, remotely, of course, and we need a 400- to 500-mile altitude, low equatorial inclination orbit, with very wide band TV-type data transmission.

Let's look at this orbit. We haven't been talking very much about the orbits of these different types of satellites, and it is a very important concept.

The Solar Observatory OSO–I, which is now orbiting at an altitude of some 350 statute miles, is moving in a plane which is inclined at an angle of some 33° to the Earth's equator. What we are trying to do is to stay away from the Van Allen belt radiation, which might interfere with sensitive optical detectors, and at the same time get as high above the atmosphere as we can. This puts a rather rigid floor under our orbital altitude, and an equally severe ceiling on top of it.

For the geophysical observatories, on the other hand, we are trying to sample the total environment of the Earth, the atmosphere from the lowest altitudes at which satellites will remain, to the highest altitudes which we can attain stable satellite orbits. This requires most geophysical satellites to be in polar orbits. Any satellite will cross the equator twice during each orbit, but only those of high angular inclination to the equator will go close to the polar regions. So there exists a very strong divergence of orbital requirements between our geophysics and astronomy programs.

Specifically, the astronomical observatories and early solar orservatories will use the low-altitude, low-inclination, near-equatorial orbit. In later solar observatories there will be significant advances. If we could obtain a polar orbit at a time of day so that the satellite would always be going around the Earth at dawn or dusk—in other words, as the Earth turns underneath we would always be looking out above the horizon at the Sun, so that we would never have to lose the Sun and reacquire it after going around behind the Earth.

The Polar Orbital Geophysical Observatory is for the sampling of the first thousand miles or less of the Earth's atmosphere. This is where things change rather rapidly from a photochemical composition point of view.

Then we have the highly eccentric orbits of the Eccentric Geophysical Observatory starting in 1963, in which we want to go out as far as we can from Earth with the particular vehicle and spacecraft combination we are working with, to investigate the magnetosphere and its interactions with the interplanetary plasma.

For OGO on the Atlas-Agena B, this is 60,000 miles apogee and a few hundred miles perigee. We are able to carry this same spacecraft in the polar orbit at a lower altitude by means of the Thor-Agena and thereby get the economies of the less expensive vehicle in combination with the economies of the repeated use of the same spacecraft.

Other programs have other orbital requirements. The communications satellite program uses a synchronous orbit at 22,300 miles altitude for the one type of system. The Nimbus meteorological satellite has a requirement to look down at the Earth from a relatively constant 500-mile altitude. An orbiting Satellite Ionosphere Monitor is planned for use starting in 1964–65, the Year of the Quiet Sun, and

through the next solar cycle. This satellite requires a circular, polar orbit at an altitude of 1,200 miles.

Thus, although we can go a considerable way toward combining experiments in large observatory-type satellites, there are also other orbital requirements for relatively few but critical experiments. It is more efficient to use small launch vehicles, such as Scouts and Deltas to meet these special requirements, than it would be to attempt to launch such experiments along with other experiments and go through the difficult process of providing these experiments with their own individual propulsive capability, to enable them to change their orbit after initial injection and separation. The economics of the situation rule out this other alternative because the costs are an order of magnitude higher. Then, too, the reliability of this alternative system would not be comparable to that of the present Explorer-type satellites for a long period of time.

Mr. KARTH. Doctor, how many of the objectives of these satellites will also be sought in the Samos and Midas satellites of other agencies of the Government?

Dr. CLARK. The programs of the Department of Defense and NASA are very closely coordinated through the Aeronautics and Astronautics Coordinating Board. The scientific satellite and sounding rocket areas are coordinated through monthly meetings of the Unmanned Spacecraft Panel of this Board. We compile program summaries annually. We have undertaken reviews with DOD as a whole, and with components such as the Air Force. Last summer, for example, we had a very productive all-day session with technical experts from the Air Force and their opposite numbers in NASA, going over in detail all of the satellite and sounding rocket experiments of both agencies for the coming year.

So the NASA and DOD programs are very closely coordinated, and the answer to your question is that none of these objectives of the NASA payloads will be met with any of the DOD payloads.

Mr. KARTH. Any questions of committee members?

Mr. Hammill?

Mr. HAMMILL. I have one question, Doctor. Very early in your testimony a chart was displayed on which seven satellites were indicated as scheduled for launch in 1961 and 1962.

Dr. CLARK. Right.

Mr. HAMMILL. And you stated that one had been delayed, but you didn't indicate the reason for the delay. Will you identify that satellite and tell the committee why it has been delayed?

Dr. CLARK. Yes, that was the Atmospheric Structure Satellite. The experiments are Goddard Space Flight Center experiments in the areas of atmospheric structure and composition. The major reason for the delay of this satellite was difficulty in developing the spectrometer for the measurement of atmospheric composition, which required more time than had been planned.

This satellite is hermetically sealed and battery powered, to make measurements of the atmosphere in the immediate vicinity of the satellite without any possibility of contamination by gases leaking from the satellite or solar cells, so it has a lifetime which is limited by the absence of solar cells. There is a spectrometer looking out of an orifice, which is one of the primary experiments for the measurement of the neutral composition. The delays in development of this spec-

trometer resulted in approximately a 6-month delay in the launching of the satellite.

Mr. BERESFORD. May I follow up on two of your questions?

Mr. KARTH. Yes.

Mr. BERESFORD. First with relation to the earlier question as to your scientific satellites and those of the Department of Defense, specifically what is the relation between the geophysical satellite and Project Anna?

Dr. CLARK. Project Anna is a geodetic satellite program of the Department of Defense. The NASA Orbiting Geophysical Observatory satellites do not, thus far, contain any geodetic experiments. However, NASA has obtained valuable geodetic information relative to the shape of the Earth from precise observations of the orbits of many satellites, particularly those of spherical shape whose drag can be computed with great precision, and those whose high density and and altitude cause the atmospheric drag to be unimportant.

Mr. BERESFORD. May I carry on a little further the chairman's line of questioning which was designed to find out, I think, if any of these programs were a limiting factor, a bottleneck on the manned space flight program.

I was never certain whether they were, but it seems to me they might well be.

For instance, in the case of these space shots that we have attempted to make to find out the nature of the immediate Moon environment, the lunar surface, and so on, and all of those have failed in that mission.

Dr. CLARK. Mr. Nicks will be discussing the lunar program in the next phase. It might be more appropriate to find out then.

Mr. BERESFORD. Well, if this is true, we may want to find out what can be done to improve the situation, speed up the program.

Dr. CLARK. I do not feel that at the present time in the geophysics and astronomy programs, there is anything more that we should do to meet the requirements of the manned space flight program. We do retain flexibility, and if new knowledge indicates there is something that should be done, we will certainly utilize our reprograming authority to do it quickly, as soon as the need becomes apparent.

At the present time, my answer would be no, there is nothing new that I would recommend be done.

Mr. HAMMILL. Does NASA's program now include a future manned Orbiting Observatory of any type, and will this be under the direction of the Office of Space Sciences? If so, what are the prospective dates for launch?

Dr. NEWELL. At the present time, NASA's program does not include any hardware effort on a manned Orbiting Observatory but does include the study of such a project in conjunction with Apollo.

If such project is undertaken, the observatory, the laboratory itself would be under the direction of the Manned Flight Office and the science would come under the direction of the Office of Space Sciences, so we would work together on it.

Mr. HAMMILL. Would this involve any reprograming of your present programs?

Dr. NEWELL. No, it would involve—I would call it an involvement of programing. We would program our efforts so that the manned

observations and the use of a manned observatory would fit in with, dovetail, with the unmanned effort.

Mr. HAMMILL. But as far as you know, it wouldn't make any of the unmanned experiments unnecessary?

Dr. NEWELL. As far as I know it would not make them unnecessary.

Mr. KARTH. Any further clarification necessary, Doctor?

Are there any further questions of Dr. Clark?

Thank you very much, Dr. Clark.

Dr. Newell, what is your plan now for proceeding?

Dr. NEWELL. Mr. Chairman, we would like next to ask Mr. Nicks, who is the director of our lunar and planetary programs, to go into more detail on those programs than we went into on the general material last week. I think that in the time between now and 12 o'clock we can cover a goodly portion of his presentation.

Mr. KARTH. Fine.

If Mr. Nicks would like to proceed, any time he is ready.

Mr. Nicks.

While Mr. Nicks is getting ready, Dr. Newell, I might just say to you that it has been necessary for us to postpone those hearings that we had scheduled for tomorrow and the rest of the week.

We are having a caucus tomorrow morning beginning at 10 o'clock, and it is urgent that all of us be there from the Democratic side, at least, and Thursday I have to go out of town.

I thought perhaps we could reschedule those two meetings for Monday and Tuesday next, if this meets with your schedule.

Dr. NEWELL. Right. Do we know where the meeting will be next Monday; will it be here?

Mr. KARTH. We will have to depend upon Mr. Hammill to make those arrangements.

Mr. HAMMILL. If it is at all possible to arrange for another hearing room, it won't be here.

STATEMENT OF ORAN W. NICKS, DIRECTOR, LUNAR AND PLANETARY PROGRAMS, OFFICE OF SPACE SCIENCES, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. NICKS. To start with, you have heard from Dr. Newell and Mr. Cortright about the overall space program which includes lunar and planetary programs.

What I would like to do is give you a little closer view of the hardware, and the implementation of the lunar and planetary program. To review for you briefly, our objectives are the scientific exploration of the Moon and the planets and interplanetary space, and in addition to make the technological advances which can contribute to future programs, both manned and unmanned, in the exploration of space.

I would like to start with a discussion of the lunar program.

Figure 435 indicates the kind of lunar missions we envision and the launch vehicle and spacecraft to be used on these projects.

The Ranger flights began in 1961. There were two flights in 1961, three are scheduled this year, and four next year, for a total of nine.

The first two were test flights of the spacecraft carrying interplanetary instruments. It was hoped these would provide long "lifetime" experiments in space, and at the same time evaluate the spacecraft.

The engineering aspects of these missions were generally accomplished, but because of launch vehicle troubles, the spacecraft were

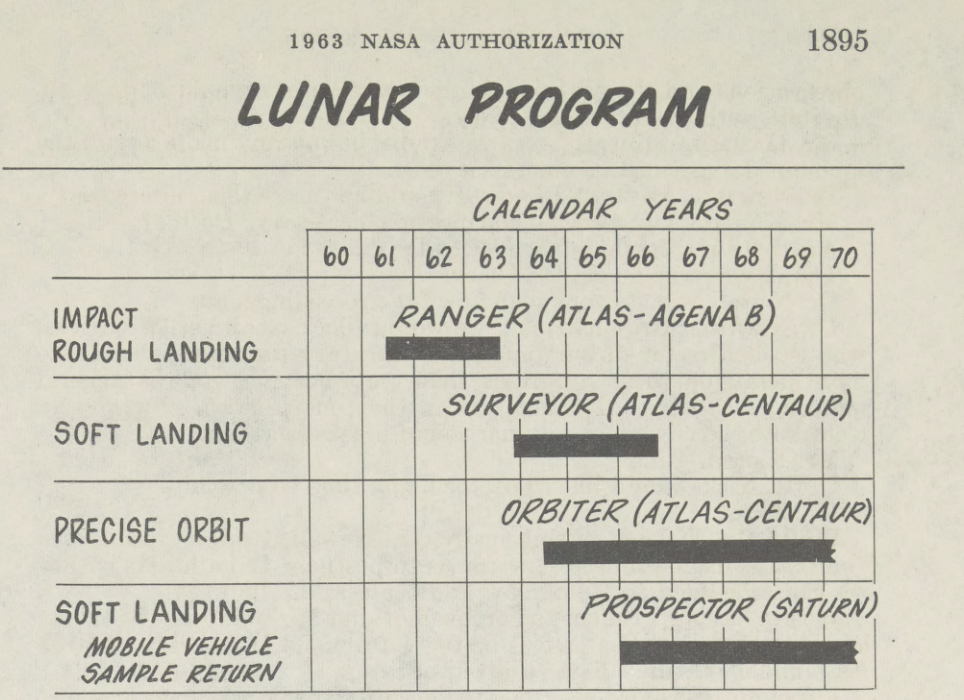

FIGURE 435

put into low orbits instead of highly elliptical orbits where they would have remained in space a long time.

Mr. KARTH. Was there a change in launch vehicle systems which caused this?

Mr. NICKS. I don't believe so, sir. I would say these problems are the normal kind that are intermittent and not specifically design problems.

Mr. KARTH. Was there a change in program planning?

Mr. NICKS. No, sir; those flights went on schedule, essentially, after having maintained the schedule for over a year.

The first Ranger flight at the Moon which occurred early this year, as you know, missed the Moon. I will talk about this a little later.

The initial soft landing series is identified as Surveyor; and we hope for tests of Surveyor spacecraft late in 1963. The Surveyor series beginning with tests in late 1963 or early 1964 is presently contracted as a series of seven flights. This spacecraft is designed to go to and land on the Moon with a complement of instruments.

Mr. KARTH. Is that the original Surveyor schedule, Mr. Nicks?

Mr. NICKS. This is essentially the original schedule. The first flight originally was scheduled for the third quarter of 1963. It is still the same. Our objectives may have slipped a little in terms of performing scientific missions, but for a short period of time, as Mr. Cortright indicated the other day. I will get into that a little more later.

The precise orbiter is an adaptation of the spacecraft to do an orbiting mission and to ascertain those things about the Moon that can be best learned by orbiting.

The soft landing Prospector missions scheduled here on a planning basis begin in 1966 with a large vehicle.

May I go to the next slide, please? (Fig. 436.) The significance of this figure which you saw briefly in Dr. Newell's presentation, is to indicate the family relationships of the Ranger series of spacecraft.

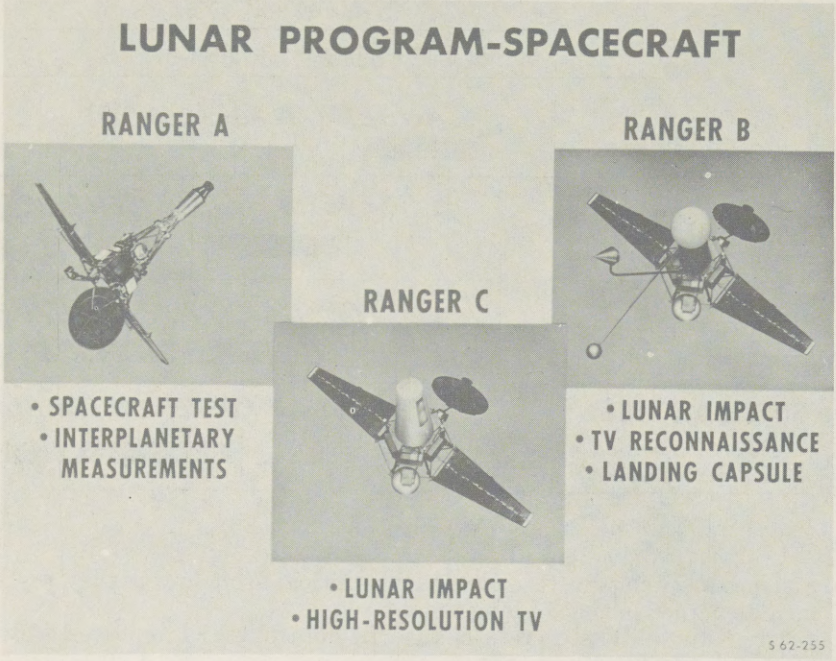

FIGURE 436

The concept is one of a bus which is a basic platform to which can be added various kinds of experiments. The early tests carried interplanetary experiments, including a magnetometer, ion chamber, Geiger tubes, and such instruments, to measure the interplanetary medium.

Ranger B has an instrumented landing capsule, a television camera, a radar experiment, and a gamma-ray spectrometer to measure radiation from the surface of the Moon.

Ranger C has as its principal payload a battery of TV cameras to obtain high resolution photographs of local lunar areas.

Could I have the next slide, please? (Fig. 437.)

Here is a closer view of the Ranger B launched at the Moon in January, showing again the basic spacecraft, the solar panels, the high gain antenna for transmitting television pictures back to the Earth as the spacecraft approaches the Moon, a retrorocket and a capsule, a marking radar to signal ignition for the retrorocket—which can decelerate this capsule to a soft landing—a gamma-ray spectrometer, by which we hope to measure the radiation background in space and of the surface of the Moon to determine whether it is composed similarly to the Earth.

This is an antenna designed to transmit and receive with the spacecraft in any attitude, such that it is usable, whatever happens to the attitude stabilization system.

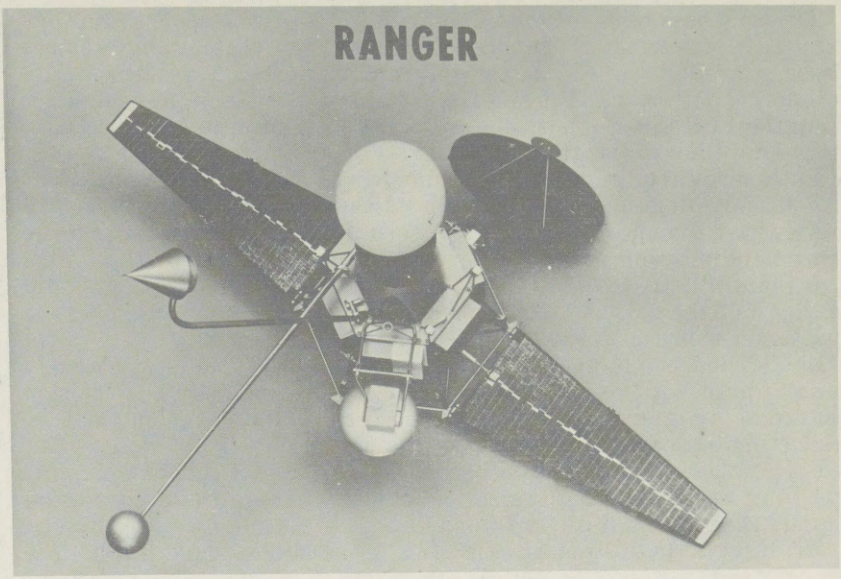

FIGURE 437

The next slide (fig. 438), illustrates the Moon briefly, to show you the region of the Moon in which we expect to land with these early Rangers.

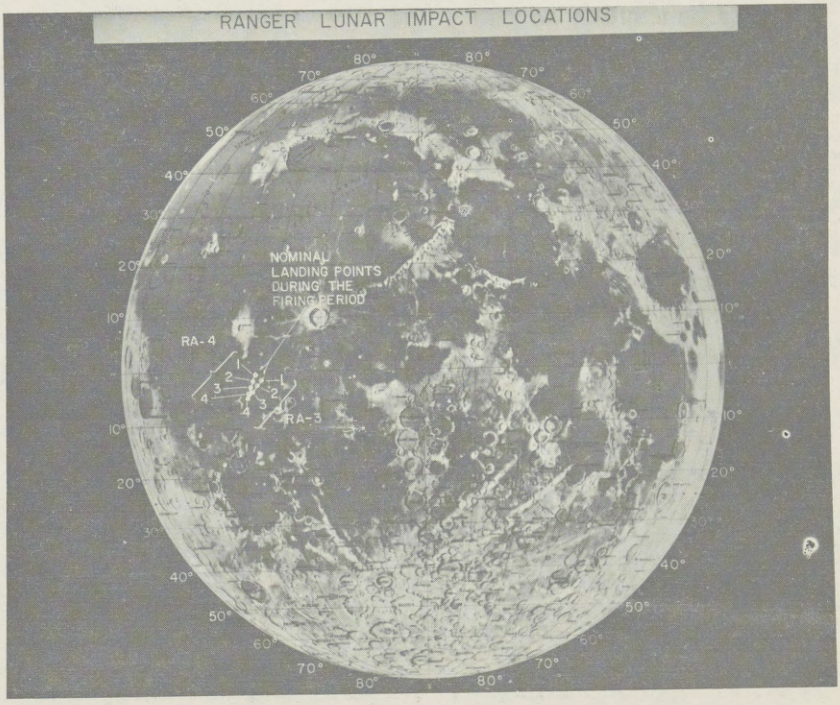

FIGURE 438

This area is chosen for these landings for several reasons. For one thing, the spacecraft is launched in such a way that as the Moon is rotating around the Earth, the spacecraft and the Moon essentially collide. That means that the front edge of the Moon, as you see it from the Earth, is the most logical area to hit because of the relative motions of the spacecraft and Moon.

The energy requirements for launching to the Moon are such that if a spacecraft is launched with an excessively high velocity it will merely have to remove that velocity when it gets there in order to make a soft landing, thus expending greater energies. Most of the flights now planned will have a time of flight on the order of 66 hours, and in this way the velocity requirements are near minimum, that is, the spacecraft approaches the Moon as slowly as it reasonably can.

In addition, the Ranger flights are scheduled to come in on a nearly vertical path with respect to the surface. This makes the television picturetaking easier and the landing problem easier, but will be restricting our early flights to a fairly small region of the Moon.

Part of the variation shown here is due to the fact that the Moon is wobbling up and down some in its orbit and moves to and from the Earth in the course of its trajectory.

Mr. KARTH. Is this picture the result of an actual photograph, or is it a drawing?

Mr. NICKS. This map was made by the Air Force for NASA and was done by using photographs that have been collected from observatories over many years of time. Cartographers are working on this sort of map right now. As we get better data on the Moon, that is, better pictures, these maps will be upgraded such that we can have a better idea of where we are going.

The next slide (fig. 439) please.

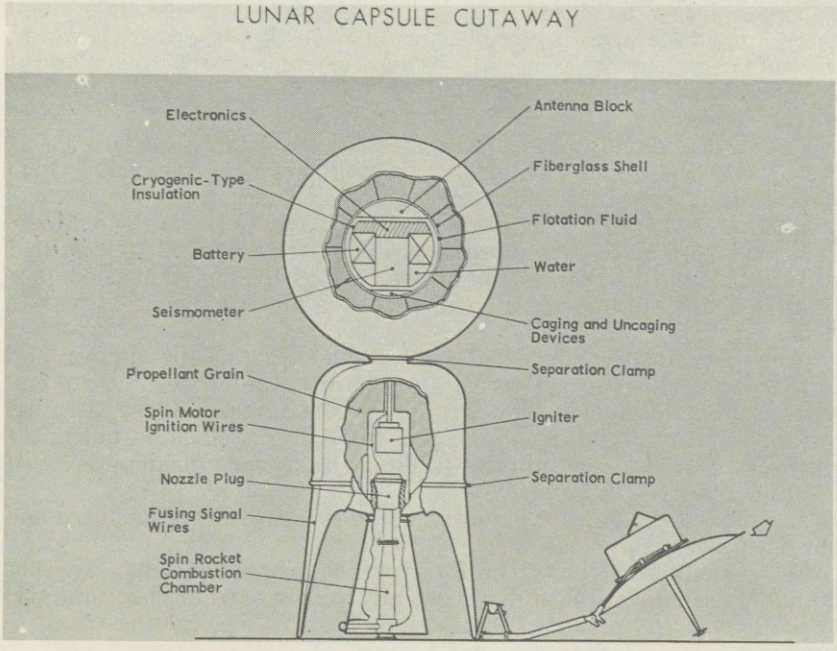

FIGURE 439

This illustration is a cutaway of the small Ranger capsule. I have a model here which you can examine more closely.

There is a solid rocket mounted on top of the Ranger bus. This is the radar altimeter which bounces the signal off the moon and indicates when this motor should fire.

The capsule is surrounded by balsawood to cushion the shock of landing, and inside this sphere are two spheres, one supported in a fluid in the way that a baby chicken is supported in an egg, and the other sphere for structural integrity.

This capsule is designed to land on the Moon with a fairly low impact velocity, something like 100 to 240 feet per second, to survive that impact, and when it rolls to a stop, this capsule will right itself by rotating in this fluid; its weight is distributed such that it will right itself.

There is a transmitter in the upper part of the capsule which will transmit through the balsa block. The major instrument is a seismometer which will listen from 1 to 3 months for any seismic activity on the Moon; that is, lunar quakes, equivalent to earthquakes, or to record impacts of meteors in the vicinity of the capsule.

With these kinds of data we hope to find out a good deal about the composition of the Moon, whether it has layers, or whether it has a hot center—if that were so, there would be some lunar quake activity—and whether it was cold formed and internally inactive.

Mr. KARTH. If it buries itself on impact, will it still fulfill its mission?

Mr. NICKS. It depends on the depth that it buries itself. Calculations indicate it might transmit and receive through several feet of dust, if dust exists to that depth. However, it is conceivable that it will fall into a crack.

We don't have resolution of the lunar surface with our present photography to the extent that we know that there aren't cracks, and there are surely ways in which it could be lost. Generally, however, the surfaces that are expected are dust or volcanic-like areas, and it is designed to withstand those and, insofar as possible, any conditions we can conceive.

The next slide, (fig. 440) illustrates the next version of this spacecraft, with the upper part of it carrying a camera package. Good photographs are of extreme importance scientifically.

The best photographic resolution we have today of the Moon, using the best Earth-based telescopes is on the order of ½ mile to 1 mile. This means that we cannot see things having dimensions less than that unless they cast a shadow that is much longer that we can define.

Consequently, we don't really know much about the surface and how it looks close up. This part of the program is designed to emphasize high resolution photographs of local areas. The spacecraft will be sent in to land or to impact at fairly high velocities, but in the course of the last few minutes it should take very good pictures of landing areas.

The next slide (fig. 441) shows how those cameras are mounted and the nature of the payload.

Mr. KARTH. Mr. Nicks, the Ranger that missed the Moon by some 20-odd-thousand miles, did we get any pictures from that mission?

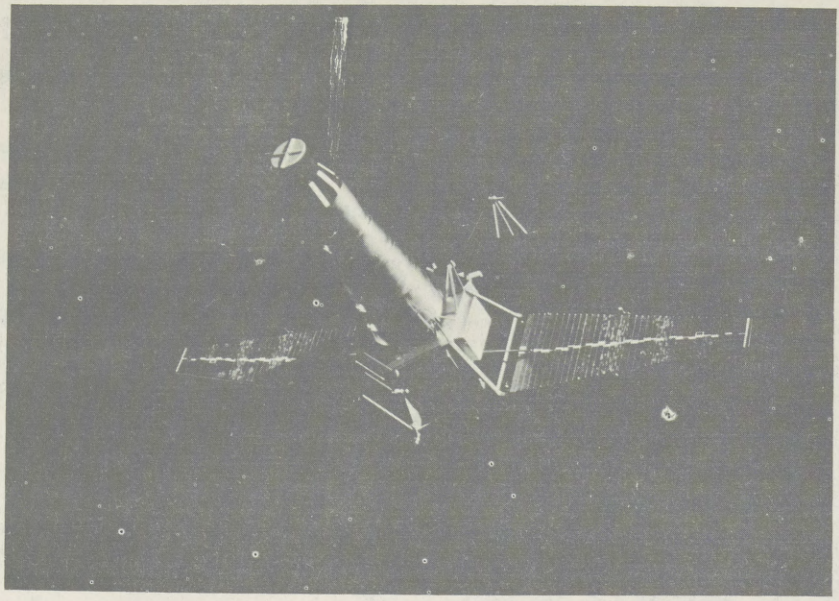

FIGURE 440

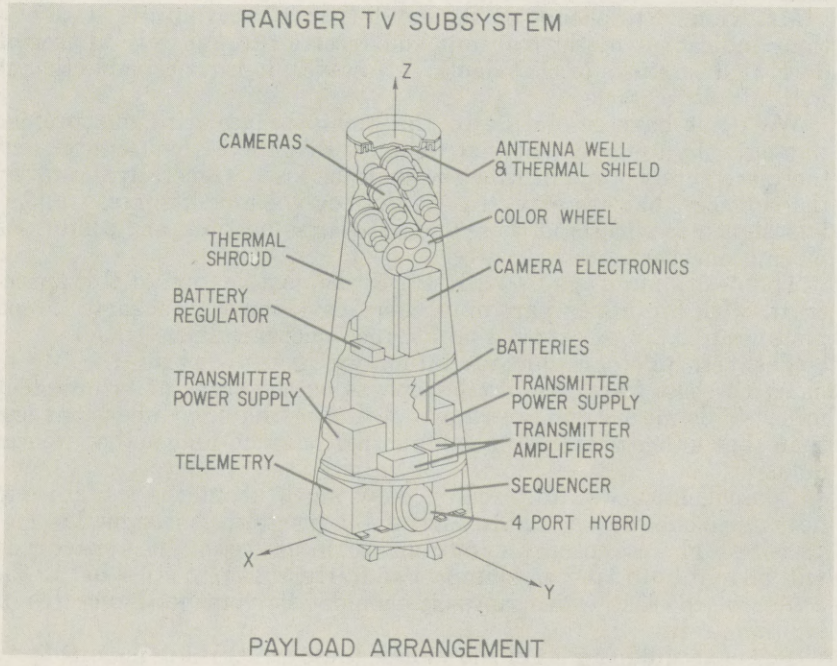

FIGURE 441

Mr. NICKS. No, sir. We did not get pictures from that mission. We got indications that the television camera worked, but it was not oriented in such a way as to get pictures of the Moon, nor to transmit quality pictures back to earth.

The problem was that the attitude control system failed, such that the large dish antenna was not pointed at the Earth in order to transmit those pictures. The Ranger is an attitude stabilized spacecraft, and after the terminal maneuver was commanded to orient it with respect to the Moon and the Earth so that it would take and transmit pictures, the attitude control system did not work properly. The spacecraft, instead of remaining locked in a position to point toward the Earth, continued a slow roll.

Mr. KARTH. Have you been able to determine the problem?

Mr. NICKS. Yes, sir; we think we have it taken care of for the next spacecraft. There have been some changes incorporated. They were fairly simple changes, as they often are. A 15-cent switch can be as much trouble as anything in these spacecraft.

Mr. HAMMILL. Mr. Chairman, may I ask a question at this point?

Mr. KARTH. Yes.

Mr. HAMMILL. The use of high resolution cameras may result in good pictures of specific areas on the Moon's surface, but we are told that such photographs introduce distortions around the periphery which make these pictures not very useful for mapping purposes. Now, is it intended that any of the cameras will carry wide-angle optical equipment so that accurate maps of the Moon may be made?

Mr. NICKS. Yes; I will come to another phase of our program which goes more into that as an objective. However, I think it is right to say that this phase of program is concentrating on the local information.

We would like to find out as soon as possible whether there are huge cracks or boulders which might influence the design of the landing gear for our own unmanned program and for the manned program.

Mapping is something that follows in our program.

Mr. HAMMILL. In other words, you believe that there isn't the need for this kind of information quite as soon as the type of information you are now going after. Is that it?

Mr. NICKS. That is our feeling. These television cameras are expected to take 1,500 to 2,000 pictures of the Moon.

The last of these pictures are to provide a resolution of about half a meter—in other words, a foot and a half or so—and you can contrast that with a half mile available today and see that for local areas at least, such pictures will really offer an improved knowledge of the Moon's surface.

Four of these cameras are faced so that their pictures overlap, and together they make a composite with some stereo of the particular area toward which the spacecraft is approaching.

One of the others is a wide-angle camera which takes a wider frame and keeps the pictures from the narrow-angle cameras within its view. The other looks off at an angle of 30 degrees, such that as the spacecraft approaches the Moon, it will sweep a swath from the edge of the Moon into the point of landing and give some reference to the landing point.

In the next slide, figure 442, I show the Surveyor series designed for the Centaur launch vehicle.

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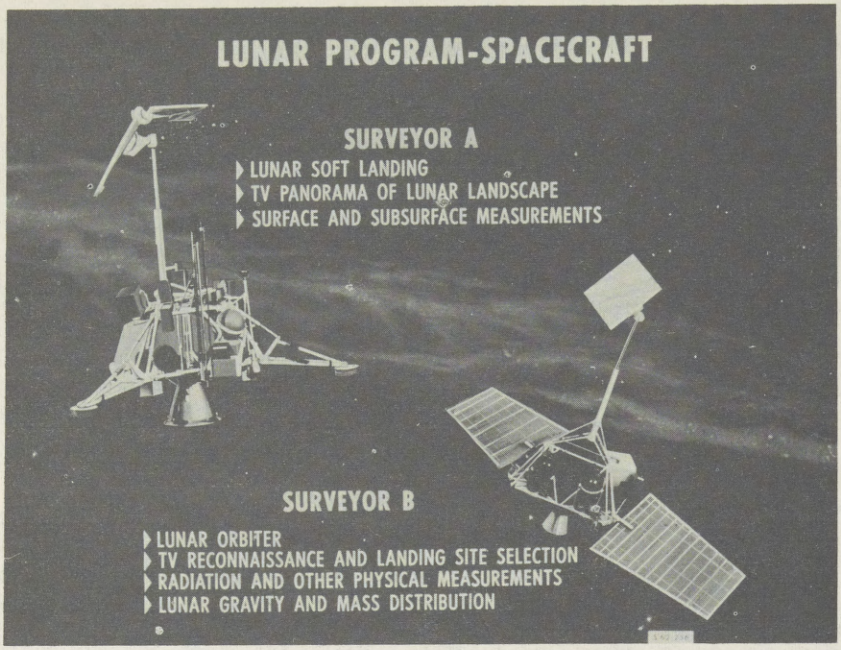


FIGURE 442

This project has been under contract a little over a year from the hardware standpoint, and for 6 months or so prior to that in the preliminary engineering phase.

You have seen models of the spacecraft. In its gross configuration it will weigh from 2,300 to 2,500 pounds, and in its landed configuration on the order of 850 pounds.

A large part of the spacecraft is a retromotor which will slow it down on approach to the Moon. It has landing gear and a space frame with a solar panel array and an antenna, a high gain antenna, in this case a different kind, a planar array, but doing essentially the same as the parabolic dish on the Ranger.

