REVIEW OF THE SPACE PROGRAM

MONDAY, FEBRUARY 1, 1960

House of Representatives,
Committee on Science and Astronautics,
Washington, D.C.

The committee met at 10 : 45 a.m., Hon. Overton Brooks (chairman) presiding.

The Chairman. The committee will come to order.

It had been our plan to take up Resolution 567, sponsored by Mr. Sisk. Since adjournment, we have contacted the Army to see whether the Army wanted to send witnesses here for that program. I understand the Secretary of the Army wants to come here to talk about the resolution, Mr. Sisk.

It so happens that he will be before the Senate tomorrow, but my thought is, after Dr. von Braun finishes his testimony, we can go into executive session and take up this resolution. We can hear the witnesses from NASA who wish to be heard and, if it is not possible for the Secretary of the Army to be here tomorrow, we can leave the matter open until the following day when he will give us his views about H.R. 567.

If there is no objection, that is the order that we will follow.

Now, this morning, do we have the other witnesses from NASA? I could swear them all in at the same time.

If you two gentlemen will stand up and hold up your right hand. Do you and each of you solemnly swear that the testimony you will give before this committee in matters now under consideration will be the truth, the whole truth, and nothing but the truth, so help you God?

Mr. Finger. I do.

Mr. Abbott. I do.

The Chairman. Who is the first witness from NASA?

Mr. Horner. Our first witness this morning is Mr. Abbott, the director of the advanced research programs. He has a prepared statement on the research programs of NASA?

The Chairman. We are happy to have you here this morning. I saw you Saturday at a panel discussion and I am glad to have you here again this morning.

You have a prepared statement. Will you proceed with the statement, sir?

STATEMENT OF IRA H. ABBOTT, DIRECTOR OF ADVANCED RESEARCH PROGRAMS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ACCOMPANIED BY RICHARD E. HORNER, ASSOCIATE ADMINISTRATOR

Mr. Abbott. Thank you, Mr. Chairman and members of the committee.

I want to talk to you about NASA's advanced research activities. It is through these activities that we provide the research information needed to permit the development of the new advanced vehicles that will be required as our Nation's space program progresses. I use the terminology "advanced research" to encompass the following activities (fig. 38).

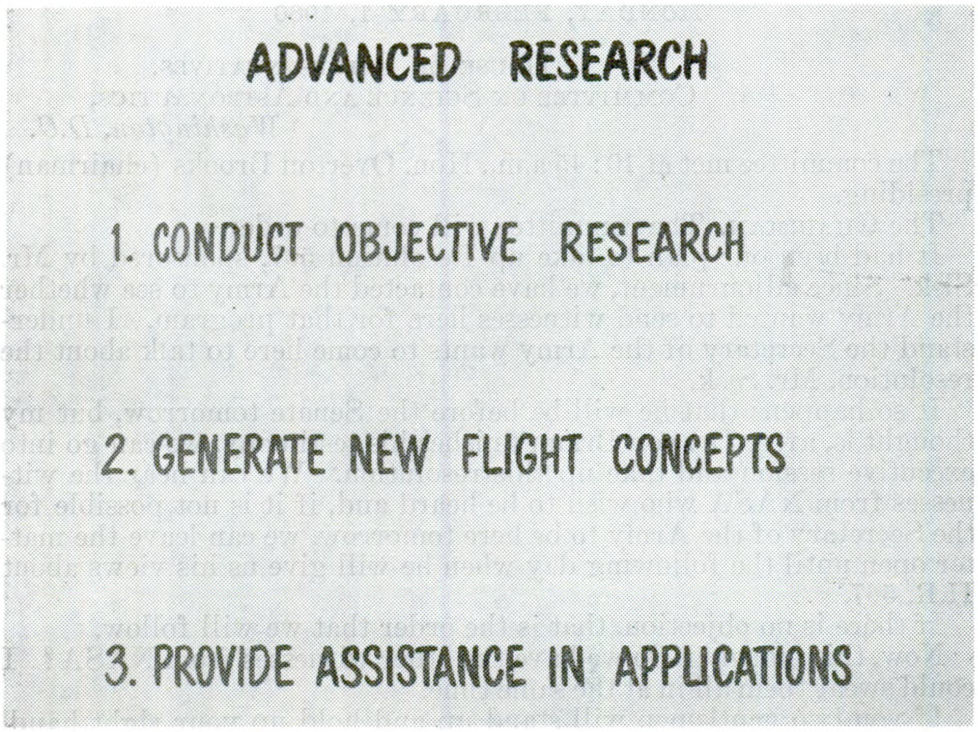

FIGURE 38

First, the conduct of objective research to provide the technical background necessary for manned and unmanned exploration and use of space;

Second, the use of our research findings as a basis to generate new and advanced concepts for future space missions;

Third, to provide research assistance to assure the prompt and effective application of the research results by NASA, by the Department of Defense, and others.

NASA research is performed by our research centers and also through research grants and contracts with universities and other organizations.

You are, of course, familiar with the fact that the NASA's research centers were acquired from the former National Advisory Committee for Aeronautics. This plant cost about $400 million to build. These facilities are being modernized and the larger part of our effort is now on a broad program of advanced research relating to the many scientific problems of NASA's mission of space exploration.

In addition to this research relating to space technology, we are continuing to respond to our responsibility, inherited from NACA, to conduct research, to support and guide our Nation's activities in aeronautics and missiles.

Much of the research relating to missiles is identical—or nearly so—with that relating to space missions, but special problems do exist. One such problem, for example, on which we are conducting a cooperative program with the Department of Defense, is that of radar acquisition, identification and trajectory prediction of incoming ballistic missile warheads. This problem is, of course, basic to any defense system against this type of attack.

In aeronautics our research is now concentrated on certain special problem areas relating mostly to future types of aircraft. One example is the vertical and steep takeoff and landing aircraft that will be needed for certain Army missions, and, probably, for short-haul commercial use.

Another example is the large, economical transport of the future that will cruise in the neighborhood of 2,000 m.p.h. In addition to providing the scientific information to make such transports possible, we are preparing to cooperate with the Federal Aviation Agency to provide information needed by the FAA before such transports can be put into commercial service.

Another example of our aeronautical research is the X–15 airplane with which you are already familiar. This chart will refresh your memory of the X–15 configuration and the expected surface temperatures ranging up to 1,200° F. You will recall that this airplane will reach speeds in the vicinity of 4,000 m.p.h., and will be able to leap out of the atmosphere for a short time. In addition to the aeronautical implications of this work, the X–15 will enable us to gain operational experience on controlled manned reentry into the atmosphere with a winged vehicle (fig. 39).