The instrument compartments and electronics compartments are packaged very accessibly around the outside; here is a drill designed to drill from 18 inches to 5 feet into the lunar surface.

There is a probe which can be lowered into the drill hole to sample the subsurface in very much the same way the petroleum industry does their logging of oil wells.

There are measurements grouped into several categories, and I will show you a list of those in a minute.

The Surveyor B as shown here is the orbiter, and it is intended to get what Mr. Hammill was referring to; a better look at the Moon in general.

For a long time it has been an objective of the scientific community and NASA to get an orbiter around the Moon so that we can look at it in more detail, because there are lots of things that can be done better from an orbiter than from a point landing.

For example, a television system on this spacecraft, and there are five cameras, four of them looking in different directions, can only see about 2 miles after the spacecraft has landed, due to the curvature of the Moon.

The Moon is small in diameter and the horizon is fairly close. With the orbiter, of course, we hope to see all of the surface of the Moon during the course of a month from a polar orbit.

This particular configuration is designed to look at the Moon in varying resolutions from fairly high values to much less, as there is a back side of the Moon and other parts of it which we haven't seen, we would like to get a broad look at it initially.

Mr. KARTH. During its orbit, how close will it be to the Moon?

Mr. NICKS. About a hundred kilometers, or 60 miles. Its resolution should be on the order of 10 meters resolution or, let us say, 40 or 50 feet. But that kind of data for large areas, coupled with the local pictures, should help us to get a better idea of what all the Moon is like.

We hope to put these together and get a better interpretation from them.

Mr. KARTH. Couldn't we pretty much arrive at the same conclusion looking at it from 40 feet away as looking at it from 10 feet or 5, that, is, only a little more than the length of this room?

Mr. NICKS. Are you asking, couldn't we orbit closer to the Moon?

Mr. KARTH. Doesn't Surveyor B accomplish everything Surveyor A does with the exception of giving us some information about the makeup or composition of the Moon itself?

Mr. NICKS. From a photographic standpoint, you mean?

Mr. KARTH. Yes.

Mr. NICKS. It gives us many of the things that we get with Surveyor-A, but we use the cameras on Surveyor-A for a lot more than just to look down on the surface. The cameras will watch the drilling operation, for example, and see what the texture of the surface is like by determining how it reacts as the drill goes into it.

We have a microscopic system that will look closely at some particles of it and they will help in the analysis of the material.

Mr. KARTH. Which comes first of those two vehicles?

Mr. NICKS. The Surveyor-A is presently scheduled to come first, although the Surveyor-B will be close on its heels, and we hope to use these interchangeably in the program, starting in late 1964 and early 1965.

Mr. KARTH. How many Surveyor-B's do you have in the program?

Mr. NICKS. At the moment, five have been approved.

Mr. KARTH. And Surveyor-A's?

Mr. NICKS. Seven.

This adaptation of the Surveyor-A space frame works out fairly naturally because this spacecraft has to do all of the things in getting to the Moon that an orbiter has to do. It is also matched with the Centaur vehicle, and the spacecraft-vehicle integration otherwise is compatible. The A and B will use the same telecommunications system, the same attitude control, and many of the same components.

Mr. KARTH. What is the total R. & D. on each of those vehicles and spacecraft, including the five vehicles for Surveyor-B and the seven for Surveyor-A?

Mr. CORTRIGHT. Mr. Taylor doesn't have those figures with him. The Surveyor-A estimate that I gave in my testimony the other day was $180 to $200 million for the seven flights.

Mr. KARTH. Do you have an estimate for Surveyor-B, Mr. Cortright, at this point?

Mr. CORTRIGHT. I would have to pull it out of the air.

Mr. KARTH. Go ahead, pull it out and we can check it later.

Mr. CORTRIGHT. For five flights it would probably run about $120 million.

Mr. KARTH. If you would, I would like to have you provide that figure accurately.

(The information requested is as follows:)

The estimated cost of five Surveyor-B flights, including development spacecraft, launch vehicle costs, salaries, and institutional support cost is $132 million.

Mr. NICKS. Could we go to the next slide (fig. 443), please?

I have brought this picture to indicate this spacecraft when it is landed, and to point out some more of the instruments as they are located around it.

These extensible booms, as was the case with Dr. Clark's satellite, are to get these instruments away from the effect of the spacecraft and conversely are to keep them from affecting the spacecraft.

The model is a better way of looking at this. Here, for example, is a surface sampler which is a pantograph arrangement that comes out and scrapes a sample and pulls it back to the spacecraft.

There is a television camera here that looks down, and here is the drill, and there is a probe that inserts down into the hole.

These experiments by and large have fancy names, but all of them are designed to get information that is very fundamental to understanding the surface of the Moon and its environment.

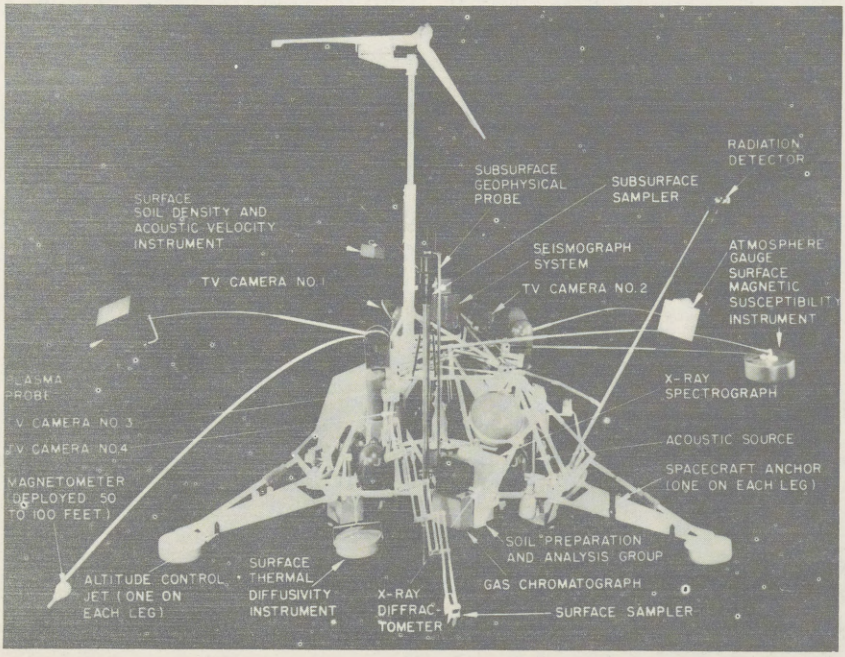


FIGURE 443

They include the kind of measurements that you would make from an engineering standpoint to determine the composition and to analyze the physical properties of the surface.

The slide of figure 444, please.

I have indicated here a typical trajectory to the Moon for the Surveyor-A lander. We would launch into a parking orbit about the Earth which normally result in a coast for a short time, 10 or 15 minutes, at about a hundred miles altitude, then the spacecraft would be injected on its way by another burn of the Centaur, and then coast toward the Moon.

These portions are regions of the trajectory where the spacecraft would be visible from a particular command station; namely, the one at Goldstone, Calif. Somewhere about midway we would have tracked it sufficiently to determine its path, and to give it a change in speed or direction by commanding the spacecraft to take up a new attitude and fire its small motors for a limited period of time.

Mr. KARTH. Will you have this capability in both Surveyor-A and Surveyor-B?

Mr. NICKS. We have this in Ranger and in Surveyor-A and Surveyor-B, yes, sir; and this part of the command system was demonstrated in the Ranger fairly well.

Mr. KARTH. Why did we miss, then?

Mr. NICKS. We missed primarily because during this part of the trajectory [indicating] the Atlas gave the Ranger additional velocity. It burned for a longer period of time than it was intended to burn. Consequently, the spacecraft had a much higher velocity than intended. The Moon, as is illustrated here, is coming around the

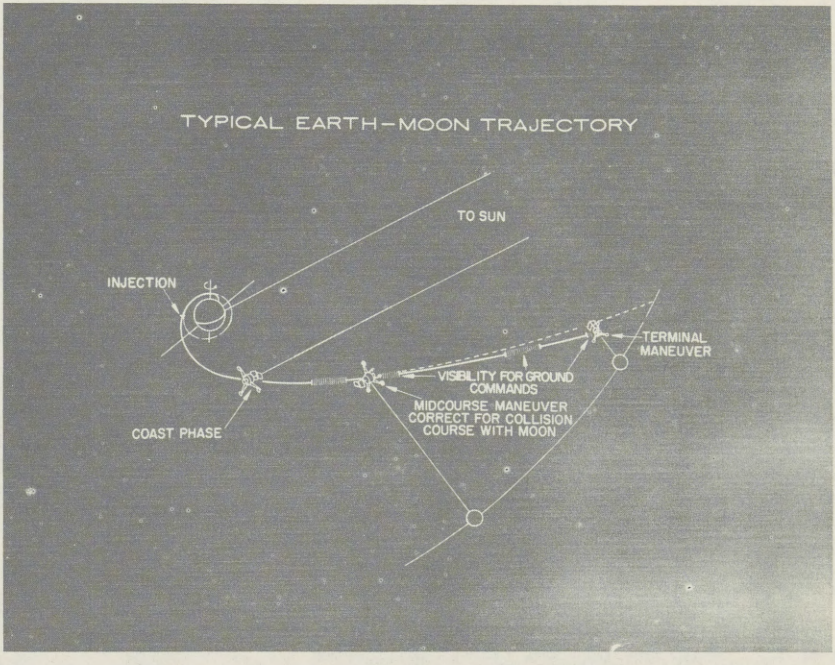


FIGURE 444

Earth on this kind of trajectory, and consequently the spacecraft got to the Moon's orbit in some 50 hours instead of the 66 planned.

Mr. KARTH. You couldn't slow it down to correct for that?

Mr. NICKS. We did not put into the spacecraft enough propulsion to correct for all of these contingencies.

It has enough propulsion to take care of the normal variations in the Atlas, but if we tried to double up——

Mr. KARTH. Do you mean that was an abnormal variation?

Mr. NICKS. Yes, sir.

Mr. KARTH. You don't expect that to happen again?

Mr. NICKS. No, sir.

Mr. HAMMILL. Why did it happen? Why did the Atlas produce so much greater velocity in the spacecraft?

Mr. NICKS. A component in the Atlas, a transponder, failed, and consequently there was no ground signal to cut off.

Mr. CASEY. Well, your midcourse maneuver couldn't correct that then?

Mr. NICKS. Not that much. It is designed to correct the normal variations in Atlases and Agenas, but if we put enough propellant in the spacecraft to accommodate all of these broad variations, we wouldn't have enough room for the payload. It is not a desirable way to fix the problem, to try to make the spacecraft good enough to take care of all of those possible variations; the better way is to fix the launch vehicle.

Mr. KARTH. Won't your Surveyors be launched with Atlas-Centaur?

Mr. NICKS. Yes, sir.

Mr. KARTH. I thought you said Agena.

Mr. NICKS. I was talking about the Rangers which use the Atlas-Agena.

Mr. KARTH. With the little we know about the Centaur, you don't foresee the same kind of problem being caused in the Atlas-Centaur as was caused in the Atlas-Agena vehicle on the Ranger shot that just missed?

Mr. NICKS. I wouldn't say that, sir. There is a possibility of this kind of thing happening all of the time, and it is because of this kind of failure that the total reliabilities are less than what we in the payload business would like, but I would not expect that exact same kind of failure to occur, because I think that having found this problem we can have it fixed.

Mr. KARTH. Having a relatively small amount of experience with the Centaur vehicle as opposed to the Atlas, don't you expect many more variables in that kind of vehicle than you would normally expect to find in the Atlas-Agena?

Mr. NICKS. Past experience would indicate that that would be the case. However, there seems to be no way to get to a new plateau of capability but to go through this period of development.

Mr. KARTH. You better build a few more craft. I know there are quite a few variables in this. It is a little iffy.

Mr. NICKS. Somebody claims that the Ranger has 19,500 parts. I don't know how he counted them.

This next slide, figure 445, is another picture of the moon, the same map as you saw before, but here it illustrates the area in which the Surveyor could land.

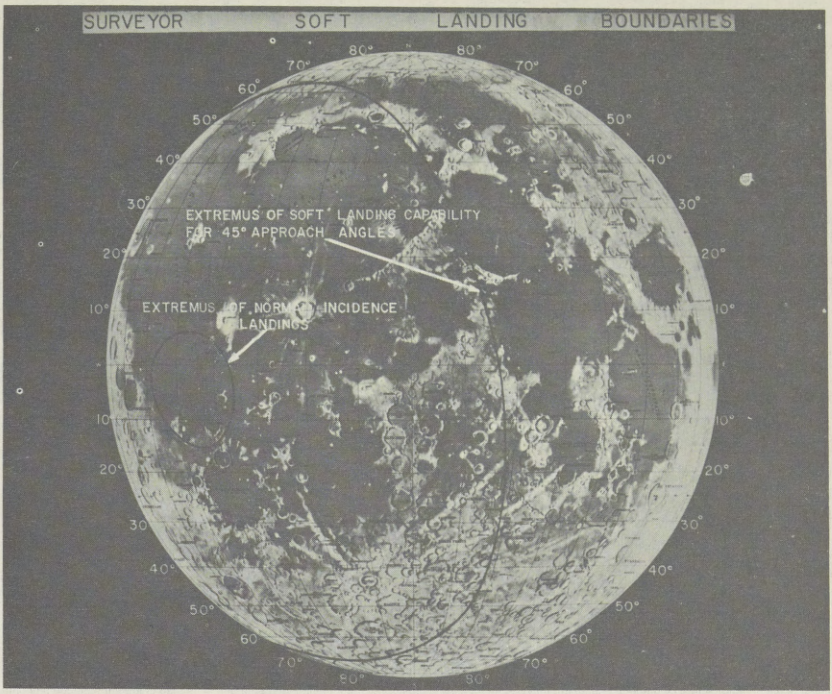


FIGURE 445

The normal incidence landings mean that the Surveyor could land with a flight trajectory that comes in normal to the surface, within this area; that is something like you could do with the Ranger over a period of time, depending on the time of year and what year it is.

This extremus indicates the total region into which the Surveyor could land, if you accept a landing approach angle of 45 degrees. The Surveyor is designed to land with that kind of approach condition.

If you were to try to have the Surveyor come in over here (indicating), it would come in so much flatter that there would be a grazing kind of impact, and it is rather difficult to design the automatic systems to take out the velocity parallel to the surface of the Moon as opposed to coming toward it, because we use radar to bounce back from the Moon to tell when to fire the rockets.

Going on then, this slide, figure 446, indicates the Surveyor instruments that are being designed to go on the Surveyor. Major categories of measurements are: (1) the physical parameters, which determine the properties of the surface of the Moon and include the subsurface geophysical probe, (2) the lunar body properties, to find out what the composition of the Moon is, i.e., whether it has a hot core like the Earth or is cold; (3) chemical analysis to find out what elements exist on the Moon; and (4) fields and particles which give us an idea of the environment from the standpoint of radiation, atmospheres, and so on.

SURVEYOR SCIENTIFIC INSTRUMENT PAYLOAD LIST NO. I

1. TELEVISION
   - 5 CAMERAS
   - HIGH RESOLUTION TELESCOPE

2. PHYSICAL PARAMETERS
   - SUBSURFACE SAMPLER
   - SURFACE SAMPLER
   - ANCHORING DEVICE
   - SAMPLE PROCESSOR
   - SURFACE GEOPHYSICAL SUBSYSTEM
     - TEMPERATURE
     - THERMAL DIFFUSIVITY
     - MAGNETIC SUSCEPTIBILITY
     - DENSITY
     - HARDNESS
     - ACOUSTIC VELOCITY
     - RESISTIVITY
     - SOIL MECHANICS
   - SUBSURFACE GEOPHYSICAL PROBE
     - TEMPERATURE
     - THERMAL DIFFUSIVITY
     - MAGNETIC SUSCEPTIBILITY
     - DENSITY
     - ACOUSTIC VELOCITY
     - CALIPER (HOLE SIZE)

3. LUNAR BODY
   - SEISMOGRAPH SYSTEM

4. CHEMICAL ANALYSIS
   - X-RAY SPECTROGRAPH
   - X-RAY DIFFRACTOMETER
   - GAS CHROMATOGRAPH

5. FIELDS AND PARTICLES
   - MAGNETOMETER
   - PLASMA PROBE
   - ATMOSPHERE GAUGE
   - RADIATION DETECTOR

FIGURE 446

This next slide, figure 447, indicates in greater detail the lunar orbiter with its panels added to the basic spacecraft, and with the camera package installed where the large retromotor was before.

Since I have already discussed it generally, I won't dwell on it.

This slide, figure 448, is the trajectory of the orbiter to the Moon. It would be injected here into an orbit around the Moon as opposed to coming to and landing on the Moon. The basic difference in the trajectory is that the spacecraft is aimed at a point which misses the Moon instead of at a point on the Moon, and the retromotor is fired so that the spacecraft will become a satellite instead of decelerating to land.

Mr. KARTH. What is the lifetime capability of this transmission system? How long do you expect Surveyor-B to be in orbit and to perform?

Mr. NICKS. We would like to have its operational lifetime extended to as much as a year. We believe that once we have the thing in orbit we ought to use it as long as possible, because it costs so much money to put it there.

We don't expect that lifetime initially, but we are hoping for 6 months, and then we would like to stretch it to a year.

In that event, it could serve a supporting role function by continuously monitoring the planetary and interplanetary environment in the vicinity of the Moon; it becomes an anchored space station, so to speak.

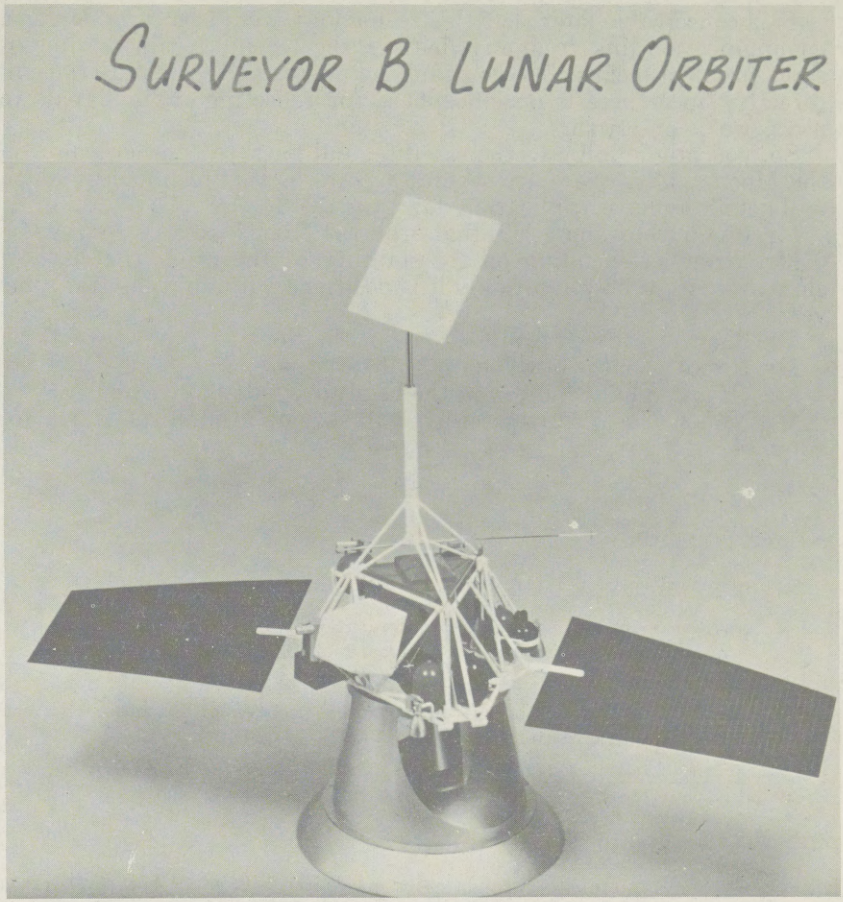
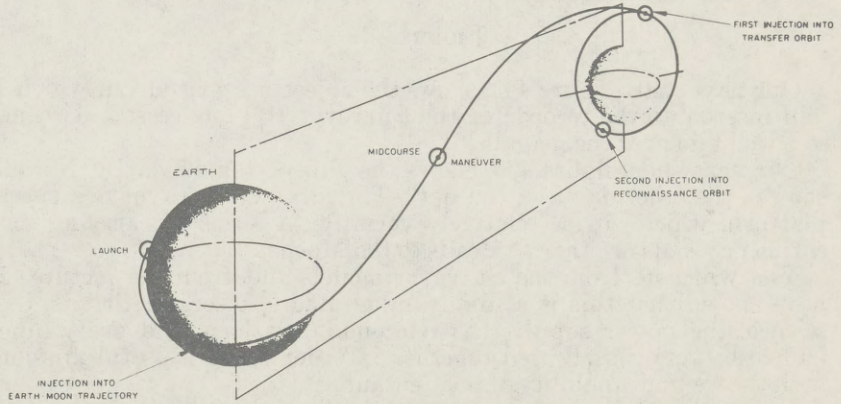


FIGURE 447



SURVEYOR B

TRANSIT AND INJECTION TRAJECTORY

FIGURE 448

It is conceivable later that this technology would be suitable for a communication link from anywhere on the Moon. Again the line of sight problem means that you can't get very far away and transmit directly, since there is no ionosphere for reflecting radio signals to use as we do on Earth.

So, you might relay to the satellite, and back to another point on the Moon. Thus there are several aspects of this technology which will definitely have application down the road.

Mr. CASEY. How long will that orbit the Moon?

Mr. NICKS. Depending on the stability of the orbit, that is how close in it is and how accurately it is positioned, it might last for some years.

Mr. CASEY. And you propose to use it that long?

Mr. NICKS. That is how long it will stay there.

Mr. CASEY. That is how long the hardware will stay there?

Mr. NICKS. Yes, just as satellites will stay up around the Earth for a number of years.

SURVEYOR ORBITER

IMMEDIATE OBJECTIVES

1. Oriented space platform for:
   a. lunar reconnaissance and topographic mapping
   b. preliminary selection of desirable landing sites for Surveyor and Apollo
2. Lunar space station to monitor radiation environment and other physical parameters in immediate vicinity of Moon
3. Selenodetic satellite for study of size and shape of Moon and its gravitational field

LATER OBJECTIVES

1. Radio relay station for lunar surface communications beyond the horizon and between far side of Moon and Earth
2. Navigation satellite for position finding on the surface of the Moon.

FIGURE 449

Our next chart, figure 449, shows the objectives written out which I will insert into the record for the Surveyor B. I have stated them, so I won't go over them again.

Our next slide, figure 450, shows the Prospector which Dr. Newell showed the other day as a concept. The idea here is to make a space platform which can be relatively versatile in terms of carrying scientific payloads or other payloads to the Moon.

You will note from the Surveyor models and from the pictures I have shown that this is a highly integrated spacecraft; that is, the science, the power supply, the telecommunications, and everything had to be very closely tied together in order to do a useful mission with the weight capability of the Centaur.

In the case of Prospector, we hope to divorce the basic space platform from all of the complex instruments it is designed to carry, such that it can have greater utility and longer usefulness.

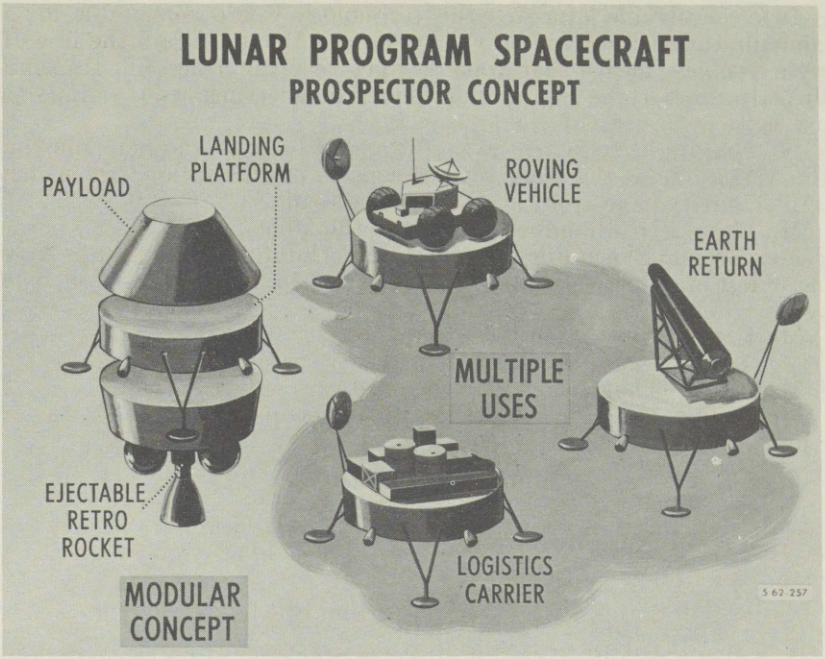


FIGURE 450

It would also become cheaper if used repetitively, and it certainly should be more reliable because it does not have to change each time there is a change in the payload.

There are two major capabilities that the Prospector, it is hoped, will give us that we don't have now with the Surveyor. One is the capability to land anywhere on the Moon as opposed to those restricted areas I indicated for Ranger and Surveyor.

The other is to give some surface mobility, so that we can survey a site or an area around a point where the spacecraft lands, as opposed to just landing and looking at one point.

If we could do this then, we might gather many data points with one mission and survey the surrounding terrain with greater detail.

Mr. KARTH. Won't this do what Surveyor B is designed to do?

Mr. NICKS. It will do more what Surveyor A is designed to do.

Mr. KARTH. I meant Surveyor A.

Mr. NICKS. Yes, sir; it could very well do exactly what Surveyor A does, but in several positions on the Moon. It cannot do them at as early a time, however.

Mr. KARTH. What is the difference in time?

Mr. NICKS. The program plans are to start getting data with Surveyor A is 1964; the best estimate of the prospector would be 1966, and this again would be with a newer vehicle and a newer spacecraft. The plans are that by midyear we will have an approach to recommend for the prospector project.

Mr. KARTH. Now, the basic difference between Surveyor A and Surveyor B is that you are going to get a surface analysis with Surveyor

A and you are going to get pictures that are a little closer up than you will get with Surveyor B.

Mr. NICKS. We get one other important technological thing, sir. We learn how to land on the Moon, hopefully, and the technology associated with that is of fundamental importance.

Dr. NEWELL. Mr. Chairman, are we going to continue because if we are not this is a good stopping point.

Mr. KARTH. I agree, Doctor, we had better stop.

Mr. Nicks, it is already past the hour of 12 here, and we have no permission to sit. I wonder if you would be so kind as to consider further questions at the next meeting and then you can finish your presentation.

And this, Doctor, will be on next Monday, and Mr. Hammill will notify you as to where we will meet.

Dr. NEWELL. Good.

Mr. KARTH. I think if it is agreeable we could arrange to meet at an earlier hour, maybe 9 or 9:30. That would certainly be agreeable to me, if it is agreeable with the other members of the committee.

Dr. NEWELL. We would be delighted to meet at 9.

At the next meeting we can wind up Mr. Nicks' testimony and if we were to meet at 9 we could get well into the vehicle problem and the Centaur questions.

Mr. KARTH. Why don't we schedule the hearing for 9 a.m. That will give us extra time.

We will adjourn at this point until Monday next at 9 o'clock. The meeting is adjourned.

(Whereupon, at 12:10 p.m., the subcommittee adjourned, to reconvene at 9 a.m., Monday, March 19, 1962.)

1963 NASA AUTHORIZATION

MONDAY, MARCH 19, 1962

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON SPACE SCIENCES,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 9 a.m., in room 214–B, New House Office Building, Hon. Joseph E. Karth (chairman of the subcommittee) presiding.

Mr. KARTH. The committee will come to order. Dr. Newell, how would you like to proceed this morning?

Dr. NEWELL. Mr. Chairman, Mr. Nicks has gotten through the lunar portion of his presentation and would like to start now with the planetary and interplanetary part.

Mr. KARTH. Yes, sir; proceed.

Dr. NEWELL. Mr. Nicks.

STATEMENT OF MR. ORAN NICKS, DIRECTOR, LUNAR AND PLANETARY PROGRAMS, OFFICE OF SPACE SCIENCES, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, AND COL. DONALD HEATON, DIRECTOR, LAUNCH VEHICLE AND PROPULSION PROGRAMS, OFFICE OF SPACE SCIENCES; ASSISTED BY DR. HOMER E. NEWELL, DIRECTOR, OFFICE OF SPACE SCIENCES; MR. EDGAR CORTRIGHT, DEPUTY DIRECTOR, OFFICE OF SPACE SCIENCES

Mr. NICKS. You will recall, Mr. Chairman, that we stopped at the end of the lunar portion of my presentation. I will proceed this morning with the planetary portion. To get this started, I might say that the objectives of the planetary program at the moment concentrate on Mars and Venus as the two planets to which we will make our first exploratory attempts.

In addition to the planetary exploration, of course, we will be measuring the interplanetary environment, and on each flight to a planet, hope to achieve a greater knowledge of the environment of space between the Earth and other planets.

The first slide (fig. 451) illustrates the planetary and interplanetary program, and I would like to point first to the planetary launch opportunities and speak for a moment about those.

The V in this case is for Venus, the M is for Mars. As you will see there are opportunities to launch to Venus and Mars in 1962, again in 1964, to Venus in late 1965, Mars and Venus in 1967, Venus and Mars in 1969, and to Venus in 1970. Opportunities to go to these planets occur on roughly 2-year centers. For Venus it is about 19 months, for Mars it is about 25 months.

PLANETARY AND INTERPLANETARY PROGRAM

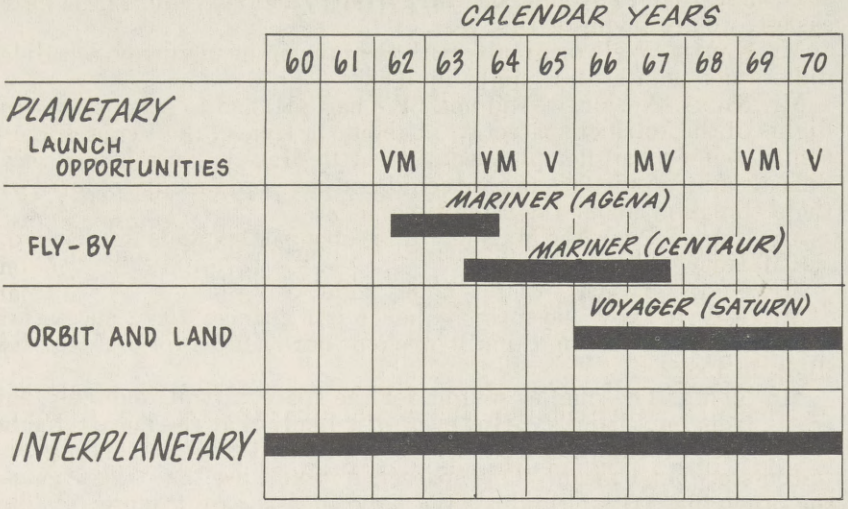


FIGURE 451

Therefore, you can see that if we are to explore these planets, we have to gear our schedule to their schedule as nature has provided it. I will discuss in a subsequent slide some of the reasons why this is true.

There are different types of missions indicated here. The fly-by mission is one in which the spacecraft from Earth will proceed to the planet, approach it, go closely by it, make observations of it and continue into an orbit about the sun. The orbit mission hopefully will proceed to a planet, the spacecraft will perform the necessary maneuvers to take up an orbit about the planet, and from there it should make continuous observations for a period of time.

The landings can be done in different ways. Initial landings will probably be by capsules ejected from fly-by spacecraft, that is, as the spacecraft goes close to the planet, a capsule will be launched and allowed to land. Later it may be possible to directly land rather large, complete spacecraft.

The interplanetary missions that are indicated here, as I have already said, occur to some extent each time we make a planetary mission because we make measurements on the way to the planets. In addition, our test flights normally are used to make these kinds of measurements. The Mariner "R" spacecraft designed for the Atlas-Agena rocket, is expected to be used in 1962 and 1964 during opportunities for launches to Venus. We do not plan to try for Mars this year. The Mariner "B" is expected to be used initially during Venus and Mars opportunities in 1964, and subsequently during each opportunity for 4 or 5 years, so that we can get some useful lifetime out of this spacecraft development.

Mr. KARTH. Mr. Nicks, why aren't we trying for Mars in 1962?

Mr. NICKS. We do not have the resources, either in rocket capability or finances to go into a full-blown planetary program at this time. A decision was made a couple of years ago that we would take evolutionary steps in a logical way, that the Moon would be emphasized first, that we would concentrate on it, and as Venus is the next easiest, we are trying it this year.

Mr. KARTH. Well, originally with Centaur in the picture on schedule did we not plan a Mars flight in 1962?

Mr. NICKS. No, sir, we did not. We had planned to make some test flights of the Mariner spacecraft at about the time of the Venus opportunity, but we had not planned a flight to Mars because it is a very difficult mission in 1962 and we could not have been ready to do all of these things at about the same time.

Mr. KARTH. Now, the Mariner "R" is about 700 pounds lighter than the Mariner "A"?

Mr. NICKS. Yes, sir; that is about right.

Mr. KARTH. Now, does this enhance our chances for a successful flight in 1962 or do you think it weakens our chances for a successful flight in 1962?

Mr. NICKS. The smaller weight for the spacecraft undoubtedly detracts from our chances. However, it is likely that the more reliable Atlas-Agena rocket will make the total probability of success higher, if you see what I mean. One spacecraft would use the Atlas-Agena, the other the Atlas-Centaur. We have in this case a more reliable Atlas-Agena rocket and perhaps a less reliable spacecraft because it is not large enough to afford redundancy and other measures which can improve its long lifetime probabilities.

Mr. KARTH. But the objectives of Mariner "R" will be quite sufficiently less than Mariner "A," will they not?

Mr. NICKS. They are somewhat less; yes, sir.

Mr. KARTH. The potential.

Mr. NICKS. Yes, sir.

Mr. KARTH. What would we have gotten from Mariner "A" that we will not get from Mariner "R"?

Mr. NICKS. Starting with the spacecraft, we would have gotten some more redundancy in the systems that have to operate for the long lifetime, such as the communications system. We might have had a little better backup for the main systems by virtue of the extra weight. From an instrumentation standpoint the measurements would not have been appreciably different in terms of their broad scope. There would have been some more detailed measurements, but it is very hard to say what additional science would have been achieved by them. We know so little about Venus that it is very probable that either the Mariner "R" or the Mariner "A" will tell us many things that we didn't know before.

Mr. KARTH. Will the outstanding difference then between the Mariner "A" and Mariner "R"—was that in "A" you had a backup communications system so that if the one system went out you had something to fall back on, is that right?

Mr. NICKS. Yes, we had some redundancy in systems of that sort and others as well. But the Mariner "A" was to weigh only roughly twice what the Mariner "R" weighs, because it was going on test Centaurs and they had a lot of extra instrumentation for the launch vehicle. Those shots were always planned as test flights, hopefully

at the time of the Venus opportunity, but they were never called Venus shots, per se. We didn't want to hang our hat on that as a total objective because it would have been a new spacecraft on an undeveloped vehicle in the test series of Centaurs, as opposed to developed Centaurs. So it was not the kind of spacecraft-vehicle combination you would want to classify as a planetary mission attempt.

Mr. KARTH. I thought Mariner "A" weighed almost three times as much as Mariner "R," 400 to 1,700——

Mr. NICKS. No; Mariner "A" was designed to go on the test series of Centaurs and was somewhat lighter. It was hoped that it could grow in weight. Marine "B" is being designed for the operational Centaurs and there is extra poundage to the order of 250 pounds or so available to the spacecraft.

Mr. CORTRIGHT. Mr. Chairman, you are correct inasmuch as we indicated 1,150 pounds for Mariner "A" the other day. If that is in error I think we should correct it. Mariner "A" was designed at about 1,050 pounds.

Could I have the next slide, please?

This slide (fig. 452) indicates the type of missions to be flown in the

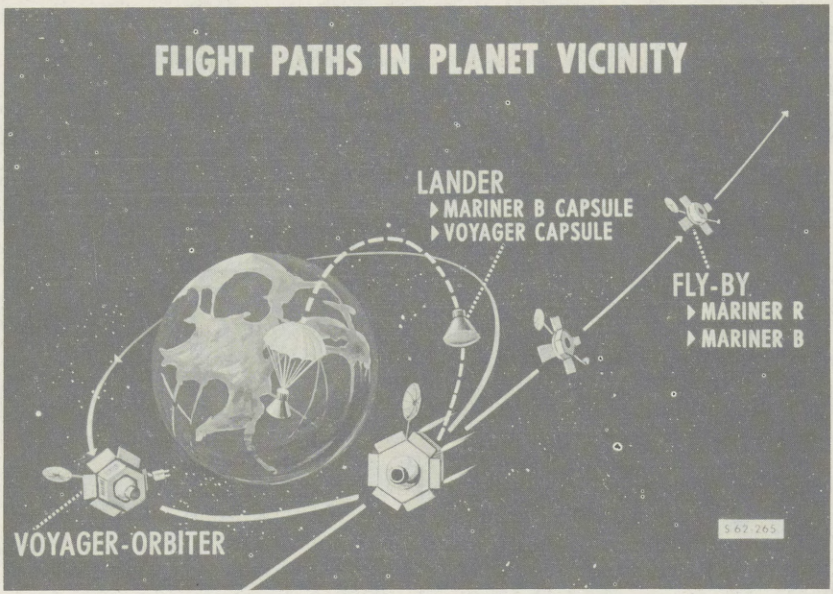


FIGURE 452

vicinity of the planet. A fly-by mission, as I have already stated, would come by the planet and proceed to orbit about the sun. An orbital mission would inject itself with retromotors into an orbit about the planet. A capsule mission could be performed either by ejecting a capsule from the spacecraft in orbit or from one that was going on past. Initially we will do the fly-by missions because they don't require propulsion energy in the vicinity of the planet. Mariner "B" is designed to do a capsule mission at some time.

The next slide (fig. 453), please.

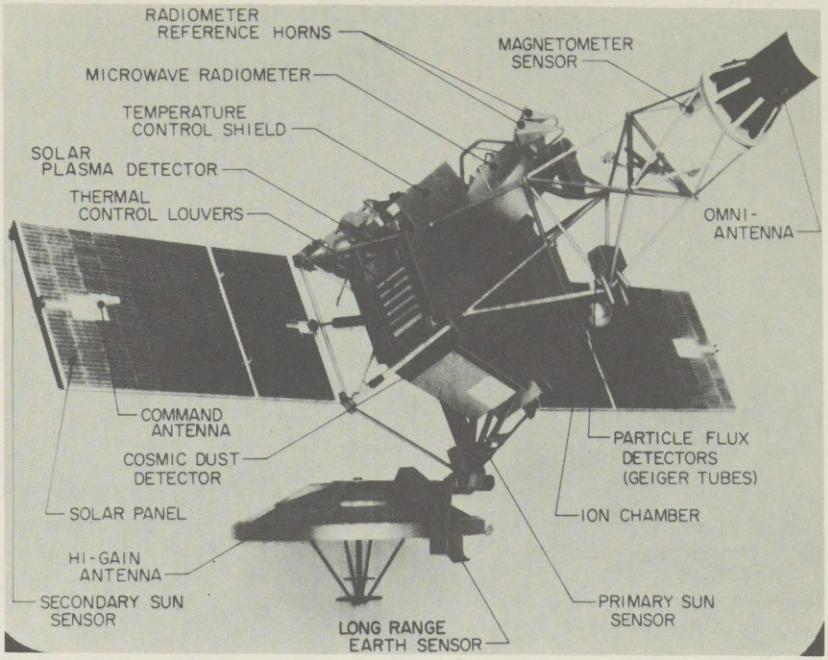


FIGURE 453

Here we have a picture of the Mariner "R" spacecraft. You will notice its very strong family resemblance to the Ranger. The Mariner "R" and Ranger models are here behind you.

Basically it is from the same lineage. It has a hexagonal spacecraft structure. I will point out in the Mariner "A" picture that this part of the spacecraft is essentially the same as that part originally developed for Mariner "A." Carried on this spacecraft are six types of experiments, including about eight instruments. There is a magnetometer to measure magnetic fields in both interplanetary space and near the planet, radiometers to scan the planet and obtain information on its temperature and heat radiating from it, a solar plasma detector for measurements on the way to the planet, meteoritic dust, particle detector, and ion chamber measurements in the vicinity of the planet as well as on the way. There are about 17 experimenters participating in the experiments for the Mariner "R," including J.P.L., University of California, Harvard, MIT, State University of Iowa, Goddard Space Flight Center, Marshall Space Flight Center, and NASA headquarters.

The next slide (fig. 454) illustrates the trajectory that will be used for the Venus flights with Mariner this year. The outer circle in this case is the orbit of the Earth about the Sun, the inner one represents the orbit of Venus.

Venus travels much faster than the Earth. Its speed is about 78,000 miles per hour as opposed to 66,000 miles per hour for the Earth. Consequently its complete orbit of the Sun, or its year you might say, is about 7½ Earth months. These two points indicate the position

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1962 VENUS TRAJECTORIES

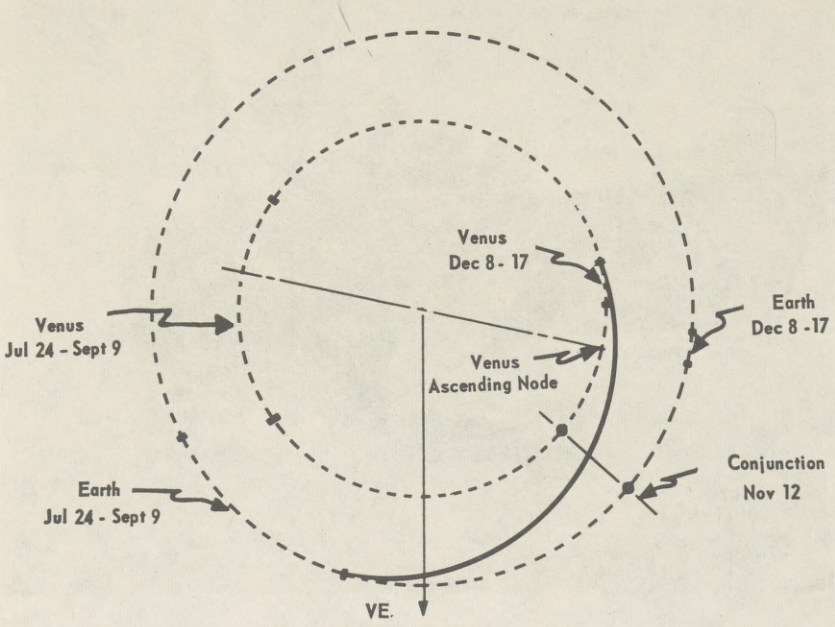

FIGURE 454

of Venus from July 24 to September 9. These two points illustrate where the Earth passes during that time period, and this is a typical trajectory, with a launching from this pont, showing where it should intercept the planet. Now, interestingly enough, spacecraft launched from any of these points along the Earth's orbit would reach Venus along this small region of its trajectory. Launches early in the opportune period have a slow trajectory, spacecraft launched later travel faster, and in either case arrive at the planet about the same time.

The conjunction, or the time when the two planets are nearest each other, occurs about here. At that time their separation is on the order of 26 million miles. Communications distances from the Earth to Venus range around 30, 35 million miles at the time the spacecraft reaches Venus.

A trajectory from the Earth's orbit to the Venus orbit involves elliptical transfers, and the minimum energy trajectory you have heard so much about would arrive at the other orbit at 180° from the point of launch. We are going somewhat faster, and require more vehicle energy because we would like to have the Earth close, if we can, so that the power required for communications is less.

The next slide (fig. 455) shows the Mariner "A". I have put this in because of the previous discussions about it. Portions of the hex structure, as I mentioned, are basically the same as on the Mariner "R". The panels are slightly different in shape. These are larger than those we need on the Mariner "R" because of the second deck of electronic equipment which would have been carried. Again you

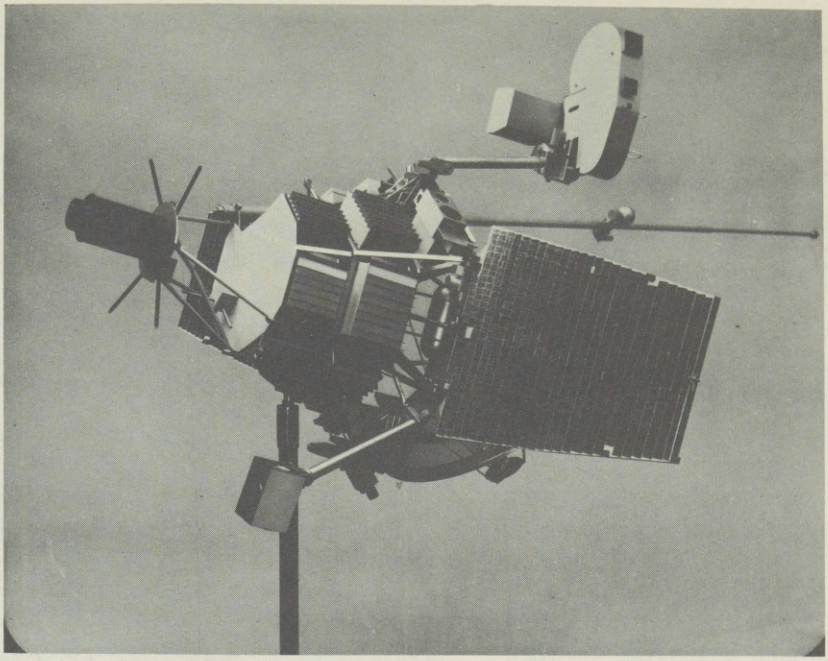

FIGURE 455

see the high gain antenna, the omniantenna and some booms for instruments to scan the planet like those of the Mariner "R".

I should say one more thing here. A summary of the Mariner "A" funding picture has been supplied for the record as requested earlier. A detailed review indicated $3.9 million unrecoverable from the Mariner "A" project due to its cancellation.

The next slide (fig. 456) shows a mockup of the Mariner "B," in its Mars configuration. As Mars is further from the sun than Venus, about four times as much solar panel area is required at Mars than at Venus in order to provide the same power. The basic type of structure is roughly the same with equipment boxes that will be accessible, and an entry capsule here. In this sense it is a little like the Ranger, as it will carry a capsule which can be ejected to land on the planet.

The objectives of the Mariner "B" are several.

It is expected to obtain high resolution photographs of the planet surface, to search for the existence of microbial life with instruments that it carries to observe the planet, and, to determine the scale height, density, temperature, and composition of the atmosphere. It will also map interplanetary fields and particles on the way to and in the vicinity of the planet.

The next slide (fig. 457) is a picture you have seen before in Dr. Newell's presentation, illustrating a concept for the Voyager spacecraft. Two major things are hoped from this larger spacecraft. One is longer life in the vicinity of the planet by orbiting; another is the deployment of a larger capsule which likewise could have a long life on the surface of a planet.

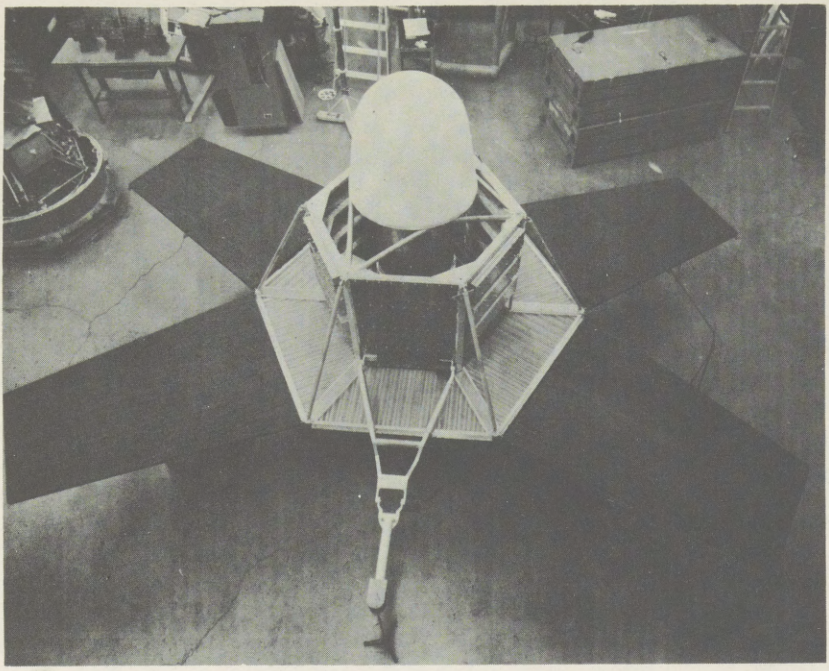

FIGURE 456

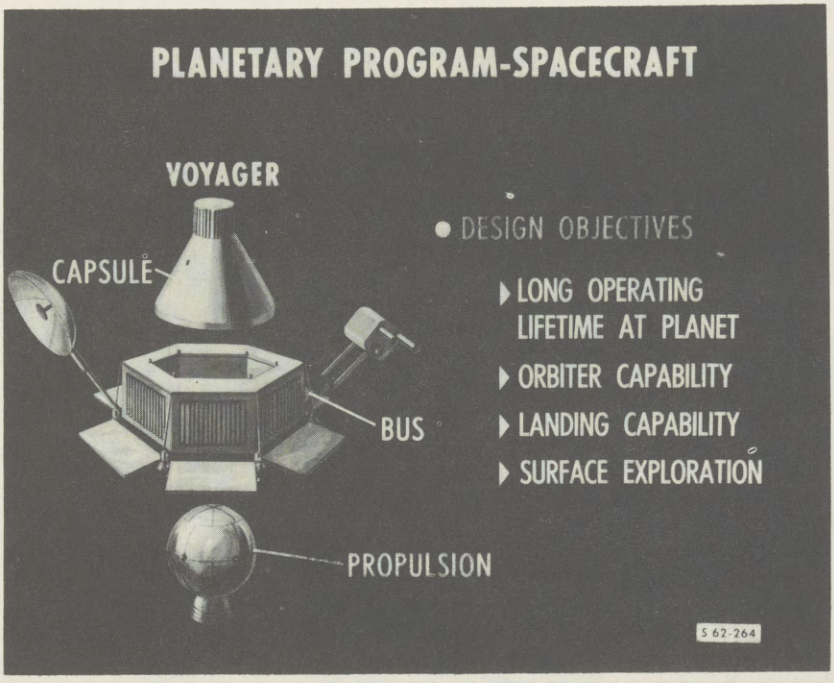

FIGURE 457

There is some hope that the basic Mariner "B" bus might be suitable for adaptation to this mission and that the extra weight capability of the Saturn could largely be used to carry a bigger capsule, or a retropropulsion module applied to the Mariner bus. Wherever possible we like to use the same spacecraft in an evolutionary way, not only from the dollar standpoint but from the reliability standpoint. The more missions you get on a spacecraft the more debugged it becomes, and the better you can count on it.

PARTICIPATION ON RANGER, SURVEYOR, AND MARINER PROJECTS

PROJECT	UNIVERSITIES	JPL	OTHER NASA PARTICIPATION	OTHER GOVERNMENT PARTICIPATION
RANGER	39%	35%	18%	8%
SURVEYOR	64%	26%	5%	5%
MARINER	59%	26%	5%	10%

FIGURE 458

Now, in the next slide (fig. 458) I have indicated for your interest the participation of the scientists in the Ranger, Surveyor, and Mariner projects. This represents a total of almost 100 scientists. In some cases there is some overlap, that is; some of the people who participate in Ranger lunar missions are also qualified to participate in the Surveyor program.

Of these about 28 scientists are involved in the Ranger, some 38 to 40, in the Surveyor, and perhaps as many as 50 for the Mariner missions. The majority of the participation, as you can see, is from universities. The Jet Propulsion Laboratory participates in these because principal responsibility for the spacecraft rests there, and the close integration of experiments in many cases makes it desirable for JPL to participate. Some of the other NASA centers have experiments on these spacecraft, as do other Government agencies, such as the Naval Research Laboratory and the U.S. Geodetic Survey.

Now, I would like to change the theme slightly from talking about the launch vehicles, the spacecraft and their hardware, to what I consider to be a very major element with respect to the successful completion of these programs; namely, the facilities that are necessary to build, check them out and operate them properly. The next slide (fig. 459), please.

I have grouped all these facilities into three categories. Spacecraft development facilities, tracking and data reduction facilities, and launch facilities.

In the next slide (fig. 460) I have taken the spacecraft development facilities to illustrate to you some of the kinds of things required.

TYPES OF FACILITIES REQUIRED

- SPACECRAFT DEVELOPMENT FACILITIES
- TRACKING AND DATA REDUCTION FACILITIES
- LAUNCH FACILITIES

FIGURE 459

SPACECRAFT DEVELOPMENT FACILITIES

▶ SYSTEMS AND SUBSYSTEMS FUNCTIONAL TESTING

- GUIDANCE AND CONTROL -
  - GAS BEARING TEST TABLE
  - CELESTIAL SIMULATOR
  - OPTICAL RESEARCH LABORATORY
- TELECOMMUNICATIONS
  - ANTENNA TESTING RANGE
  - ELECTRONICS LABORATORIES
- SPACECRAFT PROPULSION TEST CELLS
- SPACECRAFT MATERIALS TESTING LABORATORY
- SPACECRAFT STRUCTURAL TESTING LABORATORY
- SPACECRAFT ASSEMBLY FACILITY

FIGURE 460

With spacecraft, unfortunately, it is not profitable to count on test flights to do development, as opposed to, say, an aircraft which can be flown and flown and flown. In a spacecraft it is economically desirable to do as much as you possibly can on the ground before the flight, boosters costing what they do. But even then it is impossible to

do everything you need on the ground, and you always end up having to do some testing in flight.

But here are ground facilities that are important to a spacecraft. These are simply illustrative.

Guidance and control system: We have sensors which must practice looking at things like the Sun, the Earth, and stars in space. We have attitude control systems with very small forces which need to operate on a system with very low friction. We have long-range Earth sensors that have to see the Earth or its equivalent as if they were leaving it behind in going to a distant planet.

Telecommunications: It is necessary to check out the communication system of the spacecraft, obviously in much detail, before you send it off into space. I might say as a sidelight that if the Mariner "R" communicates from those distances it is hoped to this year, it will set new records for communications. The farthest a signal has been received to date was from the Pioneer V at 22 million miles. We shall surely hope to hear from the Mariner "R" at 35 to 40 million miles if we go to the planet Venus.

Spacecraft propulsion, materials, structural testing and assembly facilities: The need for these is fairly self-evident.

The next slide (fig. 461) just illustrates a photo of a spacecraft assembly area at the Jet Propulsion Laboratory. Of significance here are the racks of electronic equipment that are necessary for complete checkout of such a spacecraft.



FIGURE 461

The next slide (fig. 462) shows a cutaway sketch of the space simulator that has just been completed at JPL. This simulator is designed to provide, insofar as possible, the environment of space with respect

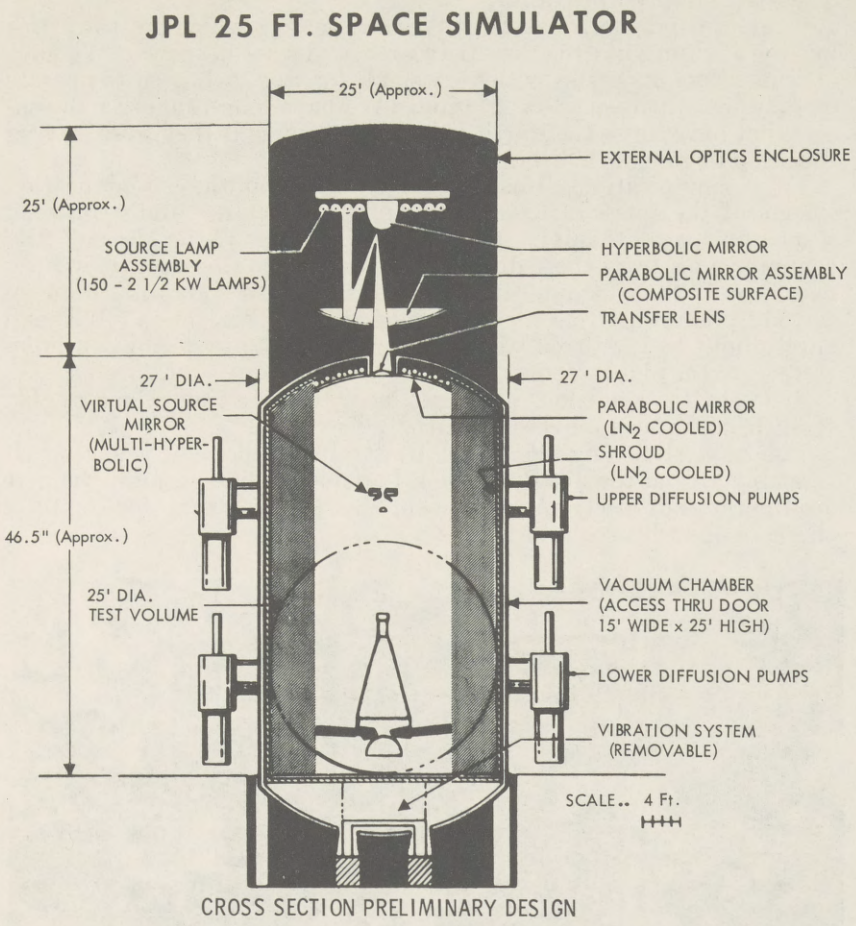

FIGURE 462

to its vacuum and the solar energy. It is a large chamber about 25 by 40 feet. The test area is described as a 25-foot diameter circle. It is cooled and evacuated to very low pressures, such that it would represent on the order of 100 to 300 miles altitude above the Earth. The Sun's energy is simulated by batteries of lamps which reflect into the chamber and which are then spread into a collimated light over the spacecraft.

With this setup we can put spacecraft in the environment of space, leave them for some time and evaluate their reliability. Temperature control is vitally important. Spacecraft, like human beings, have a relatively narrow range of temperatures over which they are allowed to operate. Even a slightly steadily increasing temperature could result in the death of a spacecraft before the 6-month trip required to go to a planet is completed.

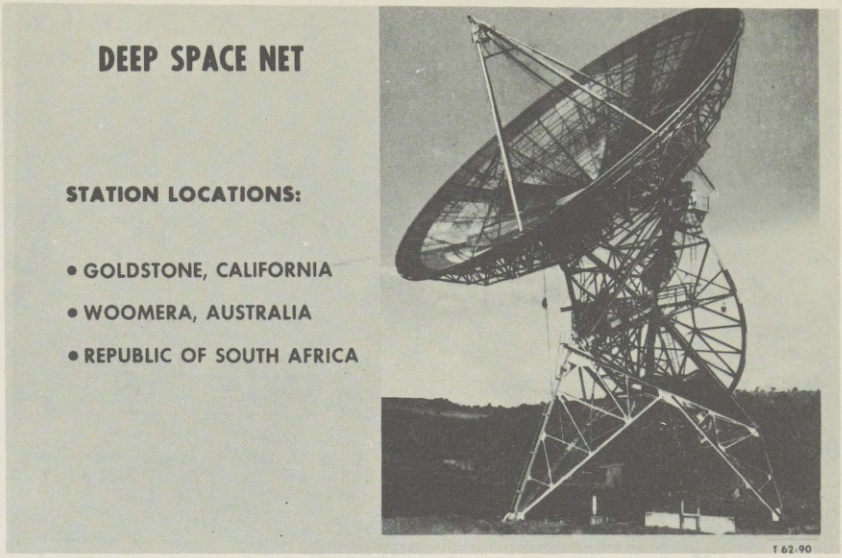

FIGURE 463

The next slide (fig. 463) shows an operational facility you have seen and heard a lot about, perhaps. This is the ground communication system. Communications being absolutely essential to the success of an unmanned system and weight being such a problem, it is desirable that we have the large facilities on the ground. This is one antenna of a type located at three stations around the world, to continuously track and monitor planetary spacecraft.

The next slide (fig. 464) indicates in block form a facility that we hope to have built this year. It is called the Space Flight Operations Facility. In that facility we will receive data from each of these stations in the net around the world, we will have it displayed so that real-time performances can take place, the exact flight path and position of the spacecraft will be obtained, data will be computed and commands sent to the spacecraft. There will also be a data storage and reproduction facility associated with this, such that scientific or engineering data can be analyzed as rapidly as possible. This facility will include computers.

That concludes my slides. I would like to say in summary, if I may, about the lunar and the planetary programs that the spacecraft and launch vehicle families for these bear a marked resemblance and are evolutionary in almost every respect. There are three classes of launch vehicles involved in the lunar and planetary program at the present time. There are three spacecraft models for lunar, three for planetary, but two of those for the planetary are very much like developments for the lunar. Thank you.

Mr. KARTH. Any questions of Mr. Nicks?

Mr. VAN PELT. No questions.

Mr. KARTH. Mr. Casey?

Mr. CASEY. Mr. Nicks, in your summary there you mentioned something that I think some of us would like a little clarification on,

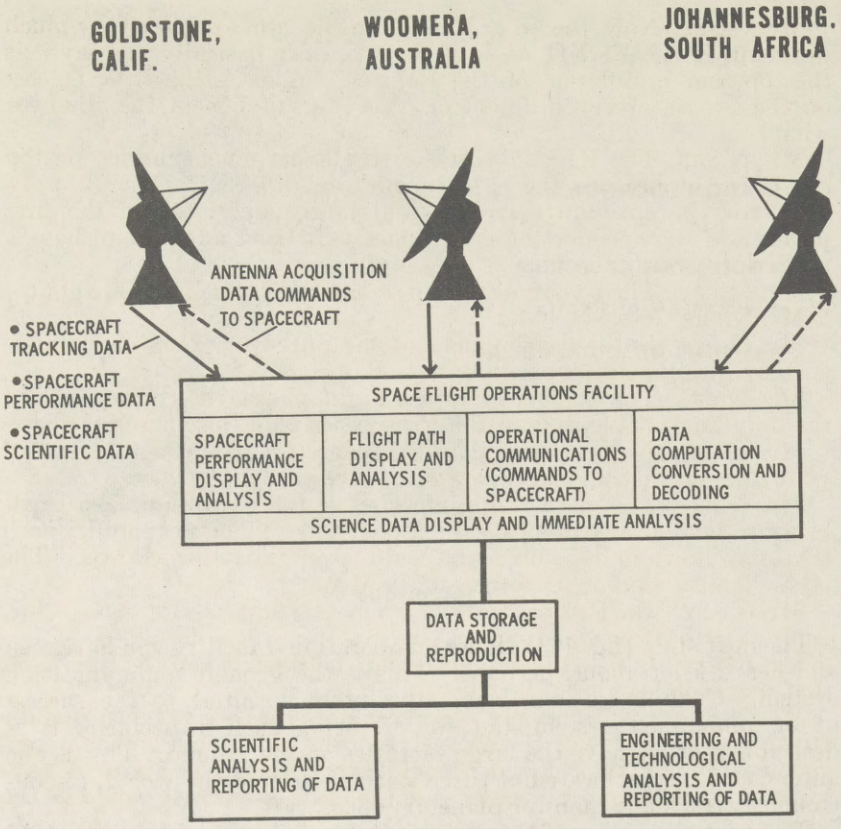

FIGURE 464

the need for not only the three classes, but, I think in the Ranger, for instance, you have two classes of Ranger, do you not?

Mr. NICKS. Yes, sir.

Mr. CASEY. We are interested in knowing why all of the development of the various classes is necessary instead of, say, staying with one. Take the Ranger, for instance; you started out with two or three classes of the Ranger.

Mr. NICKS. Well, you might say there were three classes. Actually, they are all the same except for the payload carried on top. What you would call the basic spacecraft bus, that is what we call it because it is intended to carry different things on it, are the same for all Rangers.

You can take the payload sections off Rangers and they would all look alike. We do carry different instruments on top. The first in the series carried interplanetary instruments so that it could make measurements on the environment of space. The next one carried a capsule to be landed on the Moon, and the next one is to carry television cameras so that it can take pictures of the Moon. But I would not classify these as different spacecraft, but rather as different uses of the same spacecraft.

Mr. CASEY. Now, the R. & D. costs in the two, are they very much different, in the R. & D. costs of the top, since basically you say it is the top that is different on the Ranger? What is the R. & D. cost on the two; are they different or does one supplement the other, or what?

Mr. NICKS. The R. & D. costs for the experimnets carried on top are different because the experiments are different. The R. & D. costs for the spacecraft are, by and large, amortized in the first series, and we consider the basic spacecraft bus thereafter to have a relatively constant cost.

Mr. CASEY. Then your next step is the Surveyor, is that right?

Mr. NICKS. Yes, sir.

Mr. CASEY. Is the development of the Surveyor going on simultaneously with the development of your Rangers?

Mr. NICKS. The Ranger is in the flight phase, the Surveyor is in the development phase, and the Prospector is in the planning phase.

Mr. CASEY. Now, what will the Prospector give you that one of your Rangers or your Surveyors won't give you?

Mr. NICKS. The main thing expected of the Prospector is a capability to land at any point on the Moon, and a mobile capability such that once down on the surface it could cover fairly large areas. The others land at a point, or points, on the Moon.

Mr. CASEY. The Prospector then is a mobile unit?

Mr. NICKS. It is hoped so; yes, sir.

Mr. CASEY. Is that the only difference between it and the Surveyor, that it is mobile?

Mr. NICKS. No, sir; there are other uses that we hope to put the Prospector to. One of the most significant differences is that we envision it as a platform which could carry numerous kinds of payloads to the Moon and in every case the basic spacecraft would be the same.

Mr. CASEY. You say numerous payloads. You mean instruments that you haven't started designing yet, or something that may be in the future, or what?

Mr. NICKS. I mean things like a roving surface vehicle, like a rocket that could return a sample from the Moon to the Earth, like supplies, perhaps, even after the time when the man goes there; that sort of thing.

Mr. CASEY. Now, if that is so much more advantageous, why do we even fool with the Surveyor, why don't we just go ahead with the Prospector?

Mr. NICKS. I would say there are two reasons for that. One is we need information about the Moon as soon as possible in order to apply it to our manned space flight program, to be able to design these manned spacecraft, and the Surveyor would appear to be available on the order of 2 years, at least, before we could go there with a larger one. The other reason is it costs a good deal more and takes a lot more time to develop the large spacecraft, and it would represent a very large jump in technology from where we are today. And you have to walk before you run, I think, in this business, to some extent.

Mr. CASEY. What is the difference in size between the Surveyor and the Prospector, weightwise?

Mr. NICKS. The surveyor at injection by the space vehicle is expected to be on the order of 2,300 to 2,500 pounds. The Prospector,

depending on the launch vehicle used—and there is still some study going on about the kind of Saturn-class vehicle that should be used for this mission—may give from 5,000 to 10,000 pounds launched, up to a tremendous number. I can't tell you what it is, really, if we were to use the largest Saturn booster designed for manned missions.

Mr. CASEY. Now, is the Prospector anticipated to carry maybe a manned load?

Mr. NICKS. You mean a man?

Mr. CASEY. Yes.

Mr. NICKS. No, sir.

Mr. CASEY. But you say it will be anywhere from two times heavier, up?

Mr. NICKS. Yes.

Mr. CASEY. From the Surveyor.

Mr. NICKS. Yes, sir.

Mr. CASEY. I am just thinking out loud. What I am wondering about is what we spend for new development of a new load there in the form of instrumentation for exploration, are we getting what it is worth for the additional information that you are after? That is what I am interested in. In other words, for instance, if the Surveyor, althought it is just designed to go at particular points, as I understand it, while your Prospector would rove, it might be better to shoot more Surveyors at different points than to—that is, dollarwise, now. Scientificwise, I am sure that the scientific community wants to explore every corner and every nook and cranny in every way they possibly can; but we have also got to justify the cost of these different types of loads that we put up there, if you are getting your money's worth for the additional information that you will acquire by reason of developing another mission.

Mr. NICKS. There is a lot to this; you are certainly right; and this is something that we wrestle with, are wrestling with, all of the time.

I don't know the answer yet as to exactly what the final economics would be. There are certain things that are very difficult to do from one landing point. For example, if you were going to try and survey a site, several square miles, that you thought would be a suitable place to put down a man, you would want to have a closer look at it than you could take from one point or from several points when the line of visibility is only a few miles, say 2 miles or so from a landed point.

I think it is practically impossible to say how many point landings would be required to give you the same amount of data as one landing with a roving capability, because we don't know enough about the Moon right now and its homogeneity to say whether we can do it that way.

Mr. KARTH. Will the gentleman yield?

Mr. CASEY. Yes.

Mr. KARTH. Mr. Nicks, what is the anticipated research and development cost of Prospector? It seems to me that someone at one time during this series of meetings said $180 million; is that correct?

Mr. NICKS. That was Surveyor, sir.

Mr. KARTH. Then there were other figures used. First of all, I think it was three. Mr. Cortright corrected that later and said that was Surveyor. Was that $180 million?

Mr. CORTRIGHT. Yes.

Mr. KARTH. What is your anticipated cost for R. & D. for Prospector?

Mr. CORTRIGHT. I think it was in the neighborhood of $180 million also. I did make a guess of that, for the first three flight articles. But that could vary widely. That is why I hesitate to make an estimate. It depends on what size this vehicle or spacecraft turns out to be.

Mr. KARTH. What do you take the production cost of a Surveyor to be, for example? I think what Mr. Casey is trying to get at is the dollars-and-cents value here of the two different vehicles and then calculate whether it would be cheaper to fly X number of additional Surveyors as opposed to going ahead with a brandnew development that we are guessing at would cost a minimum, I suppose, of $180 million to develop. It would probably be closer to Mr. Cortright's original guess of $300 million. I think this is what Mr. Casey is trying to ascertain, and I am sure that the rest of the committee is interested in that line of questioning. So what would you anticipate the production cost of a Surveyor to be, Mr. Nicks?

Mr. NICKS. Including launch vehicle?

Mr. KARTH. No; just the spacecraft, itself.

Mr. NICKS. It will be on the order of $12 million.

Mr. CORTRIGHT. I think I gave 12 to 15 in the record earlier, including the instruments.

Mr. NICKS. It is possible to say how many Surveyors the developments cost of Prospector would buy. It is not possible to say how many Surveyors it would take to return the same data as a Prospector.

Mr. KARTH. Yes. But as far as the timetable is concerned you are talking about Prospector in 1967?

Mr. NICKS. That is right.

Mr. KARTH. To 1970, aren't you?

Mr. NICKS. Yes, sir.

Mr. KARTH. That is about the same time that you are talking about manned lunar and landing flights and return missions, isn't it?

Mr. NICKS. Yes, sir.

Mr. KARTH. I would assume that if we are talking about the same timetable for both, might it not be better to have visual inspection of the surface of the moon through the eyes of a man than through the eyes of a camera that you might have on Prospector, for example?

Mr. NICKS. Yes, sir; there is no question that if we can really put man's eyes on the Moon and give him an ability to act up there in person, that some of the things we had in mind for Prospector could be done better. However, we do hope to beat the man, and I would like to correct what you said just a little bit; namely, we would hope to be able to do this with the Prospector at least a year and probably 2 years before man gets there, although we are talking in the same general time period. There is every reason to think that you might do this 1 to 2 years sooner.

Mr. KARTH. With Surveyor you are thinking of doing it how much sooner—4 or 5 years sooner?

Mr. NICKS. Two to four years.

Mr. KARTH. Two to four.

Mr. NICKS. But we do it with Surveyor at a time when the data we get will help us design the systems for the man; the other would check it out just before he goes. Such things as landing site surveys could be done just before the man goes, but it would be a very necessary thing, I think, to know where he was going.

Dr. NEWELL. I wonder if I could add a few comments here to elaborate on some of the things that Mr. Nicks has said.

First of all, these points that you are bringing up we are wrestling with ourselves and considering very carefully. We have no desire to build any spacecraft that we don't need. It is a lot of work, and if they are not needed it is certainly wasteful. We are, however, considering the Prospector because it seems to us that there may well be a real need. And in illustrating this, I would like to point out a number of things. In fact, I would like to quote some words that Mr. Nicks, himself, used sometime earlier.

When we come to science in space or science in general, it is largely instrumented science. In the ordinary astronomy that went on before we had rockets, these instruments were on the ground with the man. When the rockets became available, the instruments were put into sounding rockets and satellites with the man on the ground. And we are now hoping to get the instruments out to the Moon, but the man is still on the ground.

You see, it turns out to be all manned science. Eventually we will get the man and the instruments together to the Moon. The man will take the instruments to the Moon. The point I am trying to bring out here is that the man, in order to make his observations, must have instruments. His eyes don't do it all. There are things that he can't detect without his instruments. Even on the Earth we recognize this as we study the Earth.

Now, when the man gets to the Moon it may well be—and this is the point that we are considering very carefully—that he needs a much more versatile vehicle to go with him than the Surveyor. And this is why we are considering the Prospector. For example, you see, the Prospector will have a land-anywhere capability, and the man, as he goes to the Moon, may need to have that land-anywhere capability in support of his mission. So the Prospector will provide you with a versatile platform that can carry a roving vehicle, that can carry a vehicle to pick up samples and come back, that can support the man logistically and scientifically in his mission on the Moon.

Mr. CASEY. Of course, what raised the question in my mind was that Mr. Nicks painted a very fine picture of the work that the Ranger would do, not only on landing and in low orbit and the various types of cameras, that maybe I got a more inflated idea of what you are going to get out of that than I should have. And then with your Surveyor, the two combined seemed to me like you were going to get practically everything you needed.

But I can understand also the point you are endeavoring to make here, that if you had your Prospector developed it could go up at the same time as your manned landing and possibly could even be controlled by the man there.

Dr. NEWELL. Yes, sir.

Mr. CASEY. I think it is incumbent, at least I feel it is personally incumbent upon us to make sure that the additional capability and data that you are going to get from this type of vehicle is going to be worth what it will cost.

Dr. NEWELL. Absolutely.

Mr. KARTH. Mr. Randall.

Mr. RANDALL. I think the matter has largely been covered, but as I understood from some of the questions of Mr. Casey, it didn't neces-

sarily follow the line of reasoning he was developing, it seems to me if there is any suggestion of leapfrogging the Surveyor and going to the Prospector, then we would lose the information that we need right now.

Isn't that the point of the whole thing?

Dr. NEWELL. That is correct.

Mr. RANDALL. I mean, as I see it, we need as much information as we can get prior to a manned flight which we cannot possibly get from the Prospector; is that substantially correct?

Dr. NEWELL. That is substantially correct. Both scientific and engineering information and engineering experience are required, along with taking reasonable size steps.

Mr. RANDALL. I concur, of course, with the effort to eliminate any useless space vehicle, but it seems to me the Surveyor is vitally needed at this time. I get news reports that the Russians have some other type of spectacular, and I suspect the committee is going to be under great pressure maybe before this session is over to hurry it up a little bit, and it occurs to me that this is vital, this Surveyor. I wanted to be sure of that.

Dr. NEWELL. That is correct.

Mr. RANDALL. That is all.

Mr. CASEY. I want to point out to the gentleman, too, that this committee might be under some pressure not to spend so much so fast if we are going to give all our data away.

Mr. RANDALL. That is a matter for the Executive.

Mr. CASEY. I understand, yet this committee is under pressure.

Mr. RANDALL. I stated repeatedly at the George Washington Inn, when the gentleman wasn't present, that it is very difficult to justify these expenditures, and we are trying to justify them. But on this particular one I am merely trying to establish that this is necessary, this is one of the most necessary things we can do. Is that your view?

Dr. NEWELL. That is correct.

And, Mr. Chairman, if I may present an example of why we have to give our data away in this science business, which is not my example, I believe it was due to Girard Peel, of the Scientific American. He pointed out that in the early 1930's, Fermi published a paper which concerned the possibility of nuclear fission. That was about the only paper that year. The next year, after that paper had been published, there were a few——

Mr. KARTH. What year was that, Doctor?

Dr. NEWELL. The early 1930's. The next year a few papers appeared from the whole world scientific community, and the next year a few more, and so on, until some dozens of papers appeared in the late 1930's when it became clear that fission was possible and could be built up into the nuclear weapon.

Well, now, these many, many papers that finally put the world in a position and ourselves in a position to prepare a nuclear weapon came from the entire world scientific community and the exchange of ideas and so forth; not just from the United States. And if there hadn't been this exchange, there is some question as to how long it would have taken to arrive at that point, particularly because Fermi's first paper was wrong, and if we had classified his first paper we would have been struggling with an incorrect theory.

Mr. KARTH. I am not so sure we wouldn't have been better off, Doctor.

Dr. NEWELL. That is another point.

Mr. KARTH. I understand your point.

Doctor, now how would you like to proceed?

Dr. NEWELL. If we are through with Mr. Nicks, in the early part of these presentations Mr. Cortright reviewed for you the vehicle effort in support of the space sciences program. We would like today to pick up one of the most important elements of that presentation, the Centaur.

As Mr. Cortright pointed out to you, this is of extreme importance to us in our space science program. Col. Don Heaton, of the Office of Space Sciences, would like to review that for you.

Mr. KARTH. Colonel, proceed.

STATEMENT OF COL. DONALD H. HEATON, DIRECTOR OF VEHICLES, OFFICE OF SPACE SCIENCES, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Colonel HEATON. Mr. Chairman and gentlemen, this presentation is intended as a review of Centaur program objectives, progress during the past year and the present status.

I will attempt to place in proper perspective the problems which still confront us, as well as those which we have already met and solved. It will, I hope, answer the questions which you gentlemen have regarding the Centaur project.

At this point I would like to review the objectives of the Centaur project. Viewed broadly, they are two in number, and we expect both to be satisfied. First, the Centaur is intended to bridge the gap in the performance spectrum between the Atlas-Agena and the Saturn class of vehicles. Second, the Centaur development is intended to serve as a research and development tool of great value. In it we are uncovering and solving solutions and evolving solutions to the problems of using liquid hydrogen, the high energy fuel which will be employed in virtually all upper stages of large future space vehicles, whether they derive their energy from chemical combustion or nuclear reactions.

It is noteworthy that both objectives of the Centaur project derive their significance from the importance of hydrogen as a high energy fuel.

The purpose of this slide (fig. 465) is to show that liquid hydrogen technology is most vital to the manned and unmanned lunar and planetary efforts which are at once the most important, most difficult, and most costly of the future NASA space exploration programs.

The chart specifically shows that what we stand to gain in payload from the use of the Centaur propellant combination as our program of space exploration moves outward from Earth.

You will observe here that these bars—the length of these bars depicts payload. The red bar in every case alludes to a vehicle with hydrogen and oxygen propellants in their upper stages, whereas the blue bars depict a similar size vehicle, but with conventional propellants in the upper stages.

Mr. KARTH. What do you mean by "conventional"?

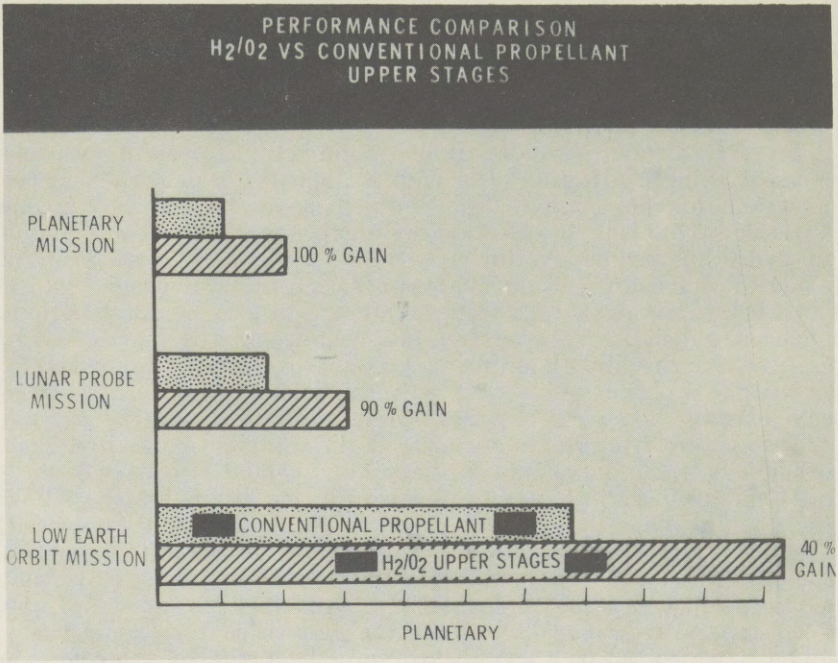

FIGURE 465

Colonel HEATON. A propellant combination with the level of energy one obtains from, say, jet fuel and oxygen, or one of the storable propellant combinations which are being used now and which have about the same level of energy per pound of material.

Mr. KARTH. Is that the propellant used in Titan, for example?

Colonel HEATON. Yes, sir; about the same.

Mr. KARTH. All right.

Colonel HEATON. Now, the lower pair of bars pertain to a low Earth orbit mission, and the middle pair to the lunar-type mission, and the upper to the planetary mission. And on the right hand end of each pair of bars are actually written the percentage gain provided by the hydrogen-oxygen upper stages over what one would expect from the conventional propellant upper stages.

Note that whereas hydrogen upper stages can lift a 40-percent greater payload into a low Earth orbit than can stages using conventional energy propellants, on a lunar mission the margin of superiority rises to about 90 percent. For the still higher velocity Venus mission, the payload increase attributable to high energy propellants rises still further to at least 100 percent—that is, double the payload which a similar size vehicle using only propellants of conventional energy could carry.

Another and highly illuminating way of interpreting these percentages is in terms of the sheer weight of launch vehicle hardware required to carry out a particular lunar or planetary mission. If we are not able to use hydrogen for the lunar missions, for example, the amount of launch vehicle hardware required to get the job done will nearly double.

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Considering the many flights of heavy spacecraft involved in these programs, both manned and unmanned, it is abundantly evident that the penalty for failing to learn how to harness the high energy of hydrogen effectively, reliably and promptly would prove exceedingly costly in money and time.

Now, the Centaur has already encountered and solved many problems of using hydrogen. The engine difficulty which plagued the program this time last year, but which is now solved, is a prime example. However, the Centaur will make its greatest contribution to hydrogen technology during the 10-vehicle flight test program about to commence. The problems of storing liquid hydrogen, which boils below minus 400° Fahrenheit, during protracted coast periods under so-called zero g., or free-fall conditions will be accurately assessed for the first time during Centaur test flights, for example, as will the problems of starting hydrogen rocket engines in the space environment subsequent to zero g. coast.

Quite apart from the importance of the contribution to hydrogen technology which the Centaur project is uniquely able to make because the Centaur exists in hardware form ready for flight test, right now the Centaur stage is being developed to fulfill an operational need. The high energy Centaur stage was originally conceived to maximize the payload capacity of the Atlas ICBM as a space booster. Because of the performance advantages of hydrogen fuel just discussed, the Centaur is slated chiefly to handle the more difficult, high velocity missions which can be accomplished with the available Atlas booster only if it is teamed with the high energy Centaur upper stage. The missions assigned the Centaur are shown on this slide. (Fig. 466.)

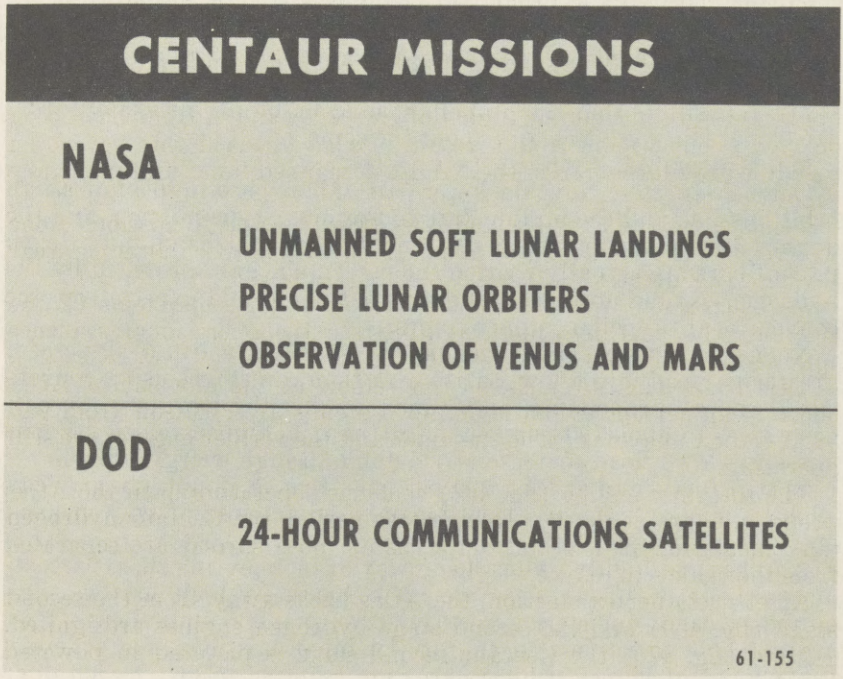

FIGURE 466

For NASA, the Centaur will carry the unmanned Surveyor lunar spacecraft and the Mariner "B" planetary spacecraft. The additional payload capability of the high-energy Centaur over the conventional-energy Atlas-Agena will permit soft landings on the Moon and orbits of the Moon—both milestones of great importance to later manned lunar landings and both milestones which we must pass at the earliest possible date in order for the Surveyor to be of greatest service to the development of the manned system to follow.

The very sizable increase in planetary payloads afforded by the high-energy Centaur stage over the Agena stage makes possible very important experiments at Venus and Mars and in interplanetary space which cannot be accomplished with a less energetic launch vehicle.

The Centaur is expected to have sufficient payload capability to perform the Surveyor and Mariner missions. Furthermore, despite delays due to technical difficulties, we believe that the Centaur will be able to accomplish the Surveyor and Mariner "B" missions significantly earlier than could any other vehicle.

The most exacting mission assigned Centaur is the task of placing the Department of Defense Advent communications satellite into a 24-hour orbit—the circular, equatorial orbit at about 22,000 miles altitude in which the spacecraft has the same rate of angular travel as the Earth, so that the spacecraft appears to hover continuously over a particular spot on earth. Fully meeting the performance and accuracy demands of this mission has posed singularly difficult problems for the Centaur development program. However, working with the Department of Defense agencies involved, the NASA has recently evolved a technical approach which promises to satisfy the Advent payload requirement.

The engine problems of last year plus the myriad difficulties of mating the new engines, new propellant supply system, new guidance and control system and new static test and launch facilities into a functioning vehicle system have caused delays in the Centaur development program. Centaur flights of Surveyor and Advent have been delayed about 6 months as a result. Atlas-Agena flights have been scheduled to fill the gap in the NASA unmanned lunar and planetary programs.

Demand for the Centaur continues strong. NASA missions alone will require the launching of about 12 operational Centaurs per year through this decade.

As background for a status report on major subsystems of the Centaur, the next few pictures illustrate the operational sequence followed in all flights of the vehicle.

This chart (fig. 467) shows the vehicle at the moment of Atlas booster engine separation, about 150 seconds after lift-off from pad 36 at Cape Canaveral. The sustainer and the vernier engines are still operating.

The sustainer engine (fig. 468) continues operating until the Atlas propellants are depleted. During this period, the Centaur hydrogen tank insulation panels and aerodynamic nose shroud are separated from the vehicle to reduce weight.

After sustainer exhaustion, the Atlas backs away from the second stage (fig. 469) and the second stage hydrogen engines are ignited.

Here (fig. 470) the Centaur second stage is pictured in powered flight.

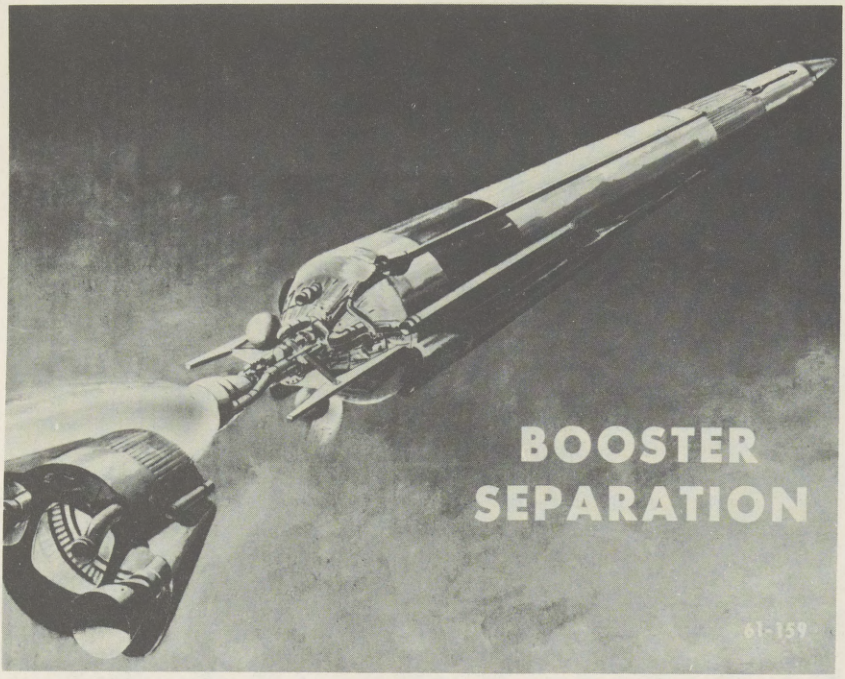

FIGURE 467

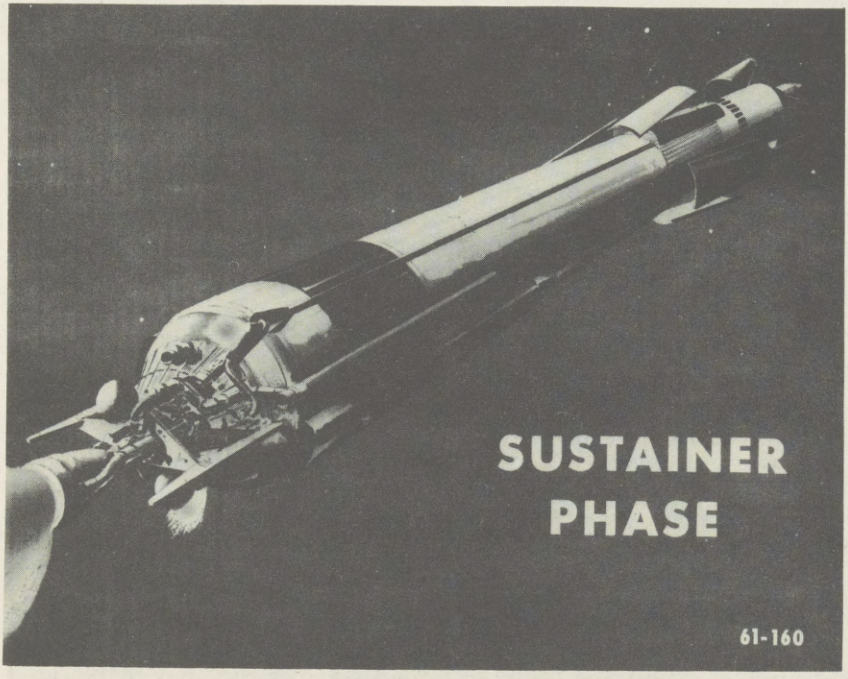

FIGURE 468

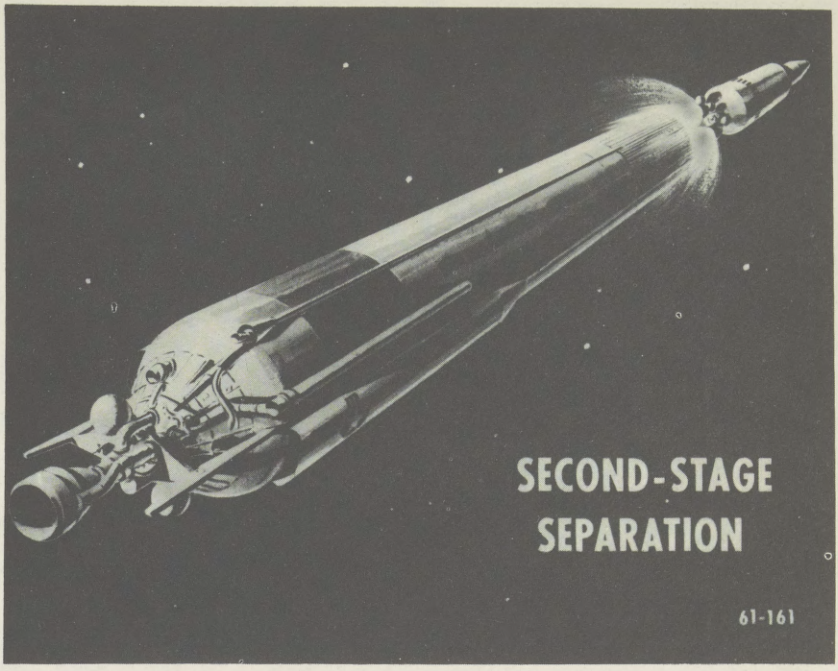

FIGURE 469

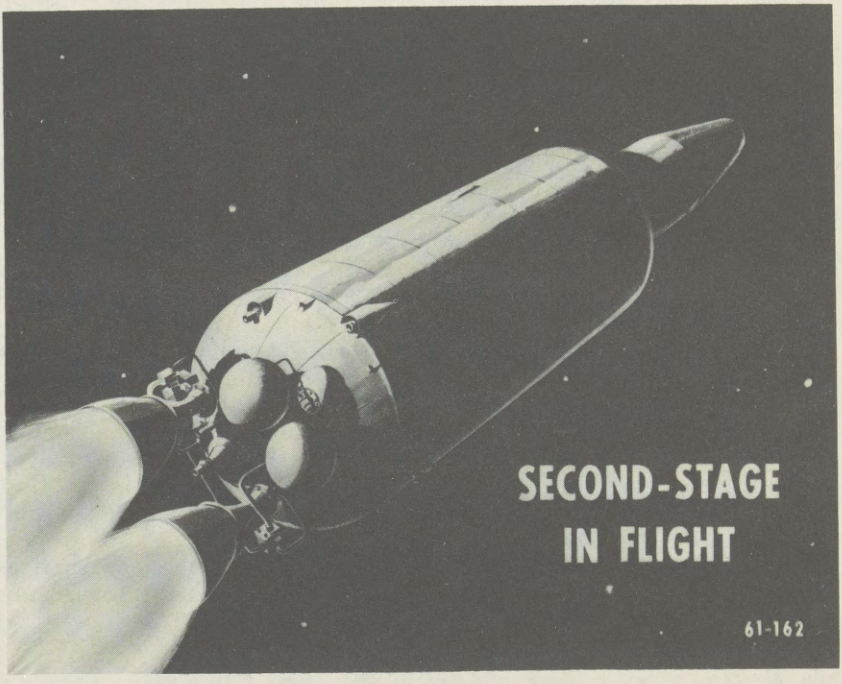

FIGURE 470

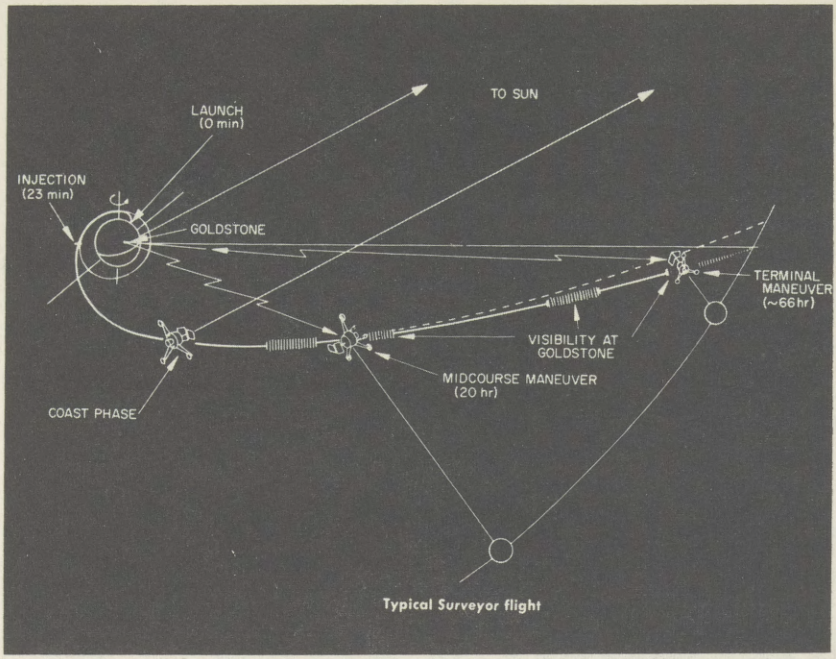

FIGURE 471

This sketch (fig. 471) of a Surveyor mission shows the role of Centaur in a typical operational flight. The launch sequence just described places the Centaur still attached to its Surveyor payload in a circular parking orbit at about 100 miles height, here and here [indicating].

This combination coasts in the parking orbit about 20 minutes until reaching the proper point, determined by the Centaur guidance system, to initiate a second period of Centaur engine operation. This second Centaur burn will place the Surveyor on a trajectory to intercept the Moon. The Centaur stage is separated from the Surveyor after Centaur engine cutoff.

This (fig. 472) shows the method of construction used in fabricating the Centaur second-stage vehicle. The tank is made of very thin stainless steel sheet formed into cylindrical segments, as you can see. The segments are then welded to each other forming two tanks, one for oxygen at the bottom, one for hydrogen at the top.

The structural integrity of this design requires that a gas pressure be maintained at all times inside the tank, much in the manner of a football which must be inflated to sustain any external weight. Gas pressure in the lower tank which holds liquid oxygen, you will remember, is higher than the gas pressure in the upper liquid hydrogen container. It is this pressure differential across a common insulated bulkhead which holds the weight of the hydrogen against the accelerations of powered flight.

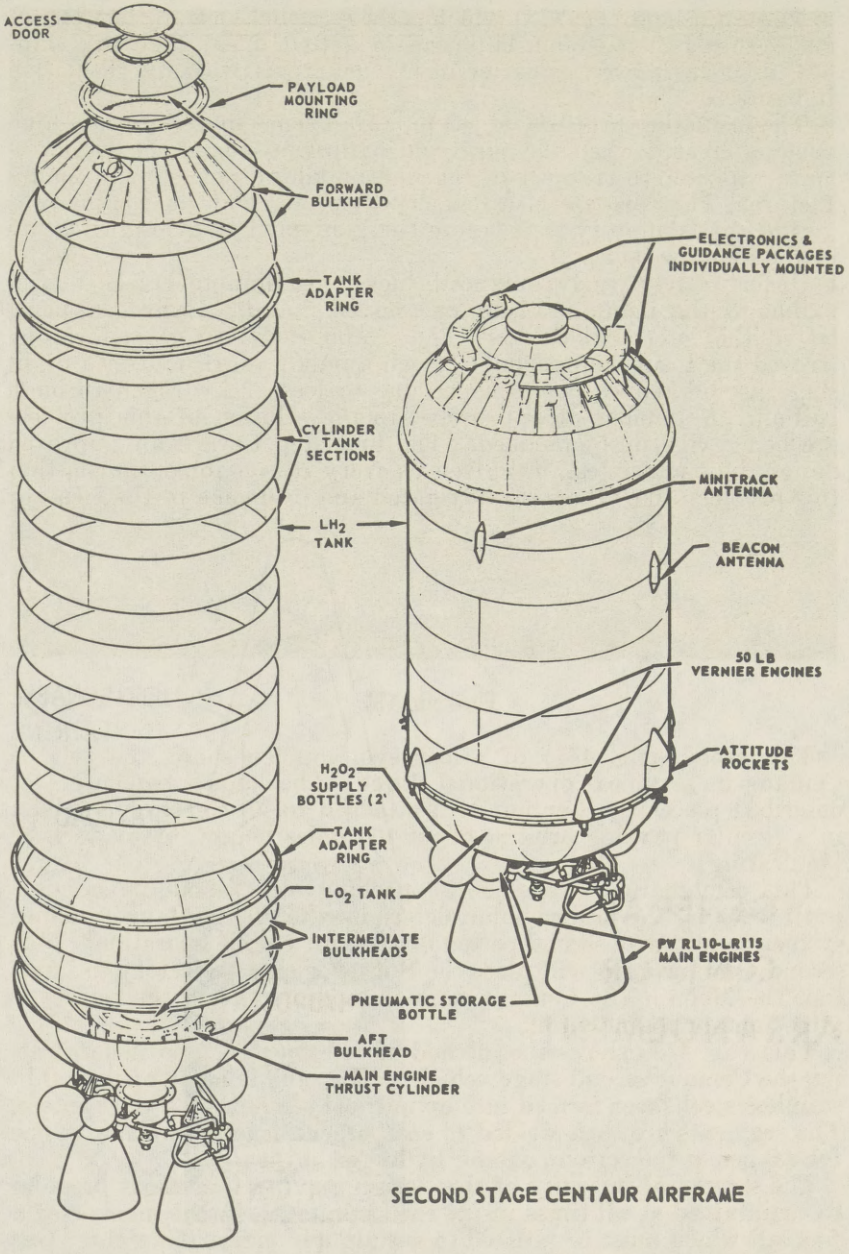

FIGURE 472

We have been troubled by excessive heat transfer from the oxygen into the hydrogen tank across this insulated bulkhead during ground tests of early flight articles. The bulkhead is made up of two nested stainless steel sections separated by a thin layer of insulating material.

The next chart (fig. 473) which is the sectional view of the Centaur stage, shows the common bulkhead in dotted lines. The two skins are just a little over a quarter of an inch apart with the insulation in between.

The insulating property of the bulkhead stems mainly from a high vacuum created when the supercold hydrogen freezes the air molecules which were trapped in the interbulkhead zone during manufacture. This process is called cryopumping and its efficacy was verified by laboratory tests before being adopted as a design feature of the Centaur tank.

Unfortunately, early bulkheads developed minute cracks attributable to the manufacturing process employed. Hydrogen penetrated the interbulkhead zone and evaporated into gas which destroyed the insulating vacuum. Such a bulkhead, if used in a flight stage, would reduce performance due to loss of hydrogen through boil-off. A number of approaches to the solution of this problem are being vigorously pursued. The first step toward an improved design, now under test, has given us every reason for optimism that this problem, like others already faced and overcome in the Centaur

GENERAL CENTAUR ARRANGEMENT

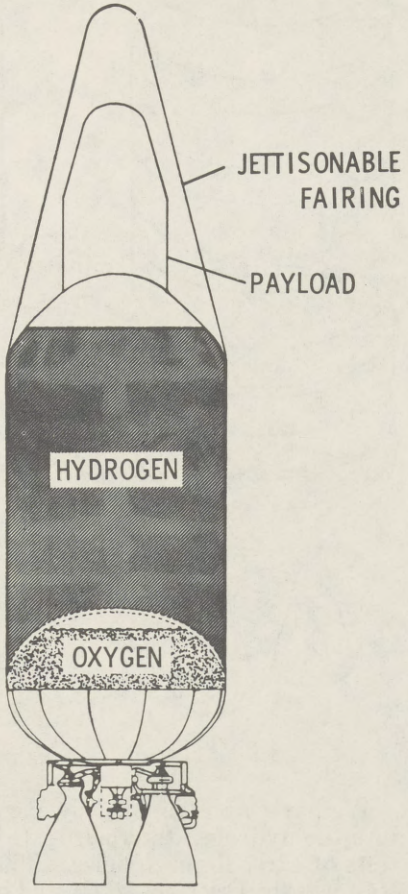

FIGURE 473

research and development program, will be resolved before the vehicle carries operational payloads, and in the process, will add to our fund of knowledge of how to employ hydrogen in space.

During the past year at Sycamore Canyon outside San Diego (fig. 474), the vehicle contractor, General Dynamics-Astronautics, made a series of tests of the propellant handling functions of the flight stage. These tests aided materially in perfecting hydrogen loading equipment and in establishing optimum engine prestart procedures. The second Centaur flight article is currently undergoing bulkhead heat transfer tests in this facility.

In this view (fig. 475) inside the San Diego factory of General Dynamics/Astronautics, we see the three versions of Atlas which are currently in use by the national space program. At top is the Centaur booster with its all-cylindrical oxygen tank. Next is the standard ICBM Atlas configuration. At the bottom is the Atlas as configured for the Mercury man-in-space program. It was such an Atlas which recently catapulted Colonel Glenn into orbit.

At Point Loma, near San Diego (fig. 476), tests of propellant handling and storage methods and (fig. 477) nose cone and insulation panel ejection tests (fig. 478) and coast-phase control systems tests. These tests are in advanced stages at the present time.

I would like to point out what is depicted in this view of the Point Loma coast phase test setup. This framework has the same mass distribution as the complete Centaur stage. This bright object here is a heat source simulating the Sun. It is picked up by a sun-seeker, which is part of the coast phase control system of the Centaur. Not

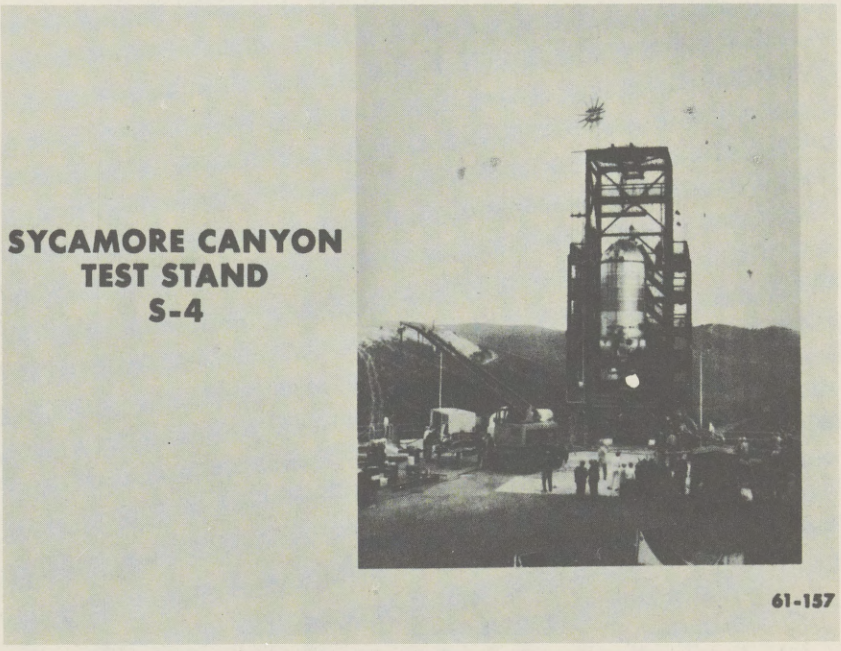

FIGURE 474

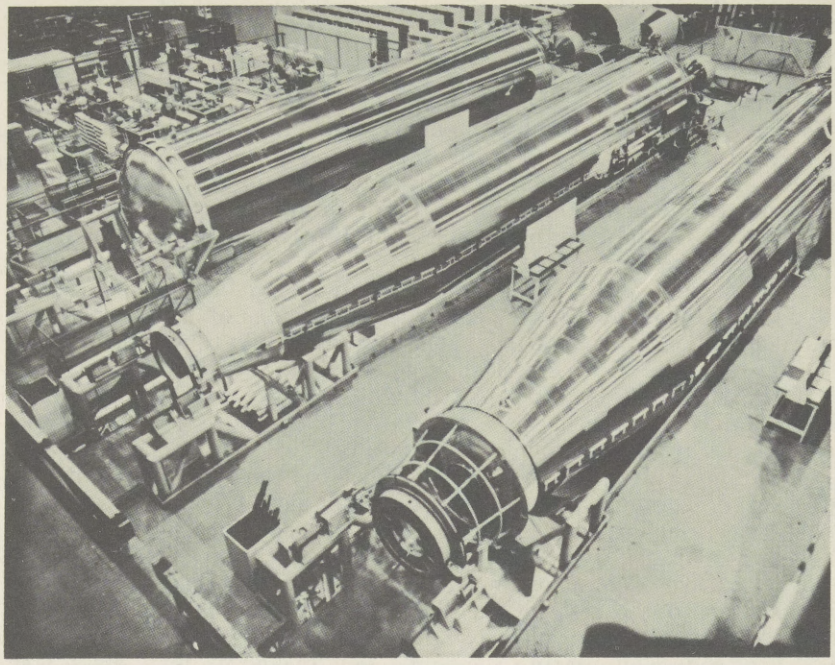

FIGURE 475

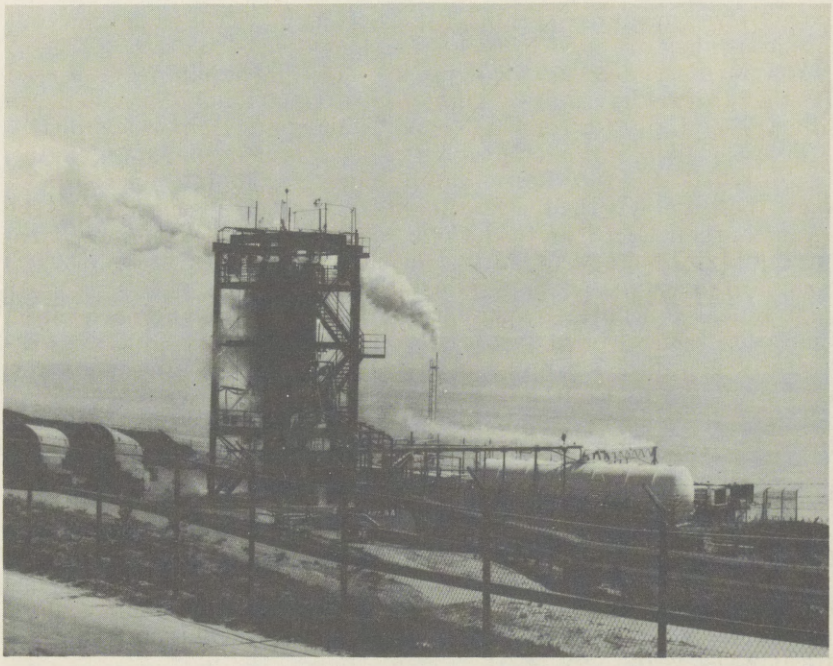

FIGURE 476

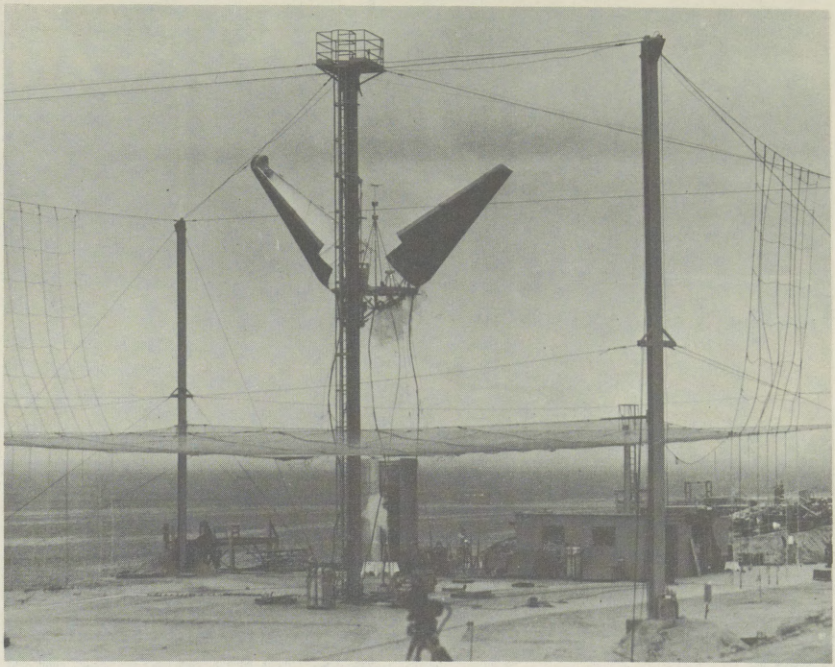

FIGURE 477

too clearly shown are small hot gas jets, which are the same as rocket engines. They are used to point the vehicle.

The middle jets are used for pitch control. The left jets are used together to yaw left and the right jets to yaw right. These jets are used differentially for roll. These particular tests are now completed.

This (fig. 479) is a photograph of the Centaur second-stage engine, designated RL10–A–3. Pratt & Whitney is developing this engine in their West Palm Beach, Fla., facility. They will manufacture the engine in their East Hartford, Conn., plant. Two such engines, burning liquid oxygen and liquid hydrogen as propellants, provide 30,000 pounds of thrust to the Centaur during flight in space.

Technical difficulties experienced last year with engine ignition and thrust control have now been overcome, and the engine was successfully qualified for flight in November 1961. Engine deliveries are now on schedule.

In the foreground of this photo (fig. 480) is the engine test area at the Pratt & Whitney Florida plant. The component engine facilities are at left, and in the far background are the plants, offices, and factory.

This (fig. 481) is test stand E–5 at the engine test area, where we are currently running duel-engine hot firings. There have been over 1,000 hot runs totaling more than 120,000 seconds of running time at Pratt & Whitney. Over 700 successful engine runs, without a single ignition failure, have been accomplished since the engine explosions of early last year.

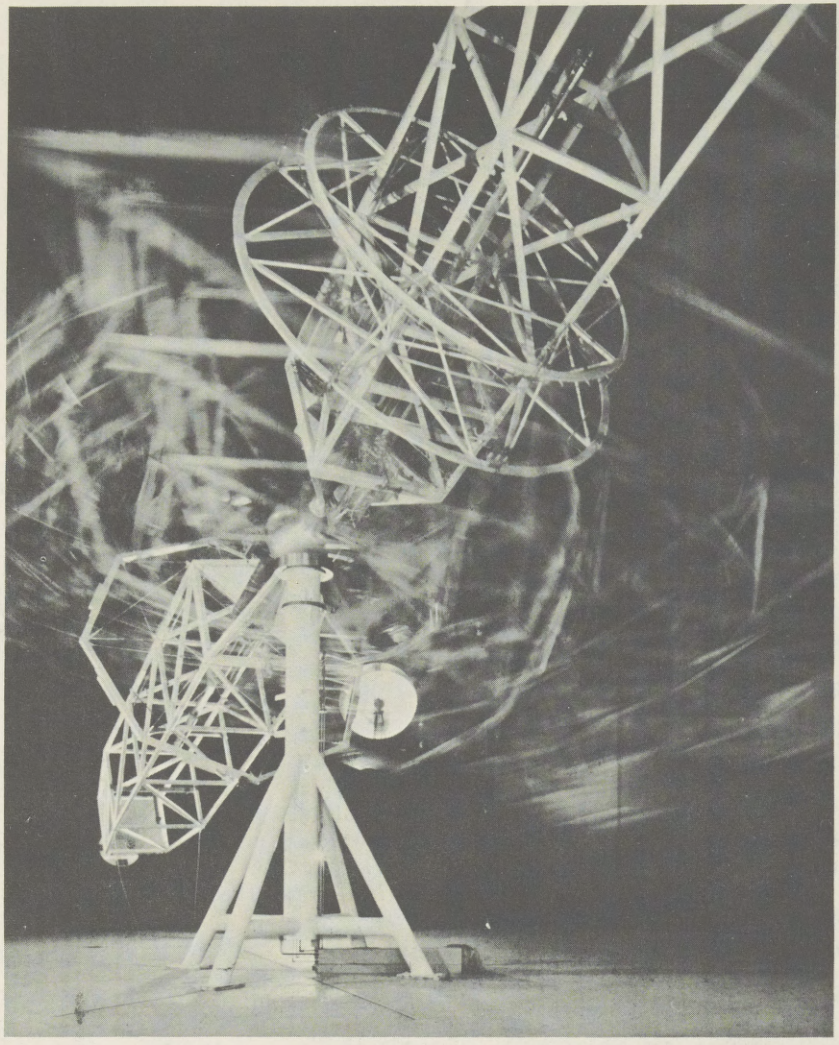

FIGURE 478

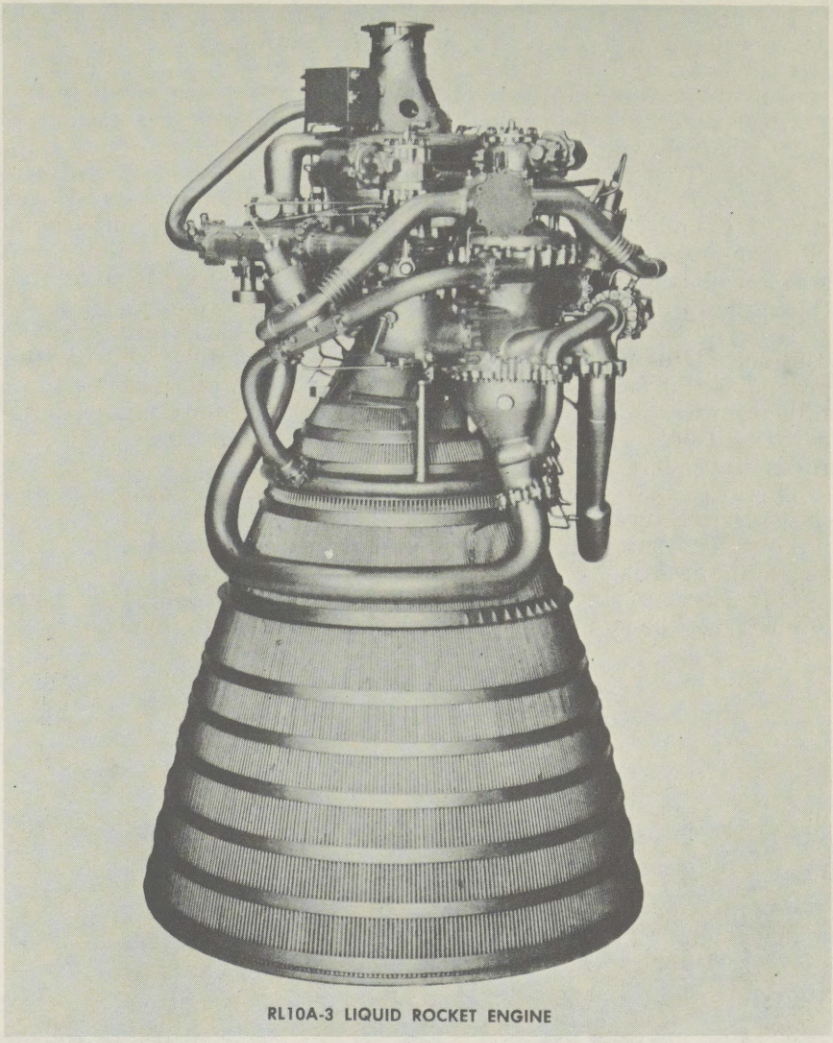

FIGURE 479

In horizontal stands such as this (fig. 482) single engines are run for development testing and acceptance testing before delivery to the Government. The tall vertical stack is a part of the steam jet-ejector system used in all Centaur engine ground firings to create a partial vacuum at the engine outlet, thus simulating the vacuum of space where the engine will operate in flight.

At this (fig. 483) propulsion test vehicle test stand at Edwards Air Force Base, Calif., complete Centaur propulsion system tests are currently underway. Recently an 80-second-duration, dual-engine hot firing was accomplished with very successful results. Later tests will last as long as 270 seconds to reproduce the longest burning time the engines will experience in flight.

This (fig. 484) is launch complex 36 at Cape Canaveral, specially constructed for the Centaur vehicle. The service tower in the foreground is 120 feet tall and is backed away from the launch pad on rails prior to vehicle launch. Another launch pad for Centaur, designated pad 36B, is under construction at the intersection of the two roads, upper left.

This (fig. 485) shows the Atlas-Centaur, minus nose cone, nestled in the service tower on pad.

This (fig. 486) is the Centaur second stage being hoisted into position atop the Atlas.

This (fig. 487) closeup shows the Centaur second stage being lowered into the interstage adapter which fastens it to the Atlas.

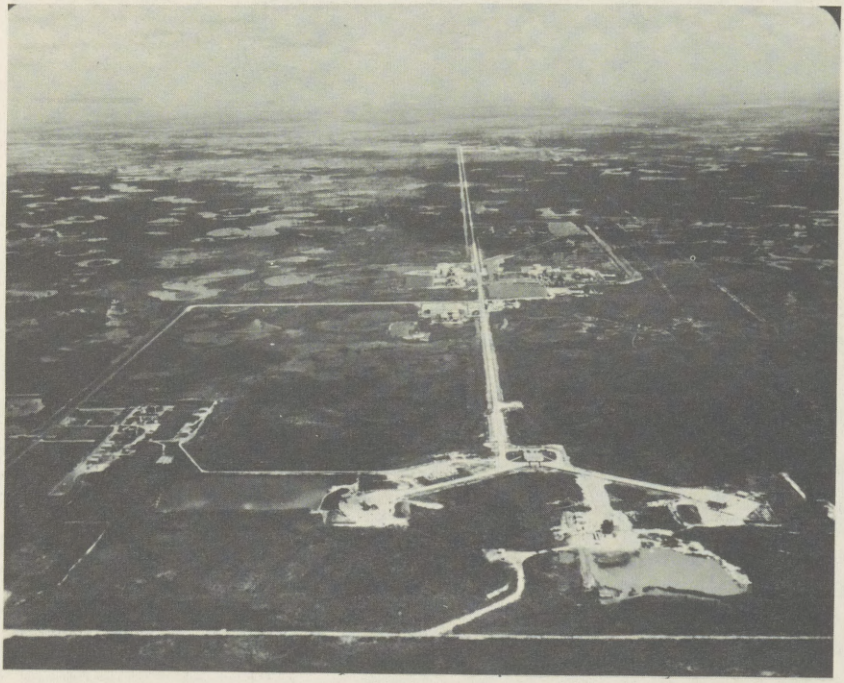

FIGURE 480

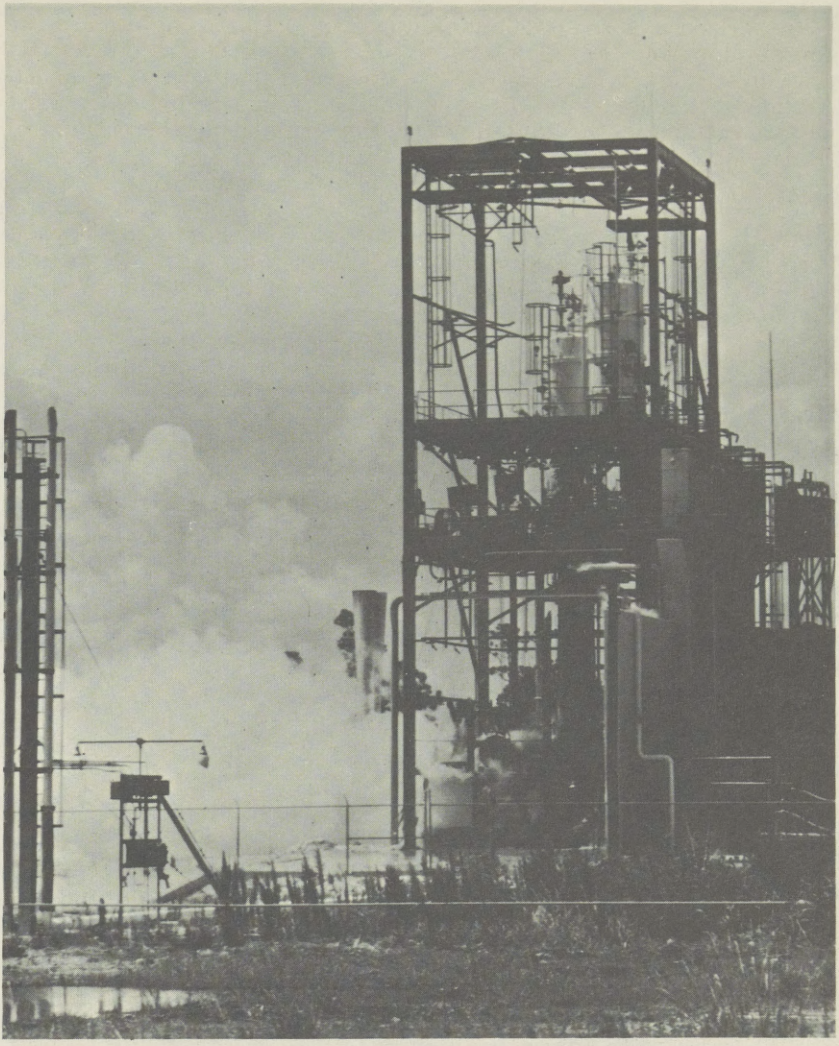

FIGURE 481

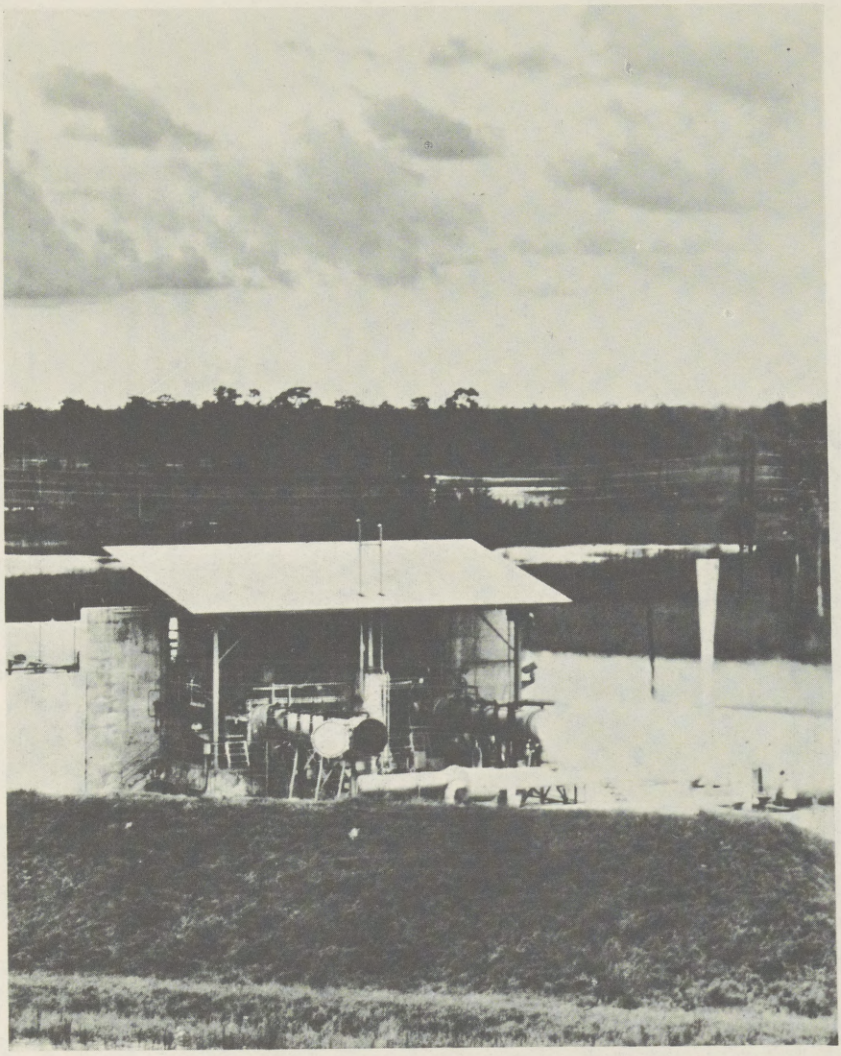

FIGURE 482

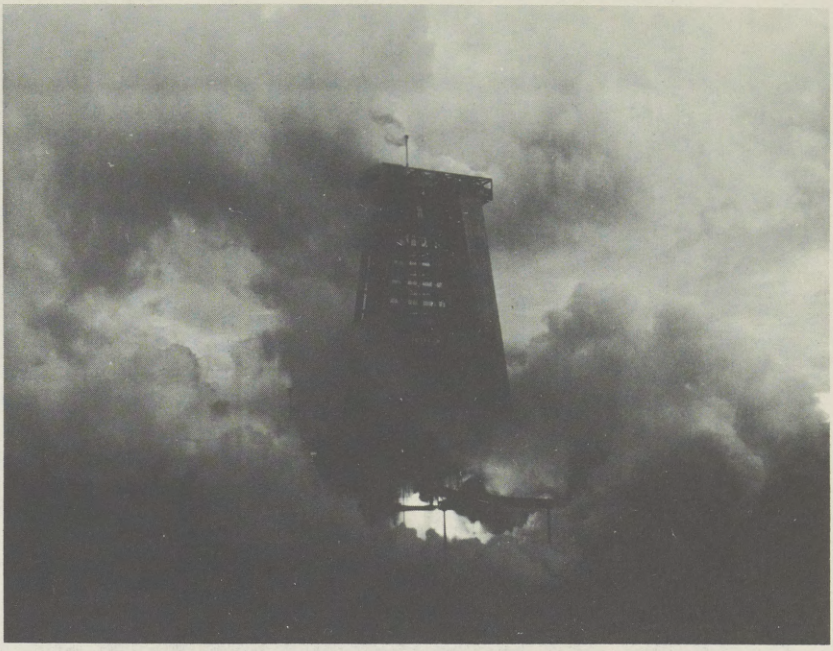

FIGURE 483



FIGURE 484

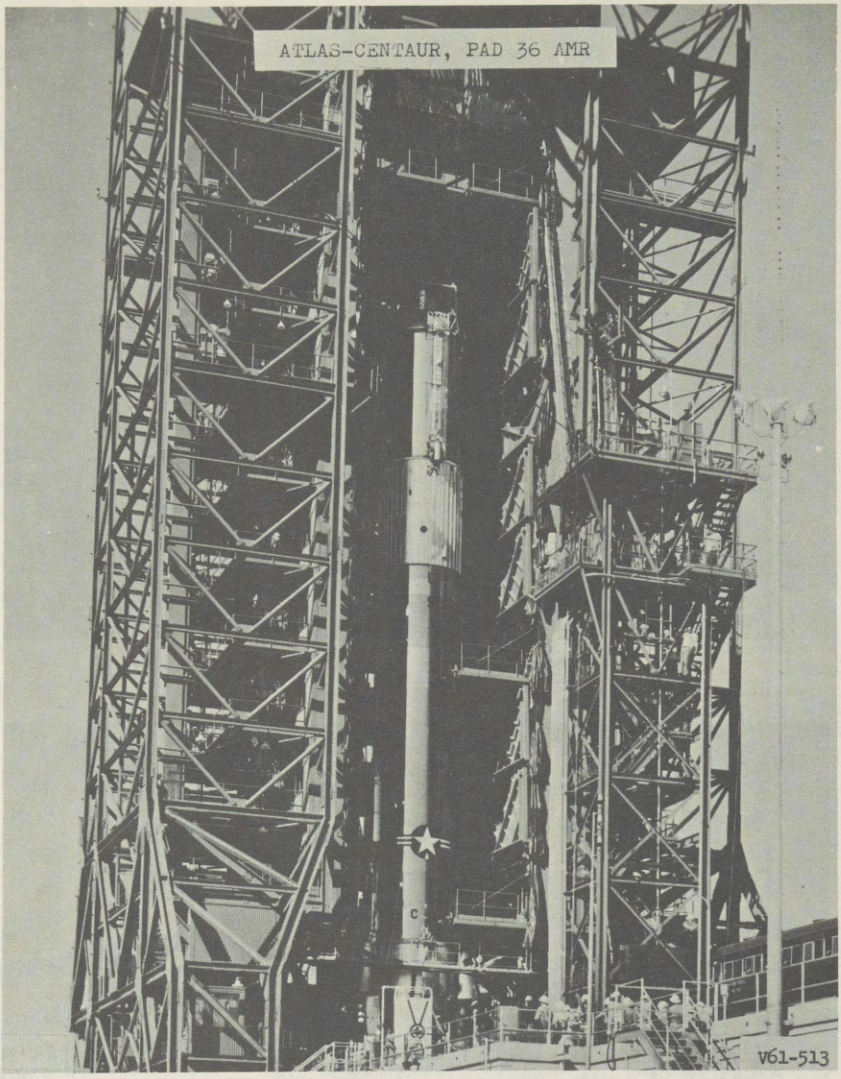

FIGURE 485

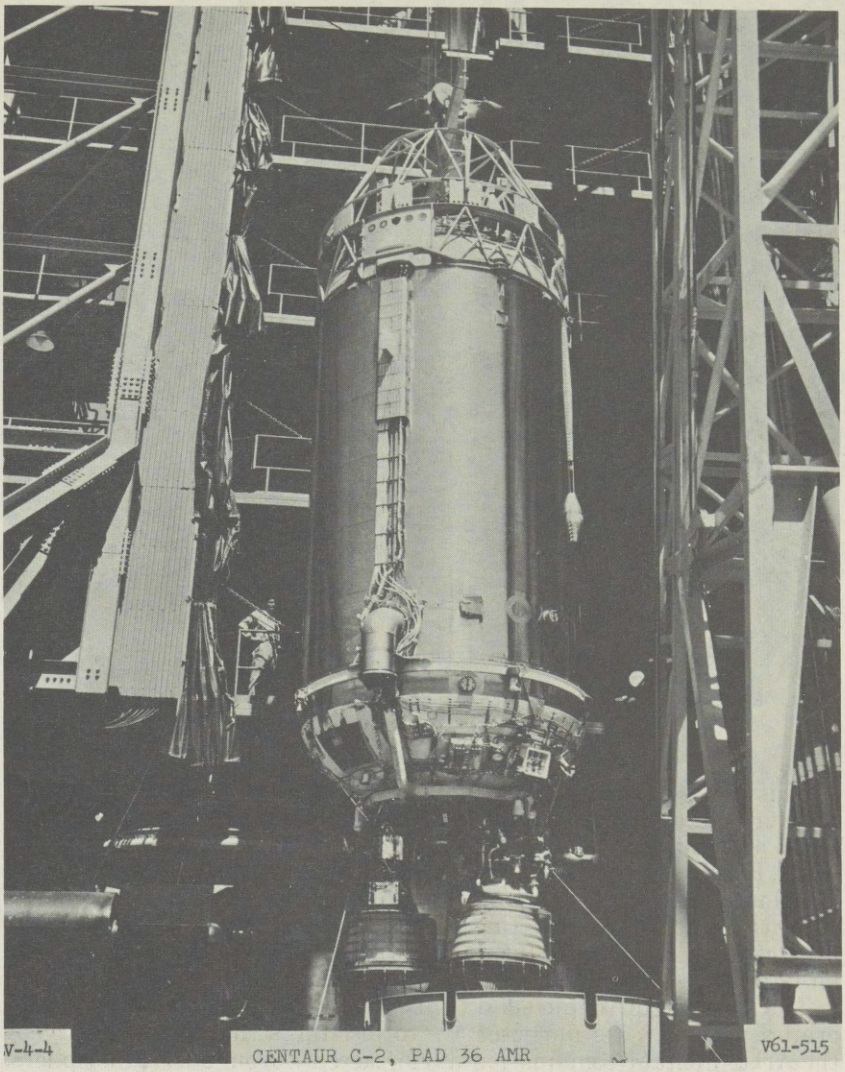

FIGURE 486

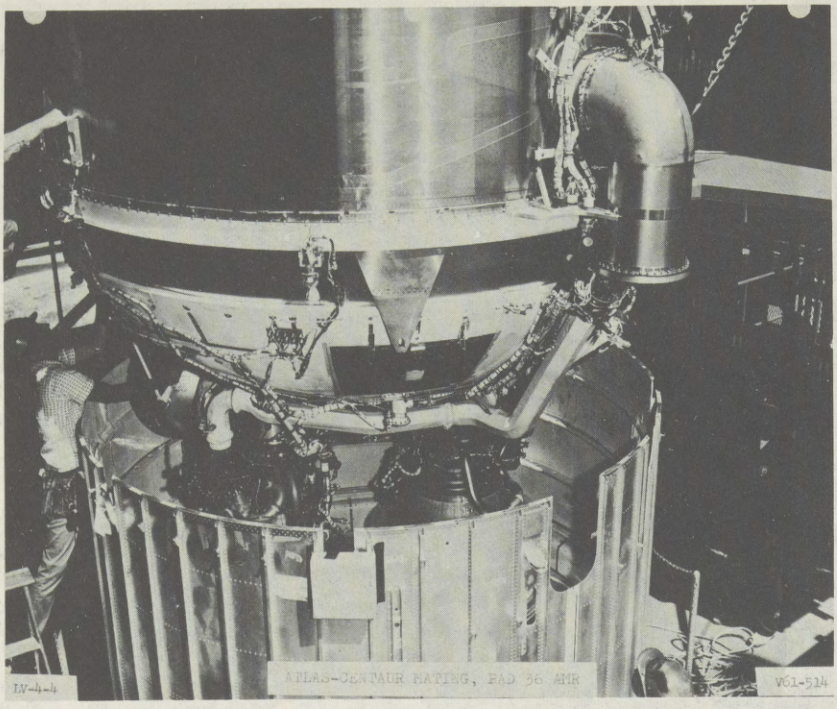

FIGURE 487

This next chart (fig. 488) shows the first Atlas Centaur flight vehicle erected on the launch pad of complex 36 preparatory to its flight in the near future.

Mr. KARTH. When will that be, Colonel?

Colonel HEATON. Until we are within a very short period of days prior to flight we consider that confidential information. But it will be, I can say, in the near future. I will touch upon this topic a little bit later, sir.

The first flight, depicted on this chart (fig. 489), will be a suborbital mission. Its purposes are to test the structural integrity of the Atlas-Centaur combination during ascent through the atmosphere, jettisoning of protective panels and fairings, stage separation and coast control, orientation with the aft end toward the Sun to maintain proper heat within the engine metallic parts and finally just prior to reentry on its downward portion of the trajectory we will probably ignite the engines. The Centaur will be destroyed as it reenters the atmosphere.

The trajectory will be the one shown here, range about 1,175 miles, with impact area south of Bermuda, down the range.

Mr. HAMMILL. May I interrupt for just a moment, Colonel?

Colonel HEATON. Yes, sir.

Mr. HAMMILL. Following up the chairman's question, you stated that the information was confidential. I understand that you can use these designations only for purposes of national security. Is there a security aspect to this date?

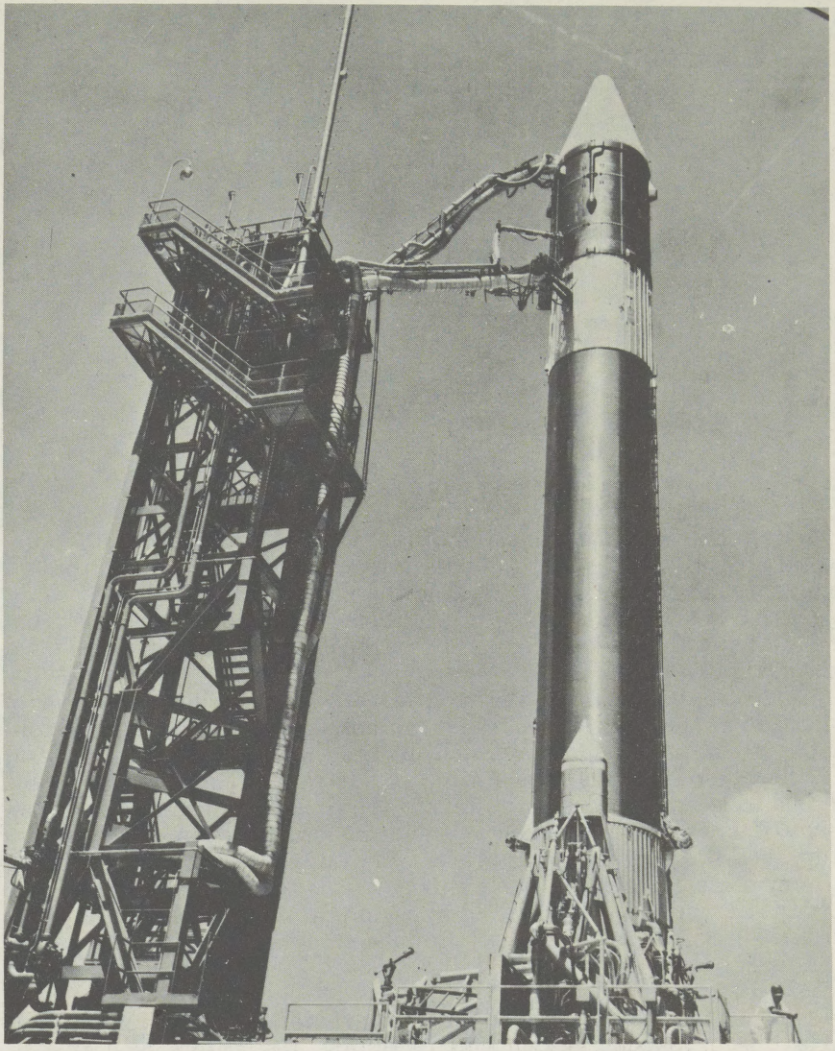

FIGURE 488

Colonel HEATON. No; I wouldn't say a real security aspect to it. We have always, though, held these dates as confidential until they are close upon us, and then we issue them.

Mr. HAMMILL. Do you think that the committee might be given this information?

Colonel HEATON. Yes, sir; we can provide it to you, certainly, on a closed session basis.

Mr. BERESFORD. Are you planning any tests of the Centaur itself?

Colonel HEATON. Yes; this is principally a test of the Centaur, sir. The Atlas, of course, does have some changes in it to adapt it to the Centaur vheicle. Atlas testing will be included among the mission test objectives. However, the main test is for Centaur. A very im-

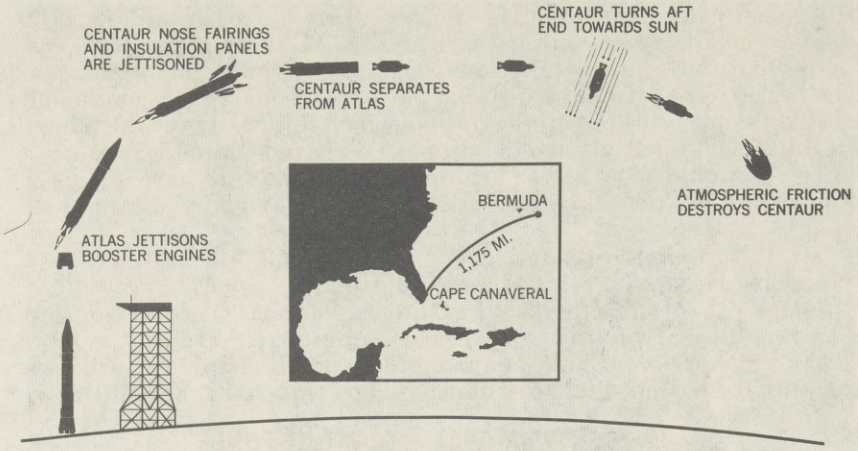

FIGURE 489

portant test of the Centaur, and of the Atlas as well, will be its structural ability to withstand the pressures and buffeting as it pushes its way through the atmosphere. And there is also the problem of being sure that we can, in space, eject the protective insulation panels from the walls of the hydrogen tank of the Centaur vehicle, and also eject the nose fairings.

Then the next will be the separation. Then maintaining control attitude as the vehicle coasts through space, testing the attitude control system, then the Centaur will acquire the Sun, and as I described in the case of the test vehicle which we have had under test at Point Loma, reorient itself with its tail to the Sun, and then finally to assume the nose-down attitude on the descending portion of the trajectory, followed on engine ignition. So you see we are accomplishing a very large number of tests in this particular flight.

Mr. BERESFORD. They are all very important, but they still don't test the Centaur as a means of propulsion?

Colonel HEATON. Yes, sir.

Mr. BERESFORD. They do?

Colonel HEATON. Yes, sir. The prestart sequence is very important. Also the propulsion system will be ignited just before reentry, followed by a short period of operation of the engines. I might add that one of the things which we particularly want to observe during this flight is the zero g. behavior of hydrogen within the hydrogen tank. This is exceedingly important; it is information not only for further development of Centaur, but for further development of all of the stages which will employ hydrogen for long coast periods. We are accomplishing such tests by two types of instrumentation during this flight. We have a television camera which peers down into the tank and also a multiple instrument setup which senses the distribution of liquid and vapor in the hydrogen tank under zero g. coasting flight. So we plan on this flight to do a very great number of important things we must know how to do in our flights that will come later.

Mr. HAMMILL. Can you explain to the committee why it is necessary to turn the aft-end of the Centaur vehicle toward the Sun during this coast period?

Colonel HEATON. Yes. The purpose here is to insure that the engine metallic parts have sufficient heat in them so that we can be insured uniform start, inasmuch as these engines do depend upon the heat derived from the metallic parts, particularly the nozzle and thrust chamber, to spin up the turbine which in turn drives the pumps to force the propellants, both hydrogen and oxygen, into the engine.

If you would like further information on this, I do have a slide if you want to see the engine operating diagram. Would you care to see that?

Mr. KARTH. Perhaps later.

Colonel HEATON. Perhaps later. All right.

Despite the technical difficulties the program has encountered, 1961 has been a year of very considerable progress. Some of the more noteworthy accomplishments during this period, many of which have already been alluded to, are summarized on this chart (fig. 490).

CENTAUR 1961 - 62 MILESTONES

- COLD FLOW TESTING OF PTV AT SYCAMORE CANYON - DEC 60 TO APR 61
- COAST PHASE TESTING AT PT. LOMA - DEC 60 TO NOV 61
- MATING VEHICLE TO COMPLEX 36, AMR - FEB TO MAR 61
- TESTING OF SHROUD AND INSULATION EJECTION AT PT. LOMA - APR TO JUL 61
- FIRST SUCCESSFUL COMPLETE PROPULSION SYSTEM TEST - OCT 61
- FIRST FLIGHT ARTICLE ERECTED ON COMPLEX 36, AMR - OCT 61
- FIRST PIGGYBACK FLIGHT OF CENTAUR GUIDANCE SYSTEM - OCT 61
- ENGINE PFRT COMPLETED - NOV 61
- FIRST HOT FIRING OF PTV AT EDWARDS - FEB 62
- SECOND AND THIRD FLIGHT ARTICLES IN CHECKOUT AT PRESENT
- FIRST FLIGHT - EARLY 1962

FIGURE 490

The propulsion test vehicle cold flow testing to validate operation of the propellent supply system on the vehicle, and to check out ground equipment used in loading propellants was accomplished by April 1961 at Sycamore Canyon.

A combination of a hot gas jet control system and a sunseeker is used to orient the stage and its payload when it is coasting during the interval between periods of main engine operation. This system was tested at Point Loma between December 1960 and November 1961.

During February and March 1961 an Atlas and a ground test Centaur stage were erected on the newly completed Centaur launch

pad 36 at AMR to verify mechanical compatibility of the facility, the ground support equipment, and the vehicle.

Between April and July 1961 tests at Point Loma verified the means of ejecting the insulating panels from a tank filled with liquid hydrogen and the means of ejecting the nose shroud.

Although the RL–10 engine was back on test with its present, successful ignition system less than 2 months after the last explosion in late January 1961, it was in October of 1961 when the Centaur twin-engine propulsion system complete with tank boost pumps was first tested on the vertical stand E–5 at West Palm Beach, the scene of the first explosions. This program is proceeding very satisfactorily.

In October 1961 the first flight article was erected on the launch pad of complex 36. Although the mechanical mating accomplished in the spring was invaluable, electrical mating could not be performed until the first flight vehicle arrived at the cape. The delays we have experienced there stem largely from working the "bugs" out of the electrical equipment which must work together. Fortunately, most of these delays will occur only with the first flight.

In October, the Air Force gave the Centaur guidance system a first, free, space ride on an Atlas missile to afford NASA a chance to test the performance of the system "open loop"; that is, not actively controlling the vehicle. This test yielded very valuable information.

As already noted, the engine successfully completed its preliminary flight rating test in November, less than 3 years from the date of original contract, which is about par for the course for conventional-engine programs and very creditable for an engine as novel as the RL–10.

In February of this year, the Centaur propulsion system was test fired for the first time by vehicle contractor personnel using a group test Centaur on a converted Atlas stand at Edwards Air Force Base. This program is progressing very gratifyingly with four successful "hot" runs out of four tries.

The second and third flight articles are in checkout at the present time in California.

We are nearing first flight. We have been very deliberate and thorough in our preparation for this flight. Our objective is to have a good flight which will accomplish our test objectives and to have such a flight as soon as possible.

Although everybody connected with this flight is motivated by a high sense of urgency, the perspective of the operation is first to have a successful flight and secondly, to launch as soon as possible. The delays experienced so far with this flight have not interfered with the timing of the second flight.

As we stand on the threshold of flight test, we are working hard to resolve residual problems from the preflight development period. As you know, it is not unlikely that new problems will crop up in the course of the flight-test effort. In fact, it is the purpose of the flight-test series to discover latent deficiencies which did not show up in ground test and to validate corrective measures. The principal Centaur contractors and the NASA are geared to deal swiftly with problems as they arise in flight test. It is our intention to make a success of the Centaur program.

That concludes my prepared presentation. Have you any questions?

Mr. KARTH. Colonel, inasmuch as this is extremely important to NASA's whole program, I wonder if you could tell me why Dr. Seamans mentioned the word "Centaur" only three or four times during his whole presentation to the full committee Monday?

Colonel HEATON. I know of no particular reason why he did, nor do I——

Mr. KARTH. It had the effect, you see, of minimizing its importance in the minds of many committee members.

I was just wondering, as long as this is so vital, so very essential——

Colonel HEATON. I feel very sure, sir, that there was no intended implication that this program is of low relative importance in the NASA program.

In fact, Dr. Seamans has many times stated that this is one of the most important programs we have and that we have to make a success of it.

Mr. KARTH. Colonel, this started out as a feasibility study with ARPA, I think.

Colonel HEATON. That is right.

Mr. KARTH. Then it was transferred to the Air Force. Then in the summer of 1959 it came to NASA, and I understand it has changed hands a fourth time from a management standpoint.

Can you explain the reason for this series of transfers?

Colonel HEATON. I think I can.

Mr. KARTH. Go ahead.

Colonel HEATON. The first one occurred as the result of a decision made by the Space Council that more programs using the Centaur and Centaur technology would fall to NASA than to the Department of Defense. For this reason the program responsibility was passed to NASA at a time when NASA did not have, as we do now, the Marshall Space Flight Center as a launch vehicle development agency.

We did what appeared to be the most logical thing at the time; we retained the management the Air Force had assigned at the start of the program. These people continued in this role while we acquired Marshall and Marshall came up to speed, so to speak.

As you know, Marshall had very many jobs to do, stepping up from the development of small Jupiter-sized missiles, to vehicles such as the Saturn. So it was a period of time before Marshall could take over the complete charge of the program.

Mr. KARTH. Has this series of transfers resulted in management failures in part, Colonel, would you say, as well as mechanical failures?

Colonel HEATON. No, sir, I really don't believe so. I think one can say that in any program, in retrospect, management can be improved. There is no question about that, but I feel that there have not been what one would call real management errors in this program that would have had a significant effect on the course of the program technically or as far as the schedule is concerned.

Mr. KARTH. But if you take a brandnew technology, Colonel, and you transfer it from one management to another, to still another, and then even to a fourth in a relatively short period of time, don't you think that the program suffers just as a result of management transfer?

Colonel HEATON. Perhaps I had better correct——

Mr. KARTH. Considerably more than average or normal?

Colonel HEATON. Perhaps I had better correct the count on the number of transfers.

The Air Force personnel who initiated the program under an ARPA order remained with that program until last summer.

Mr. KARTH. I see.

Colonel HEATON. There was a period of overlap from 1959 until this summer while an organization was gradually being built up at Marshall Space Flight Center with a good foundation in hydrogen technology and with all the other technical backup which Marshall applies to programs for which they are responsible.

And it wasn't until this point that we felt it wise to move the entire scope of the program to Marshall. So there has not been the end-on-end type of management transfer which perhaps one might be led to believe.

Mr. KARTH. Mr. Cortright?

Mr. CORTRIGHT. Mr. Chairman, during the time that the Air Force management team was utilized to manage the Convair organization it reported, starting in the summer of 1960 or early fall in 1960, to the Marshall Space Flight Center. So that this was a rather natural phasing and not a situation where we suddenly went in and radically switched the management around.

Mr. KARTH. Most of your problems have been ignition problems, isn't that correct, Colonel?

Colonel HEATON. The principal engine problem was an ignition problem. I think its importance was unfortunately judged more by the spectacular results of the three explosions we experienced than by the difficulty in solving it.

As I mentioned in my testimony, within 2 months' time after our last explosion, we had an engine back on the stand and operating and we have had no further troubles with the ignition system at any location. But it did get quite a play in the press.

Mr. KARTH. Yes. Well, this is usually true, Colonel. What problems do you feel you have now?

Colonel HEATON. With what, sir?

Mr. KARTH. With the Centaur.

Colonel HEATON. With the Centaur vehicle?

Mr. KARTH. Which has caused repeated delays since the time that you no longer experienced difficulties with the ignition system?

Colonel HEATON. The problems here stemmed from mating of all the subsystems, or pieces of this vehicle together, and making them work together for the first time, considering we are dealing with a completely new type technology.

For example, we had considerable difficulty learning how to pump hydrogen into the vehicle tanks. It took a while down at Cape Canaveral to get the loading system to work properly.

These things have an unfortunate tendency to occur one after the other and we can't quite lick them all concurrently.

So it is mainly the problem of mating of pieces of hardware together and making the result work as a system, both mechanically and electrically, which has been the cause of our delays to date.

Mr. KARTH. Are you going to have the same problems, I suppose, when you start mating this to the Saturn, is that correct?

Colonel HEATON. Hopefully, the Saturn will profit materially from the experience we are generating on hydrogen in the Centaur program.

Of course, Saturn uses hydrogen in its upper stages, but also very fortunately Marshall Space Flight Center is in charge of both programs and the same people that are working to solve the hydrogen problems with the Centaur are the men responsible to see that the Saturn works.

It is our fond hope and expectation that the Saturn program will move more swiftly and smoothly into its use of hydrogen for having worked so diligently to solve the problems of the Centaur in conjunction with our contractors. And, of course, as you know, the second stage of the C–1, the original version of the Saturn, employs six of the same type engines which are being used in the Centaur.

Mr. KARTH. Does this have any slowing down effect on the two-engine Centaur development, Colonel?

Colonel HEATON. I am not sure what you are alluding to.

Mr. KARTH. You said something about the development of the six-engine vehicle for the Saturn.

Colonel HEATON. No, sir. At one time we had our fingers crossed on this question. I think now we can say that it has not because the problem was one of engine deliveries.

Mr. KARTH. I see.

Colonel HEATON. And our deliveries are now coming along very well. Of course, one is always inclined to be a bit pessimistic after one has had troubles and perhaps we were unduly so.

Mr. KARTH. As I understand it, Colonel, the Centaur was initiated on this so-called gas generator pumping system rather than the so-called bootstrap system.

Colonel HEATON. I don't believe so, sir. What I think you are referring to is that——

Mr. KARTH. The bootstrap pumping system is the one that has been developed for Centaur.

Colonel HEATON. Yes, sir, and at the time that the vehicle contractor was first conceiving the Centaur idea and before a union was effected between Pratt-Whitney and Convair, now the Astronautics Division of General Dynamics, Convair was thinking in terms of a pressure-fed system in which the propellants are forced into the thrust chamber by gas pressure rather than by pumps. Systems such as this are employed in the Able stage and used in the second stage of the Delta vehicle. However, once Pratt-Whitney was brought into the program, which occurred almost simultaneously with the program initiation but subsequent to the early study phase, Pratt & Whitney has used this bootstrap principle.

Mr. KARTH. So it was a decision by the manufacturer originally, or by the contractor, rather than——

Colonel HEATON. It was a proposal by the engine contractor that he use the bootstrap system.

Mr. KARTH. And now you are using the gas generator pumping system?

Colonel HEATON. No; now we are using the bootstrap system. The gas generator scheme—perhaps I had better have the slide describing the propellent flow scheme for the RL–10 engine.

Mr. KARTH. If you have, so we can get the benefit of the difference between the two systems.

Colonel HEATON. Yes. There are actually three systems that might have been used and I want to try to distinguish all three, one from the other.

Mr. KARTH. Fine. I think it would be helpful.

Colonel HEATON. This (fig. 491) is a propellent flow scheme for the Centaur bootstrap engine. Liquid hydrogen enters through this valve into a two-stage pump, and then flows through a line into the nozzle—passages made of tubes brazed together—acquiring heat and becoming a gas in the process. Next it passes through the turbine which supplies the horsepower to drive not only the hydrogen pump but, through gears, also the oxygen pump.

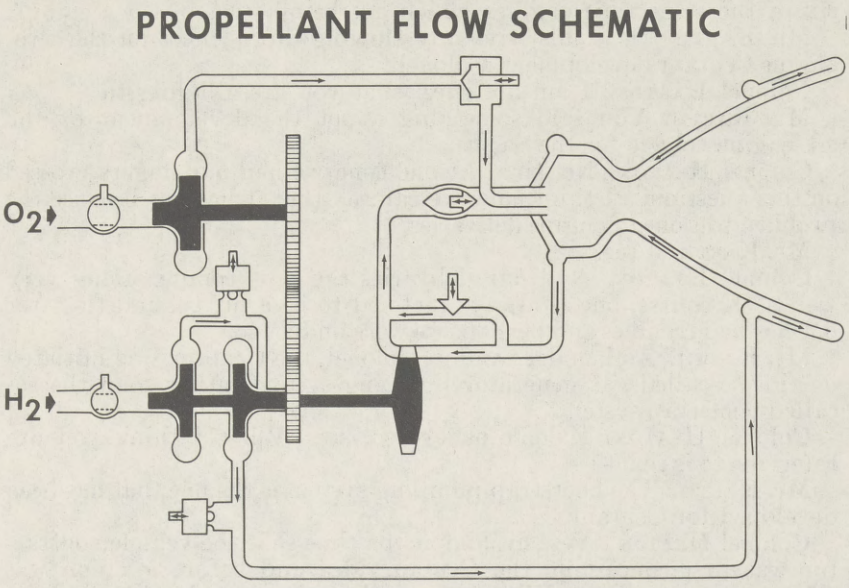

FIGURE 491

The hydrogen continues into the thrust chamber. Oxygen is pumped into the chamber and ignition occurs. Here is where this engine differs from the gas-generator, pump-fed system which is employed in all of our later hydrogen-oxygen engines such as the J–2 and M–1.

Mr. KARTH. Which system indicates the advanced stage of the art, in your opinion?

Colonel HEATON. I would not say one is more advanced than the other.

Mr. KARTH. Which one is more practical?

Colonel HEATON. The bootstrap scheme has advantages and disadvantages.

Mr. KARTH. Which one is more practical in your opinion?

Colonel HEATON. For large engines, I think the gas generator scheme for driving the turbine is more practical. This stems from the fact that as you go up in the engine size, the weight of propellants which must be pumped becomes greater, relative to the area of the walls of the nozzle. Consequently, as engines get larger and larger, power available to drive the pumps, which depends on nozzle area, becomes marginal. However, for smaller engines, such as the RL–10, the bootstrap system is entirely practical.

Returning to a description of the bootstrap principle, to maintain constant speed, some of the hydrogen is bypassed around the turbine by this valve which is controlled by the engine speed control. If the engine starts to speed up a little too much, the bypass valve opens and less hydrogen passes through the turbine.

As the engine slows down a little bit too much, this valve closes and then more of the hydrogen flows through the turbine.

Now, if this were a gas-generator, pump-fed system, rather than a bootstrap system, the hydrogen would pass through the nozzle and thrust chamber walls providing cooling only and then would go into the engine to be burned. Gas to drive the turbine would come from a separate gas generator. In the case of a hydrogen-oxygen engine, the gas generator would probably be an auxiliary hydrogen-oxygen burner operating fuel rich so that the temperature of generated gas wouldn't be so hot it would destroy the turbine.

The engine thrust control would determine how much of this gas was supplied to the turbine. So you see, the bootstrap system results in a more integrated engine. It is more tied together than the other type system and this has both disadvantages and advantages.

But suffice it to say that for an engine of this size it is a completely practical scheme and we do not foresee any major difficulties with it. However, one never knows for sure until one gets into flight testing.

Mr. KARTH. That may be true for this size engine it is practical enough, Colonel, but you are talking about the other system being more applicable to larger engines. It just seems to me that we probably should have been researching and developing a system that is going to have future use in other engines rather than spending a lot of money on research and development on a system such as this that when you graduate from this engine to another engine, at least an engine of larger size, quite frankly you can't use the technology you have gained.

Colonel HEATON. Sir, I think the technology, most important to be acquired on this engine, is not that of obtaining hot gas to drive a turbopump. Gas generator design is a pretty well known art. I certainly don't think our engine manufacturers charged with the J–2 and the M–1 engines feel any great trepidation over their ability to design and perfect gas generator systems for their powerplants.

Mr. KARTH. I am sure they don't, but I still say, Colonel, and I respectfully disagree, that we should go ahead and spend a lot of money researching and developing a system like that that we are not going to be using on the J–2's and M–1's.

This just doesn't make good dollar sense to me.

Colonel HEATON. Sir, I can see your point of view, certainly However, recall that this engine was originated in 1958. Those charged with the responsibility for it felt that this was the design with which they should proceed. The contractor proposed it, the Government bought it, and we have been working with this design approach ever since.

Subsequently, when competition was held for the next type engine, a much larger engine, the contractor who won proposed a different system.

However, it was not possible when the Centaur engine was laid down to foresee what the next man would elect to use in the way of a system of driving his turbine.

Mr. KARTH. Yes, but we had experience in the other ones already, didn't we?

Colonel HEATON. Yes, sir; we had more experience in gas generator systems than in the bootstrap system.

Mr. KARTH. How much do you expect this program will cost before we have an operational vehicle, Colonel?

What is your best guess?

Colonel HEATON. Considering everything, that is, the personnel charges, the engine, guidance system, facilities, everything, I would guess right now about $350 million.

Mr. KARTH. Let's just take the engine then. How much for the engine?

Colonel HEATON. I believe somewhere in the vicinity of $70 million or possibly more. I am not as sure of my ground on this point.

Mr. KARTH. You expect the first operational vehicle to be accomplishing a part of its mission, at least, in the very near future, is that correct?

Colonel HEATON. The first operational vehicle, no.

Mr. KARTH. All right. When do you——

Colonel HEATON. We have the 10-vehicle flight test program.

Mr. KARTH. When do you expect the first operational vehicle to be ready?

Mr. CORTRIGHT. Early in 1964.

Mr. KARTH. Early 1964. Do you see any duplication between the Centaur engine and Titan III, for example, Colonel?

Colonel HEATON. No, and I think I can speak for the Department of Defense as well as for the NASA. We consider these programs more of a complementary than of a competitive nature.

Mr. KARTH. Is there anything that you wanted to further explain?

Colonel HEATON. The only thing I didn't tell you about is the third scheme for injecting propellants into thrust chambers of rocket engines, a scheme which doesn't employ a pump at all. Pressure is generated from high pressure gas bottles and the pressure so generated is used to force propellants from a propellant tank into the thrust chamber.

Now, it was that scheme which was first envisaged by the Centaur vehicle contractor when they were doing their early design studies in the early part of 1958. That was the only other point I wanted to make.

Mr. KARTH. Mr. Hammill?

Mr. HAMMILL. Colonel, you testified earlier that the Centaur development program was designed to furnish a vehicle in a certain performance range between the Atlas-Agena and the Saturn.

Now, the Titan III presumably would be in that same performance range, would it not?

Colonel HEATON. Titan III would encompass in all of its versions a somewhat broader range than that.

Mr. HAMMILL. But at least it would fill that gap?

Colonel HEATON. The Titan III will, when it is available, fill this performance gap, that is right.

Mr. HAMMILL. You said earlier they were complementary, but are they really?

Colonel HEATON. Yes; I feel they are. One of the key points as to why we consider them complementary is the fact that the Centaur

is based on the use of high energy propellants, particularly hydrogen. It therefore is most suitable for high velocity missions. It becomes the most economical way of carrying out missions of a high velocity character, such as going to the moon or going to the planets.

Now, the Titan program is based upon the use of storable-type propellants which have virtues of cutting the time required for launch preparations. But because the storable propellants are less energetic, a much bigger vehicle than Centaur is required to do Surveyor or Mariner B type jobs. Beyond this, the Titan III people are considering the Centaur as a candidate top stage to realize the full potential of the Titan III for high velocity missions. A Titan Centaur is further downstream in time than the Atlas Centaur, and I tried to make a strong point of the urgency of the applications of the Atlas Centaur for NASA programs.

Mr. HAMMILL. Recognizing the limited growth potential of the Centaur vehicle because of the use of this bootstrap pumping system, if NASA had it to do over again, would they choose this route or would they go to the gas generator system?

Colonel HEATON. I would like to state first that there is no difference in the growth potential of the RL–10 engine because it employs the bootstrap cycle. This feature doesn't limit its growth in thrust.

The engine presently used in the Atlas, Thor, Jupiter, was about a 150,000-pound thrust engine. That engine has grown through development to the 188,000-pound size we use in the Saturn C–1 first stage.

You can continue to grow the RL–10 engine, too, by making appropriate changes. We at one time were thinking of growing the Centaur engine to 17½ thousand pounds thrust, and at one time to 20 thousand pounds of thrust. The growth of the possible RL–10 engine is not inhibited by the type of turbine drive.

Mr. KARTH. Well, it is possible to grow this bootstrap system, but you don't intend to do it?

Colonel HEATON. We don't need so much to really grow this, sir, because, remember, the RL–10 is an upper stage engine.

In an upper stage we are not fighting gravity to any significant extent, and because of this, thrust is not quite so important. So we could increase the thrust of this engine but we have no present plans to do so. We want it to grow in reliability and in efficiency.

Mr. KARTH. In all probability, as the engine grows, you will go to the gas generator system, won't you?

Colonel HEATON. No, sir, not necessarily. There are no plans to do that.

Mr. KARTH. You mean you have no plans?

Colonel HEATON. No plans to change it to a gas generator system; no.

Mr. KARTH. As you get to the larger engines, J–2 and M–1 they are going to be gas generated, I thought that is what you said.

Colonel HEATON. Those engines are gas generator designs. I thought you were alluding to the Centaur engine itself. We have no plan to change the Centaur engine to a gas generator system.

Mr. KARTH. Do you have any plans on expanding the size of the engine?

Colonel HEATON. Not at the present time.

Mr. KARTH. So what you are really saying then is that you don't intend to use this system and grow it into another engine, do you?

Colonel HEATON. Oh, no, sir, that is right. That is a correct statement.

Mr. HAMMILL. Because you can't, is that true?

Colonel HEATON. This engine could grow to, about 20,000 pounds of thrust, anyway. I think there are others who are more competent to say how far it could grow. Further, if we wanted to we could build an engine as big as the J–2, not a great deal bigger, but somewhere around that size with this bootstrap principle.

Mr. KARTH. Now, "could" and "would" are two different things.

Colonel HEATON. That is right.

Mr. KARTH. We would like for the record to get the proper answer here.

Colonel HEATON. All right.

Mr. KARTH. And I think that the proper answer is that when we grow to a larger engine using these same propellants that we are going to use a system other than the bootstrap system; now, is that a fact?

Colonel HEATON. I believe that is right, sir.

Mr. CORTRIGHT. Mr. Chairman?

Mr. KARTH. Yes, sir.

Mr. CORTRIGHT. Earlier you asked a question as to the development cost of the Centaur engine and got an estimated answer. I think it should be recognized that the choice of this particular pumping system was not a major element in determining the cost of the engine development.

Mr. KARTH. Oh, I understand it is just one cost of many costs.

Mr. CORTRIGHT. It is just a part of the system.

Mr. KARTH. I tried to distinguish what this particular portion of the total cost would be. It raises a question in my mind. Maybe I should ask the question directly.

Let me do it now, Colonel.

Colonel HEATON. As to whether the bootstrap system costs us more money in this engine?

Mr. KARTH. How much money did it cost to develop this bootstrap system, would you say?

Colonel HEATON. I do not know how to separate the costs of the bootstrap feature from the rest of the engine, but if you really want us to do so we can try.

Mr. KARTH. I really don't think it is that important. I thought if you did have an idea you could tell us now.

Colonel HEATON. No, sir; I don't, and I do feel that the costs were not materially different, one way or the other, because in the other one we would have to develop——

Mr. KARTH. Except it is duplicative.

Colonel HEATON. Beg pardon?

Mr. KARTH. Except that it is duplicative, whatever the cost is, it is an additional cost?

I won't argue that point either, but it seems to me that has to be a fact.

Colonel HEATON. So is the gas generator. We would have to develop the gas generator.

Mr. KARTH. So what we are talking about is development of two instead of one?

Colonel HEATON. No, sir; I can't understand why you say that. You see, if we were to have developed a gas generator system for the RL–10 Pratt-Whitney engine, it could not be used in the next size engine, which would require a larger gas generator, of somewhat different design.

Mr. KARTH. Yes, except that you people have been telling us day in and day out and certainly I agree with your theory that once you do some basic research on that theory you have in fact worked out some of the problems for later expansion of the theory, there is just no question about it. That is why we are building all different size engines.

Colonel HEATON. That is right.

Mr. KARTH. Someone said earlier that we have to learn to walk before we can run, so I assume that all of this information that you get when you develop smaller engines is to some degree, at least, applicable to when you build a bigger engine.

Colonel HEATON. Yes, sir, to some degree, but, as I said before, I don't believe that the problem of designing and building a gas generator system for these larger engines we have now contracted for has any high probability of stumbling for lack of research.

This isn't where the research was most needed, sir. There are a lot of areas in this engine and of the Centaur project generally, as I pointed out, where we are acquiring extremely valuable information, where technical information is scant, but I don't feel that it is in the area of gas generators where our troubles most likely will lie in rocket engine development.

Mr. KARTH. Then it appears to me that the additional cost that you might have suffered from the bootstrap system is even more illuminating than it would have been otherwise, Colonel.

Well, I think we can recognize that a mistake has been made in this thing and really if you had your "druthers" now you would go to the gas generator system rather than developing over a long period of time a new so-called bootstrap system, isn't this correct?

Colonel HEATON. Sir, I cannot let the record stand agreeing that a mistake was made in this selection. I must agree that we are more likely in the future, however, to use the gas generator system in our large engines because of the reasons I mentioned. If the economics——

Mr. KARTH. If what you are saying is true, you are going to get, I think, very, very, very close scrutiny on some of these programs in the future then. Certainly we should all be able to admit to our mistakes, because as I said before, when you are experimenting with new technology, it is just the nature of the beast, you are going to find that mistakes are made.

Colonel HEATON. Perhaps I should say, and I am not trying to be defensive here——

Mr. KARTH. We just go along and willingly do these things without even questioning our own sincerity.

But we should question our wisdom in making these decisions. Then I suppose that those of us who have some responsibility to the taxpayers back home are just going to have to view these with a more critical eye.

Colonel HEATON. Sir, I can understand your concern here. I am not making this statement out of an attempt to be defensive, to justify at all costs decisions made in the past. Not that at all. There were

some other reasons which I haven't mentioned which impelled the people at that time to make this choice.

For example, there is an inherent increase in efficiency; in the gas generator system the propellants burned in the gas generator aren't used as efficiently as those propellants which pass through the thrust chamber and nozzle. All propellants in a bootstrap system pass through the nozzle.

Mr. KARTH. Colonel, you are going to have a reduced capability now aren't you, in this vehicle? It isn't coming up to what you expected it to come up to in terms of performance; is it? Isn't it going to have a lesser capability——

Colonel HEATON. Not due to engine trouble, sir.

Mr. KARTH. All right? Due to what?

Colonel HEATON. The performance troubles which we have had stemmed almost completely from problems of weight growth.

Mr. KARTH. And would you explain that?

Colonel HEATON. Required increases in the weight of the vehicle for structural purposes, increases in the amount and weight of the equipment that had to be carried, and so forth.

However, as is the history with most rocket vehicles, one starts on a fairly optimistic note before one knows all the weights that will finally be involved and after a period of time the performance sags some because weight has gone up.

Sometimes this is also because the engine is not performing up to par; but this engine is performing as we expected.

Then, as you get further down the development path, you find ways of improving your weight picture. We are now improving our weight picture, and as a result we are close to our originally specified performance. Not all the way up there, but close to it.

Mr. KARTH. Let's take a "for instance," and this is the best one I can think of: As far as Advent is concerned, I understand that the Advent satellite has grown in weight at the same time that Centaur's lifting capability has gone the other direction. Centaur was to be used to orbit Advent. Now, what kind of a dilemma are we in?

Colonel HEATON. In the case of the Centaur project, as I mentioned, that was the toughest one. We have now under active study the adaptation of the Surveyor bus, as it is called, to what amounts to a third stage to increase Centaur payload for the Advent mission.

This proposal is being studied presently by the NASA and the Department of Defense jointly to find out if its promise, indicated in the original study which was made by a very clever person in the Jet Propulsion Laboratory, will be borne out.

We want to be sure there are no practical reasons which didn't appear in the first cursory performance analysis which would stop us from using this device to augment Centaur payload capability.

Mr. KARTH. You mean for Advent?

Colonel HEATON. The study is not complete.

Mr. KARTH. For Advent?

Colonel HEATON. Yes, sir, for Advent, as a means of handling the Advent payload which is beyond what we can comfortably accommodate otherwise without considerable growth of the Centaur stage.

Mr. KARTH. So, because of this disparity—that is, Advent's weight growth and Centaur's reduced capability—you are now thinking about performing this mission by adding the Surveyor bus?

Colonel HEATON. With a Surveyor bus, yes.

Mr. KARTH. This is something new, though?

Colonel HEATON. This is something new; yes, sir.

Mr. KARTH. How much planning have you done on this, Colonel, and what would the delay be in terms of objectives if you do have to go to the Surveyor as a means of orbiting Advent?

Colonel HEATON. The Surveyor has the singular advantage of availability such that, providing it is fully usable after further study, it will not delay the Advent program any longer than we have already delayed it because of the Centaur delays.

Mr. KARTH. I see.

Mr. Casey?

Mr. CASEY. Nothing.

Mr. KARTH. Mr. Downing.

Mr. DOWNING. No questions.

Mr. KARTH. Mr. Beresford?

Mr. BERESFORD. I would like to ask a question or two first about the various dates of the program.

I believe we had testimony that the operational date was early 1964. Has there been any slippage in that date? Is that the original scheduled operational date?

Mr. CORTRIGHT. No, sir; it is not the original scheduled operational date. When the program was first conceived, and initiated, it was hoped that the vehicle could become operational about 1 year ahead of that.

Mr. BERESFORD. Well, I think also didn't you testify, Colonel, that the delay in the first flight test was not expected to cause any delay in the second flight test?

Colonel HEATON. Yes, sir.

Mr. BERESFORD. But, if so, why is there going to be the delay in the operational readiness of the system?

Colonel HEATON. That does require explanation.

You are interpreting my statement as signifying that the delay in the first flight date would not affect the originally planned program date for the second flight. I didn't mean it that way, sir.

I meant that we will have the first flight out of the way and off the pad and the pad cleaned up before we can be ready for the second flight.

Mr. BERESFORD. I see.

When was the first flight test originally scheduled?

Colonel HEATON. I believe the original date was January of 1961, but this was at a time when the principal objective of the program was hydrogen research and development and before it had acquired operational goals.

Once it acquired operational goals, it was necessary to reappraise the amount of developmental effort on the ground before flight. When this appraisal took place, we were eminently aware that we could not hope for a first flight in January of 1961, and the flight date was deferred.

Mr. BERESFORD. I think you have already answered my next question, which was whether the test objectives and programing would have been the same? You say no, they have been changed?

Colonel HEATON. That is right, sir.

Mr. BERESFORD. One more thing about the time. I notice on this unclassified card for the Atlas Centaur the first launch is indicated as occurring in the first quarter of 1962 and we only have about 10 days to go, I think, for that. Colonel, is there any backup for Centaur in any of these programs, lunar, planetary probes or Advent?

Colonel HEATON. The backup for the lunar and planetary you have heard Mr. Nicks talk about. What they have had to do in order to fill in this block of time and make the most of it is fall back on reduced payloads on the Agena until we can bring the Centaur into being.

Mr. BERESFORD. Yes. That was only for Mariner or does it apply to other programs?

Colonel HEATON. No, the Ranger program is extended somewhat to fill in this gap, also.

Mr. BERESFORD. How about the other programs?

Colonel HEATON. Well, the only other one that we are presently assigned is the Advent program. I know at the present time the DOD has the Advent program under study and I do not know whether any additional Agena shots will be programed for the Advent.

There are several, some three, I believe, Agena shots with the Advent, placing it into a lower altitude orbit for early tests of the spacecraft itself. Whether they will extend this series is a decision that the Department of Defense will have to make.

Mr. BERESFORD. Have you tried to estimate what increase in costs will occur over the original estimate because of these problems, failures, time slippages, and so on, in the Centaur program?

Colonel HEATON. Well, it is hard to put a figure on that and to get to a common base line. If you would like that for the record, I would prefer to try to make it a firmer number than I could take out of my head at this point. Is that all right, sir?

Mr. KARTH. Yes.

Colonel HEATON. Thank you.

(The information requested is as follows:)

In July 1960 a six-vehicle Centaur research and development program was estimated at $216,119,000. A year later after the scope had been increased to a 10-vehicle flight test program backed up by greater depth in supporting engineering and ground test, the estimated completion cost was $259,486,000. Problems such as slippages, overruns, and engine difficulties resulted in approximately $41,500,000 in additional costs for a new estimated total research and development cost of $300,975,000.

Mr. BERESFORD. My last question is, how the system responsibility was decided? I understand you had two contractors; they were Pratt & Whitney and General Dynamics?

Colonel HEATON. Two prime contractors. The responsibility for the integration of the overall system, enginers, structure, guidance, the whole thing, resided with General Dynamics-Astronautics from the outset.

Responsibility for the engine as a subsystem was assigned Pratt & Whitney from the outset.

Mr. BERESFORD. You also mentioned Marshall.

Colonel HEATON. Marshall Space Flight Center, of course, is a NASA agency.

Mr. BERESFORD. Yes.

Colonel HEATON. The directing agency for this program within NASA.

Mr. BERESFORD. Are they providing the technical direction for the program?

Colonel HEATON. Yes, sir.

Mr. BERESFORD. Now, originally you said your earlier delay was engine trouble. That would be Pratt & Whitney trouble?

Colonel HEATON. That is right.

Mr. BERESFORD. And then you mentioned mating problems.

Colonel HEATON. That is right.

Mr. BERESFORD. And hydrogen leakage. To whom would you ascribe those difficulties, General Dynamics-Astronautics?

Colonel HEATON. That is right, and subcontractors.

Mr. BERESFORD. Are there any other outstanding problems that you now know that you haven't identified, of that nature?

Colonel HEATON. No, I think I have mentioned all that we are aware of that are of a major character. We are awaiting flight tests to see whether we are going to find others.

Mr. BERESFORD. Thank you. That is all, Mr. Chairman.

Mr. KARTH. Could you describe for the record, Colonel, all of those programs that might have suffered a delay as a result of the time slippage in Centaur?

Could you identify all of those for the record at this point?

Colonel HEATON. Yes, sir. They are Mariner, Surveyor, Advent.

Mr. KARTH. What did the Golovin committee recommend on the Centaur program?

Colonel HEATON. I don't believe they recommended anything in the way of changes in the program.

Mr. KARTH. Can you provide their recommendation for the record, Colonel?

Colonel HEATON. We will have to get that.

Mr. CORTRIGHT. Mr. Chairman, whatever comments they had were part of a classified document.

Mr. KARTH. Then if we could have it available for the committee during the executive session, we would appreciate that very much.

Do you foresee, other than those already mentioned, Colonel, which is probably Advent more outstandingly than any others, do you see any other chores that were originally assigned to Centaur or that were originally conceived wth the conception of the Centaur vehicle?

Colonel HEATON. No, sir.

Mr. KARTH. Where these objectives are not going to be reached?

Do you foresee any of the chores that were assigned, where it is going to be totally impossible for the Centaur to assume those chores so assigned?

Colonel HEATON. May I tie your statement to time? We feel that it will meet its requirements, it will do its jobs, but not on time.

Mr. KARTH. I see. This was my question.

Colonel HEATON. The answer to your question then in that framework is, "No, sir."

Mr. CORTRIGHT. Mr. Chairman.

Mr. KARTH. Yes, Mr. Cortright.

Mr. CORTRIGHT. We had indicated earlier that the slippages were of the magnitude of 1 year from the original conception of the project.

Mr. KARTH. Yes.

Mr. CORTRIGHT. The slippages in the scheduled projects to fly on board the Centaur are considerably less than that, perhaps in the

neighborhood of 4 to 6 months, because they were scheduled into the Centaur program after some of the initial reappraisal had been made.

Mr. KARTH. But no projects that you foresaw for Centaur are no longer in the picture as a result of either the slippage or its submarginal capabilities?

Mr. CORTRIGHT. No, sir. In fact, we consider that the Centaur is going to perform as originally planned. It will have payload capabilities as originally planned on all missions.

Mr. KARTH. Colonel Seaberg's group, who were in charge of this project up until just a few months ago, had been relieved of that assignment.

Could you tell me why this is true, Colonel?

Colonel HEATON. Yes; I can. It stemmed from two reasons.

One of them is that they were fairly close to the expiration of their tour of duty with NASA. A more important reason was that Marshall was ready to accept full responsibility. They had acquired sufficient staff and it was more convenient from the standpoint of management to center all of the technical direction functions in one physical location.

Mr. KARTH. So at the time that the Colonel Seaberg group were relieved of this responsibility, the Marshall Space Flight Center group were so well integrated into the program that there was no slippage in time as a result of the transfer.

Colonel HEATON. That is right.

During the transfer there were people from Marshall living with people out at the California Space Systems Division office of Colonel Seaberg and other people from the Space Systems Division were spending a great deal of time at Huntsville to ease this transmission.

Mr. KARTH. Fine.

Mr. Hammill?

Mr. HAMMILL. I would like to pursue one question with respect to Advent. Now, you testified earlier that in order to get the Advent satellite into a 24-hour orbit, it will be necessary to go through a coasting phase of some 6 hours and during this coasting phase the rear end of the Centaur vehicle must be oriented toward the sun in order that the engines will be hot enough to make the bootstrap cycle work. That being the case, if NASA had it to do over again, would we use a gas generator system to avoid this guidance problem?

Colonel HEATON. Well, I am afraid now that you brought this point up that I did not give you a complete explanation.

I thank you for the opportunity to amplify it.

The most pronounced reason for this orientation is keeping the side walls of the hydrogen tank in a shadow.

Remember, we will have jettisoned the insulation panels from the sidewalls of the hydrogen tank after we cleared the atmosphere and no longer had to contend with aerodynamic heating. In order to keep the boil-off of hydrogen to as low a level as possible, orientation of one end of the vehicle toward the sun keeps the sides in the shade, reducing radiant heating. That is the principal purpose for this maneuver.

I would like to have the opportunity, if I may to check this point about how mandatory it is for these engines to be in the sun in order for them to start properly. I feel a bit shaky on that point.

Mr. HAMMILL. Will you furnish that for the record? If you will, I think that point might be clarified.

Colonel HEATON. I will be glad to.

(The information requested is as follows:)

To satisfy the present specification for the temperature limits of the engine chamber (to assure a high reliability of a second ignition), it is necessary to orient the engines toward the sun. However, the primary reason for this maneuver is not for engine heating, but rather for conservation of liquid hydrogen, as mentioned above. At present, the limitations of the P. & W. facility for environmental conditions of temperature had governed the criteria for the specification extremes although specific tests in the testing program have illustrated capabilities beyond the specification. Until the early Centaur flights are evaluated and their effects correlated to the vehicle system, the present engine specifications will remain to assure maximum vehicle reliability.

Mr. HAMMILL. You have this problem of keeping the sidewalls away from the sun whenever you use liquid hydrogen; is that true?

Colonel HEATON. That is right.

Mr. CORTRIGHT. For long coast periods, Mr. Hammill.

Mr. HAMMILL. For long coast periods.

Colonel HEATON. Yes.

Mr. HAMMILL. Do you now know that the use of hydrogen in the space environment is actually feasible, or could we run into a basic problem on use and storage of liquid hydrogen in space which would make the whole thing impractical?

Colonel HEATON. This has been carefully researched. The decision to use hydrogen as a propellant in the upper stages of Saturn was made after examination of this problem. We could see no reason why we shouldn't be able to use liquid hydrogen for rather protracted periods of time in space storage, providing we did such things to minimize the penalty due to loss of hydrogen as orient the tanks so that the sidewalls are not exposed to direct sunlight.

Mr. HAMMILL. One last question.

We have heard that General Dynamics utilized the technology that was developed in connection with the Atlas development program and applied much of that experience and know-how to the development of the Centaur.

We have also heard that some of the Atlas components were used.

Is it true that the tanks in the Centaur are not considered to be optimized in terms of the relative volumes of liquid hydrogen and liquid oxygen?

Colonel HEATON. That is right, at the present time.

Mr. HAMMILL. That is right?

Do you think this reflects unfavorably on the system engineering job that was done on Centaur?

Colonel HEATON. No, sir. I merely feel that reflects the decision made at the time the program was started, to make as full as possible use of what Convair had learned on the Atlas program. They had a bulkhead which was quite successful for the ends of the Atlas tanks and we used that hardware. Certainly economy was one of the motives at that time.

Mr. HAMMILL. But now we are faced with these interface problems between the tanks, in addition to the fact that the tanks don't seem to be optimized in their relative size to one another.

Colonel HEATON. The optimization is not one of great importance. In the second place, the type of bulkhead employed in the hydrogen

and oxygen tanks is not a takeoff from Atlas technology, except for the fact that the two skins of metal which comprise this bulkhead are manufactured in much the same way as the Atlas bulkheads were manufactured.

The idea of cryo pumping and insulating this bulkhead as we have done in the Centaur project originated with Centaur.

Mr. HAMMILL. Let me put it another way then. Knowing what we do today, would we have started the Centaur without relying so heavily on the Atlas "componentry,"—if that is a word—and the Atlas manufacturing techniques? Would we have built the vehicle right from the ground up?

Colonel HEATON. Well, it is hard to say. I honestly can't answer that because if we were to start now, we would be starting with different ideas, different people, a different time period. We would seek proposals from various contractors; we would evaluate these.

It is possible that Astronautics, under such hypothetical circumstances, might propose another balloon tank. We wouldn't out of hand, turn down the balloon tank on the basis of our present experience.

It would be evaluated. It might be selected. It might not be. That is about as close as I can come to transferring this issue from that time period to the present.

Mr. HAMMILL. The reason for these questions is that the committee has the impression that the Centaur vehicle is sort of a makeshift device; and since it has been described over and over again as a vehicle of primary importance to many of our more advanced space missions, it doesn't seem to the committee that the system's engineering has been quite as adequate as it might have been.

Mr. KARTH. Mr. Cortright?

Mr. CORTRIGHT. May I speak to that question, please?

In retrospect, looking back at many vehicles or other systems of engineering technology that have been developed, one is inclined to think that if we were starting all over again and were as smart as we are today, we would do a better job of it.

I think it is important to look at the Centaur, even as it is being built today, as a very efficient rocket propulsion system. It is light in weight; it has higher specific impulses than any rocket that has ever flown; it is a very advanced vehicle.

Mr. HAMMILL. But if you are not able to solve this heat transfer problem between the tanks, and this is apparently one of the fundamental difficulties in the development of the program today, you are not going to achieve the payload capabilities that Centaur is theoretically capable of; are you?

Mr. CORTRIGHT. Mr. Hammill, we are confident that these problems will be solved in the normal course of development of the stage. In the first place, one thing we have done is eliminate the 6-hour coast by putting the Surveyor kick stage into the picture. This tremendously simplies the problem of the bulkhead heat transfer, since the Centaur won't have to coast for any longer than 70 minutes maximum.

Mr. HAMMILL. Yes. But I am not concerned about the sidewall heat transfer problem so much as the heat transfer problem between the tanks.

Mr. CORTRIGHT. That is what I am talking about. That is across the bulkhead between the tanks.

Colonel HEATON. You see, to amplify his remarks, I am sure you understand that the penalty to having excessive heat transfer across this bulkhead is in terms of lost propellants. Hydrogen loss is proportional to time. If you are able to cut down then on the duration of storage by some means, such as eliminating this 6-hour coast period, you have eliminated a major share of the performance degradation. Then, besides that, of course, we expect to get this bulkhead fixed.

Mr. HAMMILL. Right now it is a question of leakage of hydrogen?

Colonel HEATON. That is right.

Mr. HAMMILL. Through the bulkhead wall because of breakdown at the points where welding has been done; is that not true?

Colonel HEATON. Yes, sir.

Mr. HAMMILL. And how does General Dynamics propose to solve that problem?

Colonel HEATON. There are a number of approaches which are in work now. The first phase of one of them is on test. The welds which were giving us trouble were spot welds, of which there are a multiplicity in the configuration which gave trouble. These have been practically eliminated on the one we now have on test by using a seam weld technique.

We are working on a number of approaches to a seamless bulkhead. One of them is an electroforming; another is spinning, another explosive forming, to name a few.

Mr. KARTH. Have there been any organizational changes in General Dynamics-Astronautics in the management of this program?

Colonel HEATON. Yes, sir, there have been, very recently some major changes. The changes that were made, I would say are principally the kind of changes one would want to make as one approaches the flight test stage of a program. However, it is also true that in our new rocket vehicle projects we desire from the outset the type of organization Astronautics has now adopted. This is the so-called projectized organization in which most of the people who work on the vehicle in question work on no other project.

Earlier the organizational trend ran to the so-called line organizational pattern. Under this arrangement, most personnel fall within functional divisions such as engineering or manufacturing. The vehicle project director had to go through the heads of these divisions to get his work done.

Mr. KARTH. Any further questions?

Doctor, how do you propose to proceed now?

Dr. NEWELL. Well, this is all that we had prepared for today.

Mr. KARTH. All right, fine.

Dr. NEWELL. I understand the committee wants to meet again tomorrow?

Mr. KARTH. Well, we have spent very little time on the whole budget, as such.

Dr. NEWELL. Yes.

Mr. KARTH. And I thought we should spend at least 1 day on the general subject. I am sure, Doctor, that the committee appreciates all of the background information and technical information you have given us, and that which your staff has given the committee. This will be very helpful, indeed, for tomorrow's session when we can actually get into the budget.

Are there any objections on the part of the committee members if that we could conclude the hearings tomorrow?

Mr. DOWNING. That is all right.

we begin tomorrow at 9 o'clock, perhaps with the thought in mind

Mr. CASEY. Where are we going to be?

Mr. KARTH. Doctor, could you and your staff be available at 9 o'clock in the morning?

Dr. NEWELL. Yes.

Mr. KARTH. I hesitate to ask you this, but I think this might be better if we meet early with the hope that we could get through tomorrow. Room 304, Old House Office Building, then, will be the meeting place, and the time will be 9 a.m.

If there are no further questions we will adjourn the committee meeting for today.

Thank you very much, Doctor. The meeting is adjourned.

(Whereupon, at 11:36 a.m., the subcommittee adjourned, to reconvene at 9 a.m., Tuesday, March 20, 1962.)

1963 NASA AUTHORIZATION

TUESDAY, MARCH 20, 1962

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON SPACE SCIENCES,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 9 a.m., in room 304, Old House Office Building, Hon. Joseph E. Karth, (chairman of the subcommittee) presiding.

Mr. KARTH. The committee will come to order, Dr. Newell, shall we start with the sounding rockets program this morning?

STATEMENT OF DR. HOMER E. NEWELL, DIRECTOR, OFFICE OF SPACE SCIENCES, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ASSISTED BY MR. EDGAR M. CORTRIGHT, DEPUTY DIRECTOR, OFFICE OF SPACE SCIENCES; DR. WEBB HAYMAKER, ASSOCIATE DIRECTOR, AMES RESEARCH CENTER; MR. JOHN ROSENBERRY, COORDINATOR OF LAUNCH OPERATIONS, LAUNCH VEHICLE AND PROPULSION PROGRAMS; MR. ELDON TAYLOR, RESOURCES MANAGEMENT OFFICER, OFFICE OF SPACE SCIENCES

Dr. NEWELL. Mr. Chairman, I wonder if you would like me to introduce some of the new people who appear.

Mr. KARTH. Yes, sir, please do.

Dr. NEWELL. We have Dr. Haymaker on the end there. He is in charge of the Bioscience Laboratory at the Ames Research Center. Next to him is Mr. Sisco from the Goddard Space Flight Center. Behind Mr. Sisco, Mr. New from the Goddard Space Flight Center and Mr. Ulmer from headquarters and next to him Mr. Von Doenhoff from my office, and I believe you have met all of the others.

Mr. KARTH. Yes, sir, thank you, Doctor. Now we are going through this budget and I really have no preference regarding the order in which we take up each item. If you just want to take them in order of sequence as they are found in the book, can we relate salaries and construction of facilities to each one of them?

Is this possible?

Mr. HAMMILL. Yes, Dr. Newell, I think we agreed that we would place special emphasis on funds for construction of facilities and increases in personnel. These are the things that might cause questions on the floor and Mr. Karth will have to be in the position to defend them. Thus, he has to understand why we are going to build new facilities and hire new personnel.

Dr. NEWELL. Well, we have some material on construction of facilities if you would like to go into that. I have summarized in a capsule statement the reasons for the items under the space sciences.

Mr. KARTH. All right. Do you hit each one of them individually?

Dr. NEWELL. Yes.

Mr. KARTH. Proceed, Doctor.

Dr. NEWELL. I would like briefly to summarize the construction of facilities portion of our fiscal year 1963 budget. After this brief presentation, we are prepared to answer questions that you may have on specific projects.

Facilities are a very important and integral part of the NASA research and development program. They provide the large and complex tools necessary for research in the space sciences as well as the traditional laboratory and office space. If one considers the cost and long life requirement of research and development projects, the payoff of ground facilities is clear.

In many cases these facilities represent developments in their own right. For example, the construction of a large vacuum chamber, including cryogenics and solar simulation, involves development comparable in many respects to that required for a satellite.

These facilities are directly related to space flight programs and since their leadtimes for construction are necessarily long, it is essential that we recognize and provide for this capability along with our research and development projects.

The total NASA proposed construction of facilities budget for fiscal year 1963 is $818,998,000. Included here are all projects involving new facilities or facility additions, modifications, alterations, extensions, expansions, conversions, and improvements where the cost (including collateral equipment) exceeds $250,000. A complete listing of these projects is shown by location on pages CF S–3 through CF S–7 of the Construction budget book.

Now in this slide (fig. 492), here are shown the nine facilities of particular interest to the space sciences program. These have a total estimated cost of $14,519,000 which may be obtained by adding the individual numbers shown on the slide. This amount represents less than 2 percent of the total NASA fiscal year 1963 facility request and for comparison purposes is roughly equal to the cost of a single large flight spacecraft.

Detailed project descriptions, sketches, and cost estimates can be found in the budget book on the pages indicated on the slide.

The biosciences laboratory will be located at the Ames Research Center (Moffett Field, Mountain View, Calif.), and will provide approximately 26,900 square feet of laboratory space at a cost of $924,000. This will constitute total funding for this facility which is being requested to provide a research capability in the field of space biology.

Research will be conducted to determine effects of the space environment in the areas of genetics, immunogenetics, radiobiology, and exobiology.

Mr. KARTH. Why don't you explain each one of those terms a little more for the record.

Dr. NEWELL. Since we have an expert here, I would like to turn to Dr. Haymaker, and ask him to explain.

OFFICE OF SPACE SCIENCES
CONSTRUCTION OF FACILITIES

	BUDGET REQUEST	PAGE NO.
AMES RESEARCH CENTER		
Bioscience Laboratory	$ 924,000	CF 1-A3
ATLANTIC MISSILE RANGE - EXISTING AREA		
Addition to Assembly Facility for Unmanned Spacecraft	2,000,000	CF 1-E1
Explosive Safe Assembly Facilities for Unmanned Spacecraft	450,000	CF 1-F1
GODDARD SPACE FLIGHT CENTER		
AttitudeControl Test Facility	915,000	CF 5-B1
Conversion of Dynamic Test Chamber	3,250,000	CF 5-C1
Development Operations Building	1,850,000	CF 5-D1
Launch Phase Simulator	3,915,000	CF 5-E1
JET PROPULSION LABORATORY		
Addition to Fabrication Services Building	605,000	CF 6-A3
Additions to Materials Research Laboratories	610,000	CF 6-D1

FIGURE 492

Dr. HAYMAKER. "Genetics" is a term which refers to alterations in the animal form in response to evolution or in response to variations in exposure to such things as cosmic radiation.

Immunogenetics concerns the relation of genetics, that is the alteration of animal form, to the immunological process, that is the immune responses which an animal or man has in response to infection. As genetics alter, so do these processes alter. In regard to radiobiology, this is the study of the effects of various forms of radiation on any biological form. Exobiology is the study of life forms, in space, either those indigenous to other bodies of the solar system, or terrestrial forms carried out into space where interactions with the space environment can be studied.

Mr. KARTH. Will you explain the facilities and all of the other paraphernalia you will have in this biosciences laboratory to conduct the necessary experiments you are talking about?

Dr. HAYMAKER. This is indicated in the diagram which is in the book. One is the immunogenetics division, one is the exobiology division; then there is the radiobiology division, and there is an area concerned in meteorite analysis.

Mr. KARTH. My question is, "What will you be working with to carry out your experiments, what products, what forms of life?

Dr. HAYMAKER. We will be using various animal forms such as mice, fish, bacteria, cell cultures of various kinds, and nerve cells. Also larger forms such as primates; and these will be tools on which we will perform research in these areas indicated.

Mr. KARTH. And what primates will you have to do your experiments on?

Dr. HAYMAKER. Monkeys and chimpanzees.

Mr. KARTH. How close is this to the biosciences laboratory that is now an in-house capability for the Air Force?

Dr. HAYMAKER. I would say that the only area in which the Air Force is conducting work along these lines is in the field of radiation biology and the big difference is that we are concerned primarily with the effect on the nervous system, whether primarily or secondarily, and the Air Force is more concerned, as I understand it, with longevity, so that we complement each other in regard to these primates.

Mr. KARTH. Are there any other bioscience laboratories in the Government today such as the one that you propose here?

Dr. HAYMAKER. Yes; I would say that——

Mr. KARTH. If so, could you define what agency and where they are located?

Dr. HAYMAKER. I would say that the National Institutes of Health is one. They are directing their activities toward public health. Secondly there are the Atomic Energy Commission's biosciences facilities. They are also concerned with fundamental information. In these areas work is going on, but it is oriented in quite a different direction from that with which we are concerned.

Mr. KARTH. How about the Army, would they have facilities such as this for conducting experiments in the areas in which they are concerned, such as the effects of nerve gases and other things?

Dr. HAYMAKER. Yes. Fort Detrick is concerned with the most fundamental aspects of microbiology; that is the study of bacteria and various uses, and so on. They are working in a different direction than we are. We are concerned with the environments of space or the environmental factors in space such as cosmic radiation, and such as weightlessness, so that the orientation of these different laboratories is entirely different from ours.

We can and do fund researches by these other governmental agencies on a task basis as needed.

Dr. NEWELL. One might point out that we are using such personnel, Dr. Phillips, for example, in our bio program.

Mr. KARTH. The reason I ask the question, Doctor, is there is some concern on the part of some members of the committee that this will amount to duplication, and that we now have in the Government these in-house capabilities which could be utilized by NASA in their program and the objectives in that program.

Now, could you define clearly for the record the areas where you feel there is no duplication and where you have got to have these facilities to properly proceed in line with the man-in-space flight program or any other scientific experimentation program of NASA?

Dr. HAYMAKER. I would say in the first place in order to conduct the experimentation needed by NASA there has to be a strong central facility. Ames has been provided with and given responsibility for biological experimentation in the space field. One cannot hope to obtain information from scattered sources. There has to be a central source. This is the reason I think that the Congress decided that there should be a central laboratory and this is why Ames was chosen to carry this out.

We have to have a strong in-house competence across the board in these fields, utilizing all of the resources across the Nation, which is what we do. In the contractual and granting fields, Ames supplements the in-house competence.

Mr. KARTH. Well, I want our record to show a very precise need for this biosciences laboratory because I think we are going to have some serious objections when the subcommittee makes its report to the full committee. So I would suggest that the best job that you can do in substantiating this request now be made for the record.

Dr. NEWELL. Mr. Chairman, I would like to pick up at this point, if I may, in an effort to speak to the question that you have raised. In this area of activity there are two clearly distinct aspects that one can define. One is the support of manned flight, in the aerospace medical work that has to go on in order to support manned flight. The other is fundamental space bioscience, which is the fundamental research we can now do because we have the rockets and satellites and space probes that can permit us to explore the Moon and planets for either living forms or precursors of living forms or residue of living forms, and to explore the effects of strange environments such as weightlessness and outer space radiation on living forms carried out there from the earth. There is a broad spectrum ranging between these two very clearly distinguishable aspects of bioresearch.

Now within NASA the activity required for the support of manned flight is being directed and carried on by the Office of Manned Space Flight under D. Brainerd Holmes. In his office there is a very strong effort to tie in closely with the capabilities of the Air Force and the other agencies in the Government that can help to support the manned flight effort.

The hope here is to avoid the building up of any facilities in NASA that we don't need. In support of this activity, Dr. Haymaker's group must be sufficiently on top of things to coordinate, orient, and organize our use of the other facilities. This requires that they from a scientific point of view keep alive; they must, therefore, also be in the research to a sufficient extent to understand what is going on, to be able to perform their coordinating, guiding, counseling function.

On the other end of the spectrum, that is, the biosciences end of the spectrum, we get into something new, something in which none of the other agencies in the Government have been involved before, simply because the opportunity didn't exist.

We have therefore in this area the problem of creating a new activity, of guiding its development. Here we must have a strong group in the fundamental researches involved to form the nucleus of the Nation's activity.

This activity comes under the Office of Space Sciences in NASA. Here again we intend to draw into this program those competences that exist in the rest of the country. But I must again emphasize that to do this effectively, we do need the facility at Ames to form the nucleus of the program.

Mr. KARTH. Mr. Downing.

Mr. DOWNING. Is one of the purposes of this Biosciences Laboratory to determine what organic and biological changes may occur in a human being if a man goes to places like the moon; the effects of the flight through space to the planets and so forth?

Dr. NEWELL. I will attempt an answer to this and then ask Dr. Haymaker if he wants to add anything. The principal purpose of the biosciences program is to do fundamental research on the basic processes that are involved in physical life and this includes the study of——

Mr. DOWNING. Well, we have the National Institutes of Health, the Air Force laboratories, and others that can take care of that, isn't that right?

Dr. NEWELL. The search into the fundamental processes is strengthened by the ability to look into these processes from a new perspective, from the point of view of weightlessness, from the point of view of radiation in space, and here it is a matter of the total radiation, not just portions, but all of the radiation that comes in at once. You might say you could study these radiation effects on the ground by using the accelerators available, but the problem is that there is no accelerator that can give you the total combination of these things, the entire radiation encountered in space plus weightlessness. The NASA approach is that we should do these things that can be done in the space vehicles and out in space in association with the new and strange environment and so forth, and the ground research related to these objectives; and that we will not attempt to do those things that the other agencies are doing and are already expert in.

Mr. DOWNING. That is my point, this is related to space.

Dr. HAYMAKER. That is correct. We are concerned with delineating the hazards of the space environment so that we know the problem and if we know the problem we can begin to find the solutions to the problem.

Mr. DOWNING. And you don't propose to take over any of the functions of other agencies?

Dr. HAYMAKER. We have to start somewhere. We have to have our base line for purposes of comparison. Now cosmic radiation cannot be reproduced on the ground by any accelerator. We are concerned with whole body radiation, on the whole man or chimpanzee.

Now here there is no facility to provide energies such as cosmic radiation on earth. Therefore we have to do our studies in space.

There are certain base lines for which we can obtain accelerators but I would say at Ames our chief concern is the delineation of the hazards of radiation in space, such as weightlessness, the magnetic field, and so on.

Mr. KARTH. So there would be no duplication in this basic life sciences work that is now being done by other Government agencies, is this correct, Doctor?

Dr. HAYMAKER. That is correct.

Mr. KARTH. And you feel very strongly about the fact that it would seriously impair your program if you were forced to use existing governmental facilities to carry on your experiments, is this correct?

Dr. HAYMAKER. That is correct.

Dr. NEWELL. Not quite. We intend to use existing Government facilities.

Mr. KARTH. I mean in the areas, Doctor, where you feel that you are not going to use existing Government facilities.

Dr. NEWELL. That is correct.

Mr. KARTH. And this is because those facilities do not exist, or because they exist in a character not sufficiently large for you to conduct your experiments, which is it now?

Dr. NEWELL. Because the facilities as they exist now are being used for other activities which should not be stopped, and we are getting into a new activity, which we have the job of supporting and directing as well as participating in. To accomplish that job we must have some of our own people active in the field.

Mr. KARTH. Do you feel that if some of the existing Government facilities were expanded so as to include the objectives of NASA in this biosciences field that it would satisfy the ambition that you have insofar as the development of a new laboratory is concerned, or would it be so far removed and divested in different directions that you don't feel you could pull it together and make a sensible study out of it?

Dr. NEWELL. That would be a way of approaching it, but I feel that it would not be as effective as the approach that we are making. Since we do have in this case the management and direction job, we have got to have people of our own who are working on our program, and have the motivation of our program in mind.

Mr. DOWNING. Mr. Chairman.

Mr. KARTH. Yes, Mr. Downing.

Mr. DOWNING. In the justification on page 183, you say that the program will concentrate on mechanisms underlying biological phenomena of hypersensitive immunological paralysis, immunological paralysis and how space environment interacts with these responses. What do you mean by that?

Dr. NEWELL. Again I will have to ask Dr. Haymaker.

Dr. HAYMAKER. As to the hyperactivity I could explain it this way: The structure of the central nervous system is such that when proteins are let loose from the nervous system they sensitize a man, and this can give rise to other reactions throughout the body, in other words the hypersensitive activity.

Mr. DOWNING. Now relate this with space.

Dr. HAYMAKER. Cosmic radiation, cosmic rays produce damage and will release the proteins and lipids in the area damaged, and these get into the nervous system of the body and cause reactions deleterious to the individual. They may occur as a consequence of radiation damage. Second, there is what is called immunological paralysis. I would say that "deficit" is a better word there. Here we are concerned again with cosmic radiation and interference with the immune mechanism so that, for example, an individual so affected could have an increased tendency to infections. This is what we mean by the immunological deficit. These are two examples in this field.

Mr. DOWNING. I know that you are going to step on the normal procedures of biochemistry in this laboratory, but it would seem to me that the basic purpose or the end result should be the biological changes that will occur as a result of our being in space.

Thank you, Doctor.

Mr. KARTH. Well, is the statement that Mr. Downing just made exclusively true? I mean will all of your efforts be and only be in this space field?

Dr. HAYMAKER. Yes, indeed. They are exclusively in the space field, but in order to get accurate information we have to have baseline studies on Earth with which to compare.

Mr. KARTH. And in these areas you will probably be using the facilities of existing Government agencies, is that correct?

Dr. HAYMAKER. In addition to our own.

Mr. KARTH. Well, why do you think you need an additional facility or an additional capability inhouse in this area where there might be duplication?

Dr. HAYMAKER. In any experiment that a person runs using a certain stimulus or using a certain deleterious influence one has to have some baseline studies in the same laboratory under as close conditions as possible. Now, where an in-house capability is inadequate for this purpose——

Mr. KARTH. In other words, for the sake of continuity you must delve into some of these other areas where it might be true the Government now has that capability in some other existing facility; is this correct?

Dr. HAYMAKER. Yes; and that would be utilized.

Mr. KARTH. This will be minimal in pretty much every case; is that correct?

Dr. NEWELL. Yes, that is correct; the motivation will be space research. I would say that these would be used for space and space-related research.

I would also like to reemphasize that the topics we have featured in our discussion here are only part of the total. There is the search for life forms on the other planets, and for the residues or precursors of life forms. This is one of the major elements of interest. Again you see this is space research.

There is also the question of the sterilization of the probes, both from the point of view of not contaminating an object of study and from the point of view of not bringing back from an object of study contaminants that we don't want to have on the earth. All of these, you see, are space related.

Mr. KARTH. Mr. Van Pelt.

Mr. VAN PELT. No questions.

Mr. KARTH. Doctor, do you want to proceed?

Dr. NEWELL. Well, we have covered the remainder of that paragraph on the biosciences laboratory, so I will proceed now to the next subject, which is an addition to an assembly facility for unmanned spacecraft.

An addition to the unmanned spacecraft assembly facility at the Atlantic Missile Range will provide a second floor to the existing laboratory area and a new two-story building with an attached high-bay checkout and assembly area at the rear.

This addition will provide approximately 26,900 square feet of laboratory space and a high-bay area of 18,225 square feet at a cost of $2 million.

This facility is required to assemble and check out the larger and more complex spacecraft under closely controlled environmental conditions and will be necessary to accommodate the currently planned 1964 flight schedule. Existing facilities are inadequate both in size and capability to handle the final prelaunch checkout of the Surveyor- and Mariner-size spacecraft.

To complement the unmanned spacecraft assembly facility, an explosive-safe assembly complex of four small buildings totaling approximately 5,800 square feet will be required at the Atlantic Missile Range. This complex, consisting of a final assembly and sterilization laboratory, a capsule laboratory, a storable liquid propellent motor laboratory, and an instrumentation laboratory, will cost approximately $450,000.

This facility will afford a remote final assembly area for the installation of explosive bolts, midcourse guidance rocket engine fuel, and solid propellent retrorocket installation and alinement.

An attitude control test facility is proposed for the Goddard Space Flight Center at a cost of $915,000. This facility will consist of two buildings (one to house a 40-foot coil; the other, a one-story control building), four enclosed concrete pads (to house reference standard magnetometers), access roads, and utilities. This laboratory will provide the following capabilities:

1. Measurement of the magnetic signature of large spacecraft.
2. Calibration of instruments in flight orientation within the influence of spacecraft-induced fields.
3. Electrical rotation of the field about a stationary spacecraft to permit evaluation of magnetic spin damping torques.
4. Electrical spin simulation to permit measurement and correction of the magnetic moment which causes precession and mutation of a satellite in space flight.

At Goddard, it is also planned to convert a large vacuum chamber to a space simulator by the addition of liquid nitrogen cooling, solar simulation, and additional pumping capacity. This conversion will cost $3½ million and, when complete, will provide a vacuum of 1×10^{-8}mm.Hg with solar similation capability. This simulator is required to carry out the ground tests necessary to provide long life to the orbiting observatory spacecraft (EGO, POGO, and OAO).

The Development Operations Building at the Goddard Space Flight Center will provide approximately 70,000 square feet of floor area at a cost of $1,850,000. This building will provide for a magnetic tape library, an instrument loan and repair area, a satellite staging area, and space for central shipping and receiving.

The magnetic tape library will provide storage and ready access to the large volume of data tape being received from satellites currently in orbit and currently scheduled for launch. This tape must be stored in a humidity-controlled area to protect it from damage.

The instrument loan and repair area will provide a facility for central calibration and repair of instruments and eqiupment so that when these items have served the purpose for which they were initially procured, they can be rehabilitated and reissued for subsequent projects.

The satellite staging area will provide a clean area for the inspection and preliminary checkout of large spacecraft prior to integration of experiments and flight acceptance testing.

The final project at the Goddard Space Flight Center is a launch phase simulator estimated at $3,915,000. This project is currently in the design-study stage, utilizing fiscal year 1962 facility planning funds. The facility consists of a 65-foot radius rotating arm, a prime mover system, environmental systems and equipment, and an operations building. With this facility, we will be able to simulate the

normal sequence of the launch environment factors such as combined acceleration and vibration.

At the Jet Propulsion Laboratory, an addition to the Fabrication Services Building is planned. This addition will provide approximately 18,000 square feet of floor space at a cost of $605,000. The Fabrication Services Building currently under construction provides for machine shops, inspection rooms, and offices.

The sheet metal shop, weld shop, assembly room area, and metal storage area are now located in substandard temporary space approximately one-half mile from the Fabrication Services Building. The proposed addition to the Fabrication Services Building will permit consolidation of all Fabrication Division personnel and equipment in an efficient work arrangement.

The last project, also at JPL, proposes the addition of approximately 20,000 square feet of laboratory space at a cost of $610,000. This will result in additions to two existing buildings: First, approximately 10,000 square feet will be provided by adding two floors on top of the Materials Research Laboratory; second, another 10,000 square feet will be gained by an addition to the Materials Research Processing Laboratory.

This space will be utilized by laboratory personnel engaged in research and development work on the many difficult materials' problems encountered by modern spacecraft, including atmospheric capsules and their propulsion systems.

I might add to this written material that the principal motivation behind these ground facilities, particularly the testing facilities, is to ensure as well as we can that our expensive spacecraft, when they are injected into orbit or into space trajectories, will really have the long lifetime that is needed to realize full value from them.

Mr. Chairman, in closing, I would like to add a word about the item in the authorization bill for advanced facility planning and design for which $10 million is being requested in the fiscal year 1963. This sum covers requirements for the entire agency in all program areas. Authorization and funding for this purpose were provided for the first time in the fiscal year 1962. It has been a most useful item in accelerating our program. By the use of the advanced facility planning and designed funds we are able to save as much as 6 to 8 months in the construction of many of our facilities. This has been especially helpful in those programs where the facilities are the pacing items.

That completes my statement, Mr. Chairman.

Mr. KARTH. What portion, Doctor, of your total budget request that this subcommittee is responsible for is in construction of facilities?

Dr. NEWELL. It is some $14-plus million.

Mr. KARTH. Out of the $558 million, I think.

Dr. NEWELL. Yes.

It is 2 percent of the total NASA budget request for construction of facilities.

Mr. KARTH. Mr. Beresford.

Mr. BERESFORD. Yes. Dr. Newell, are any of these requests for special purpose rather than general purpose facilities, facilities that would be used for only one project or are they all of continuing utility and use?

Dr. NEWELL. They are all of continuing utility and use.

Mr. BERESFORD. I understand under the new arrangements, the Western Launch Operations Office will report to you?

Dr. NEWELL. Yes.

Mr. BERESFORD. Would you tell us a little bit about that and whether that involves additional facilities which will be under your management?

Dr. NEWELL. I would like to ask Mr. Cortright to answer that.

Mr. CORTRIGHT. I am sorry I was involved in an exchange——

Dr. NEWELL. The question involves PMR and whether we anticipate any construction of new facilities.

Mr. CORTRIGHT. There will probably be construction of small facilities. That has not been determined at this time. We will have a small group involved in the launch of Agenas. The Deltas that are launched will be Air Force.

Mr. BERESFORD. Do you have any information on that, the buildings and facilities?

Mr. CORTRIGHT. Would you describe the buildings and facilities and staffing?

Colonel HEATON. I think I better ask Jack Rosenberry to answer that question.

Mr. ROSENBERRY. In answer to your questions, we plan to have approximately 15 people on the permanent staff of the Pacific Launch Operations Office reporting to Dr. Newell. Their prime purpose in life is to act as the host for the various NASA technical or operational groups that will go out on specific missions from the Goddard Space Flight Center, the Marshall Space Flight Center or the Langley Research Center. As far as the facilities go we are making maximum utilization of the existing Air Force facilities at Vandenberg Air Force Base for the launch pads for our Thor-Agena vehicles and at Point Arguello for our Atlas-Agena launch vehicles. We did fund for and construct a Scout launching pad out of last year's funds in the amount of approximately $500,000.

This pad is essentially completed and will handle our first launch within the next month or so. This top cover group of 15 people are primarily there to take care of the housekeeping services so that our technical groups can come out there and be unemcumbered and not have to worry about transportation and office space and other general support.

This group will take care of making the arrangements and coordinating with the Navy and the Air Force to obtain the use of these facilities. We were fortunate in moving out to PMR in that the Navy had previously funded and built a missile assembly building and a range-users building or engineering office space based on this forecast of increased activity and as we moved out there we were fortunate in being provided with half of a large, new hangar which we are now completing the conversion of to our spacecraft laboratory and have sufficient office space allocated to us to take care of the roughly 100 people we figure will be out there for countdown and launching activities.

Mr. BERESFORD. Where will the people be, some at Vandenberg and some at Arguello?

Mr. ROSENBERRY. All of our people will be at Point Arguello except for a half dozen or so permanently stationed at Point Mugu, the focal

point of the Pacific Missile Range, to put in our correspondence and paperwork involved in getting support from the DOD.

Mr. BERESFORD. Thank you.

Mr. KARTH. Doctor, maybe now we could go through the budget estimates beginning with sounding rockets, explain briefly in each case the reason for an increased appropriation where it appears for fiscal 1963 so that the record will show the reasons.

Dr. NEWELL. In the case of sounding rockets, the fiscal year 1963 number is $19 million as compared to $14 million for 1962. The increase required here is for several reasons. One, the sounding rocket activity has now become a vigorous and productive part of our science program. As was mentioned, the sounding rocket is an exceedingly powerful tool for studying the earth's atmosphere at all altitudes that can't be examined by satellites.

Secondly, the sounding rocket is an extremely efficient and economical way of checking out equipment that later will go on satellites in space probes. Also for checking out the technique and theory of experiments that are to be flown on satellites or in space probes.

Thirdly, and finally, the sounding rocket is extremely useful for university participation, for drawing new people into the program, and for international cooperation.

It is in all of these areas, particularly in support of the university participation and international cooperation, that we need the increase in funds this year over last year.

Mr. KARTH. Are there any additional personnel involved in the sounding rocket section of the budget, Doctor?

Dr. NEWELL. An increase of about 19 people over 1962.

Mr. KARTH. And this increase is necessary because the program is being enlarged, is that correct?

Dr. NEWELL. That is correct.

Mr. KARTH. How many people are now concerning themselves with this specific portion of the program, Doctor?

Dr. NEWELL. I would like to ask Mr. Taylor to speak up in answer to these questions. He has been digging into this material for you.

Mr. Taylor.

Mr. TAYLOR. Currently we have about 303 positions that we have assigned to the sounding rocket program.

Mr. KARTH. Are these all full-time positions?

Mr. TAYLOR. Yes, sir.

Mr. KARTH. Do you have any part-time positions assigned to the program?

Mr. TAYLOR. No, sir, we do not. We may have as occasion arises, we may utilize temporary employment during the summertime, but these do not include temporary employment so these 303 are permanent positions.

Mr. KARTH. Is this for fiscal 1963?

Mr. TAYLOR. This is fiscal 1962.

Mr. KARTH. And then to that you will add an additional 19?

Mr. TAYLOR. Yes, sir.

Mr. KARTH. I see.

Any questions?

Mr. BERESFORD. I think we might ask one question about the expenditures. What do you estimate will be the trend of future expenditures for your office? I have in mind the statements that have

been made by Mr. Webb about the total NASA budget and how it is now at or approaching a peak, or rather I should say a plateau. Do you expect that the expenditures of your office will follow the same general curve?

Dr. NEWELL. Yes, we do. This is now under discussion and examination within NASA, and currently our long-range projections indicate a leveling off at about three-quarters of a billion dollars. Whether this is the correct figure or not, as I say, is under examination.

Mr. BERESFORD. When would you reach that level?

Dr. NEWELL. We are approaching it now as you see with $558 million; presumably next year or the year after we should reach that level.

Mr. KARTH. For how long would you be on that plateau, Doctor, for the rest of the decade?

Dr. NEWELL. Yes, I should say we would remain there for the rest of the 1960's.

Mr. KARTH. Would you like now to go to scientific satellites?

Dr. NEWELL. In the area of scientific satellites, as Dr. Clark indicated in his review, we are moving out of the period of the smaller satellites into the more versatile and more capable observatory-type satellite.

The increase in funds required is largely due to our moving to the larger type satellites. For the record this increase is from about $118 million in 1962 to $175 million in 1963.

Mr. KARTH. What portion of this $175 million, Doctor, will be in the form of salaries and expenses?

Mr. TAYLOR. Approximately $14 million in fiscal 1963 in salaries and other benefits associated with salaries.

Mr. KARTH. By "other benefits" you are talking about the whole spectrum of benefits including vacation and so on and so forth?

Mr. TAYLOR. Yes, sir.

Mr. KARTH. Retirements?

Mr. TAYLOR. Retirement, overtime, social security, where you pay that.

Mr. KARTH. And how many employees are involved?

Mr. TAYLOR. 1,495 we estimate in fiscal 1963 against this program.

Mr. KARTH. What is the average salary of those thousand-odd?

Mr. TAYLOR. It is difficult to give you an average because they represent a composite of many locations and the average salary varies by location, but I would say approximately $9,000, on the average.

Mr. KARTH. At what salary level do you have your biggest complex of employees?

Mr. TAYLOR. Are you saying numbers or individuals to salary ranges?

Mr. KARTH. Individuals.

Mr. BERESFORD. What is the modal salary?

Mr. TAYLOR. I don't have that with me.

Mr. KARTH. I wonder if you could provide for the record a breakdown of the number of people in each salary range? This might be of interest to someone. What I am trying to do is anticipate questions that may arise and if you can't answer them you almost admit defeat, and this is one of the reasons, although these things may seem

insignificant and inconsequential, I am just trying to cover some of the things that might be questioned during the presentation on the floor.

There are some Members of Congress, you know, who seem to try to pick out questions that they are sure no one will be able to answer and you can figure out the motive as well as I can.

I wonder if you would do this in all areas of the budget. Would this constitute a great deal of work?

Mr. TAYLOR. It would involve some work. Could we supply this for all of NASA?

Mr. KARTH. Yes, I think that is fine if you do it that way.

Mr. TAYLOR. All right.

(The information requested is as follows:)

Salary range and number of employees

	Number			
	Range	1961	1962	1963
Statutory positions:				
Administrator	$22,500	1	1	1
Deputy Administrator	21,500	1	1	1
Excepted positions	$15,000- 21,000	284	402	437
General schedule:				
GS-18	18,500	1	1	1
GS-16	15,255- 16,295	4	4	4
GS-15	13,730- 15,030	611	1,090	1,289
GS-14	12,210- 13,510	1,000	1,409	1,732
GS-13	10,635- 11,935	1,317	1,907	2,419
GS-12	8,955- 10,255	1,401	2,139	2,788
GS-11	7,560- 8,860	1,580	2,113	2,659
GS-10	6,955- 7,985	13	16	17
GS-9	6,435- 7,425	1,161	1,514	1,854
GS-8	5,885- 6,875	25	38	45
GS-7	5,335- 6,345	993	1,269	1,434
GS-6	4,830- 5,820	319	443	548
GS-5	4,345- 5,335	907	1,184	1,485
GS-4	4,040- 4,670	823	1,013	1,232
GS-3	3,760- 4,390	648	750	895
GS-2	3,500- 4,130	157	184	219
GS-1	3,185- 3,815	1	1	1
Total, general schedule		10,961	15,075	18,622
Wage board:				
NASA-20	10,878- 13,499	4	5	5
NASA-19	10,150- 12,646	3	4	4
NASA-18	9,443- 11,814	35	38	39
NASA-17	8,882- 11,128	1	4	4
NASA-16	8,320- 10,462	106	123	136
NASA-15	7,883- 11,627	4	4	4
NASA-14	7,446- 11,170	216	240	273
NASA-13	7,010- 10,712	700	760	815
NASA-12	6,594- 10,712	1,459	1,644	1,850
NASA-11	6,157- 9,672	329	308	322
NASA-10	5,741- 9,152	1,448	1,671	1,964
NASA-9	5,470- 8,653	177	159	162
NASA-8	5,117- 8,195	386	426	485
NASA-7	4,742- 7,800	104	94	94
NASA-6	4,368- 7,446	291	300	331
NASA-5	4,035- 7,051	107	119	131
NASA-4	3,661- 6,677	104	104	135
NASA-3	3,307- 6,302	95	112	131
NASA-2	2,933- 5,928	204	244	297
NASA-1	2,579- 5,533	52	42	30
Total, wage board		5,825	6,401	7,212
Total, permanent		17,072	21,880	26,273

Mr. KARTH. Any questions on the scientific satellites?

Mr. Hammill.

Mr. HAMMILL. I would like to make one observation here. In connection with the activities of your office, Dr. Newell, questions on the floor might be directed to any substantial increases in personnel in any given area; with that in mind, if there are any particular activities where you anticipate putting on large numbers of personnel during the next fiscal year, you might want to furnish for the record the numbers, the percentage increase, and the reason behind the expansion.

Dr. NEWELL. Yes, I think we could say at this point that the total planned allocation to the space science area in headquarters and in the field, increases in proportion to the proposed increase in the total space sciences budget. They are directly related.

Mr. KARTH. What percentage of this portion of the budget is in the amount of salaries and other benefits, including expenses?

Mr. TAYLOR. Well, in terms of numbers——

Mr. KARTH. In terms of numbers of dollars.

Mr. TAYLOR. I was going to give you the number of people first. In terms of numbers of people this portion increases only 539 people as opposed to an overall NASA increase of 4,393.

In terms of dollar increases the increase over fiscal 1962 is approximately $8 million.

Mr. KARTH. Well, what percentage of the total budget request is for salaries, benefits, and expenses?

Mr. TAYLOR. I would have to do that. I don't have that percentage.

Mr. KARTH. Could you do that for the record and insert it?

Mr. TAYLOR. Yes.

Dr. NEWELL. Without relating it to percentages, we can say that 28.6 million out of the 558 is in salaries and expenses.

Mr. KARTH. Fine, thank you.

Mr. RANDALL. The 558 as I checked the figures, Mr. Chairman, is the overall, and that is a ratio of 28 into 558, so it is 2 percent.

Mr. KARTH. No, it is more than that, almost 6 percent.

Mr. RANDALL. Well, anyway it is less than 10 percent.

Mr. CORTRIGHT. It is 5 percent.

Mr. KARTH. Do you have something to add, Doctor?

Dr. NEWELL. 819 million is the total NASA request for construction of facilities.

Mr. KARTH. Would you like to continue now with lunar and planetary exploration?

Dr. NEWELL. In the lunar and planetary exploration area the increase is from 170 million in 1962 to slightly less than 274 million in 1963. The increase here is largely due to the fact that the lunar and planetary program is now getting into high gear. The Rangers, the Mariners, and Surveyors are either constructed or under construction and serious design work is going on on the more advanced spacecraft. The increase is for this increase in this programed activity.

Mr. KARTH. I notice here again, Doctor, your biological studies increase sharply from 115,000 to 1 million.

Dr. NEWELL. Yes.

Mr. KARTH. Would you give us some specifics as to what you see in this area to cause that increase?

Dr. NEWELL. In the lunar and planetary program as I indicated we have the opportunity to look for life forms or life residues on the Moon and planets, and now that the program is beginning to

launch spacecraft out into space, it is time to take advantage of this opportunity in the biological area.

Mr. KARTH. Is this separate and apart from the Biosciences Laboratory?

Dr. NEWELL. No; this is part of the total program.

Mr. KARTH. This is part of that program; is it not?

Dr. NEWELL. That is correct. However, the $1 million indicated will, in association with that program, largely be used at universities and at JPL in support of the university activity.

The entire program, however, is an integrated program.

Mr. RANDALL. Mr. Chairman.

Mr. KARTH. Mr. Randall.

Mr. RANDALL. May I inquire, I think we are constantly looking for any possible duplication or overlapping here on any of this. Can you assure us that there is none here in this?

Dr. NEWELL. I can assure you that as far as I know—and we have looked through this very carefully—there is none.

Mr. RANDALL. Well, if you spell out the particulars, I mean here we are talking about—you say look for life forms and life residues on the Moon and planets.

Dr. NEWELL. Yes.

Mr. RANDALL. Now there is a popular story I believe in the Washington paper—was it Sunday, I believe—that someone out here has developed a device that can detect germ life of some type, that is the sort of thing you are talking about?

Dr. NEWELL. That is the sort of thing that we are talking about and that we are supporting. I did not see the Sunday paper.

Mr. RANDALL. I believe it was in the Sunday paper.

Dr. NEWELL. We have supported that sort of activity.

Mr. RANDALL. That is the one that you are working on?

Dr. NEWELL. Yes.

Mr. RANDALL. And the chairman's question about the other program, wherein does that differ now, under the other committee?

Dr. NEWELL. I am lost at this point.

Mr. KARTH. You are talking about the Laboratory?

Mr. RANDALL. Yes; the Bioscience Laboratory.

Mr. KARTH. Well, it is part of the program, as I understand it, Doctor. The reason I asked the question——

Mr. RANDALL But it is a separate budget item from the one we are considering here.

Dr. NEWELL. That is correct.

Mr. RANDALL. And the reason that this is here is so that you will have within your division of NASA these funds to incorporate in such spacecraft as Surveyor and so forth and possibly Prospector?

Dr. NEWELL. That is correct, these funds go to universities and people like Wolf Visniac on such studies and to Joshua Lederberg on the microscope for future space use, and so forth.

Mr. RANDALL. Thank you.

Dr. NEWELL. We are in a position to break that number down into its component parts. There are about nine different uses for these funds that we have listed and planned.

Mr. KARTH. Do you mean in the biological studies?

Dr. NEWELL. In the biological studies, yes.

Mr. KARTH. It might be helpful if you supply that for the record.

(The information requested is as follows:)

Biological studies

	Cost
A. Radio biology experimental research	$50,000
B. Studies on miniaturized photosynthetic life support systems	50,000
C. Biosciences	900,000
1. Investigation of decontamination of spacecraft	50,000
2. Analysis of meteorites	500,000
3. Basic biological studies of exotic environments	20,000
4. Ground-based studies of extraterrestrial life	130,000
5. Biological systems in space and planetary environments	200,000
Total	1,000,000

Doctor, in the instrumentation research just above the biological studies, under lunar advanced research, I see there is $1,708,000 and nothing, of course, is budgeted for 1961 and 1962.

What does this include? Will this be in the Surveyor and Mariner programs or what?

Dr. NEWELL. This is money which will be used by the Jet Propulsion Laboratory both inhouse and with contractors for the development of instruments that are needed in carrying out the lunar and planetary exploration program, in this case it is the lunar program.

Examples of instruments of this type which were specifically funded in earlier years under individual categories would be the seismometer for study of lunar earthquakes, or detectors to see if any gas exists near the Moon's surface, or detectors for measuring lunar radioactivity, and so forth.

Mr. KARTH. Well, now in these areas where we find substantial budget requests for fiscal 1963, where none appear for fiscal 1962, and in some instances for 1961, is it because of a reorganization within NASA, a shifting of responsibility, or because of a new capability requirement? What is it, Doctor?

Mr. TAYLOR. Well, this will vary case by case. All of the illustrations you have given would be applicable under given circumstances. In this case it is a classification problem and in years past work of this type of course has gone on and in this budget we desire to pull this out to look at it separately.

It had been included in previous years under spacecraft technology work.

Dr. NEWELL. As Mr. Taylor pointed out, in previous years this has been an item under a broader category, spacecraft technology, and we felt the time had come to make a greater breakdown, so we have it here now.

Mr. KARTH. This is true in most cases where this kind of situation appears in the budget, is it not?

Mr. TAYLOR. In most cases.

Dr. NEWELL. I would say in most cases. There are some exceptions where you have special——

Mr. KARTH. Yes, new requirements.

Dr. NEWELL. That is right.

Mr. KARTH. OK, Doctor, if you would like to proceed on Scout.

Dr. NEWELL. The Scout funding remains at about the same level as in 1962. In 1962 it was $8 million. In 1963 it is roughly $9 million. The moneys requested here are to complete the development of the Scout vehicle. Funding in future years for Scouts will be for the purchase of Scouts and will be included in the budgets of the users rather than in the development portion of the budget.

Mr. KARTH. Any questions?

Mr. Hammill.

Mr. HAMMILL. Would fiscal 1963 be the last year in which substantial amounts of money would be requested for the development of Scout?

Dr. NEWELL. That is correct.

Mr. KARTH. And as far as Delta is concerned, we have already hit that peak it appears, Doctor, and I suppose in fiscal 1964 there may be no funds requested in this research and development area.

Dr. NEWELL. That is correct. In future years the funding will be for the purchase of vehicles and the users will include those funds in their budgets, along with any minor funds that may be required for adaptation of the vehicle to special purposes, but this will not be what one would call vehicle development.

Mr. KARTH. This will come under what portion of the budget then, what part of the budget would include the purchase of these vehicles?

Dr. NEWELL. Most of the Deltas would be purchased by the geophysics and astronomy people, and the applications people, although occasionally Deltas will be used for space probes in the lunar and planetary programs.

Mr. KARTH. All right, Doctor, Centaur.

Dr. NEWELL. The Centaur budget for 1963 is at a somewhat lower level than 1962 if you include the 1962 supplemental. The initial 1962 figure was $66 million, the supplemental request was $9 million, and fiscal 1963, $67 million. These funds are to continue the development of Centaur in order to bring it to the point where it will meet the requirements of the users.

Mr. KARTH. This is certainly the peak of funding, isn't it, Doctor, for the Centaur?

Dr. NEWELL. Yes.

Mr. KARTH. Are there any questions?

Doctor, until such time as we run into a question that we don't find answered in the testimony or some new questions arise that we feel we might need answers to, I think this concludes our hearings and I want to thank you very much and your staff.

I think it has been extremely educational and I know on occasions you and your staff were probably disturbed with some of the elementary questions that might have been asked by this committee, but I hope you understand that we are trying to do the job that we are here to do. We are not scientists, we are not mathematicians or physicists, and as a result, some of our questions may not have sounded to you as if we really had a grasp of the problem, and this might have been the case.

Dr. NEWELL. It has certainly been our pleasure to be here. Anything that we can do to help sell the program, we are happy to do.

Mr. KARTH. Very well. It may be necessary for Mr. Hammill and Mr. Beresford to contact you or one of your staff people. On occasion we may get further information on a particular portion of this budget, and if so, they would be speaking for us, I am sure you understand.

Dr. NEWELL. Surely.

Mr. KARTH. OK, thank you very much. The committee stands adjourned.

(Whereupon, at 10:30 a.m. the subcommittee adjourned.)

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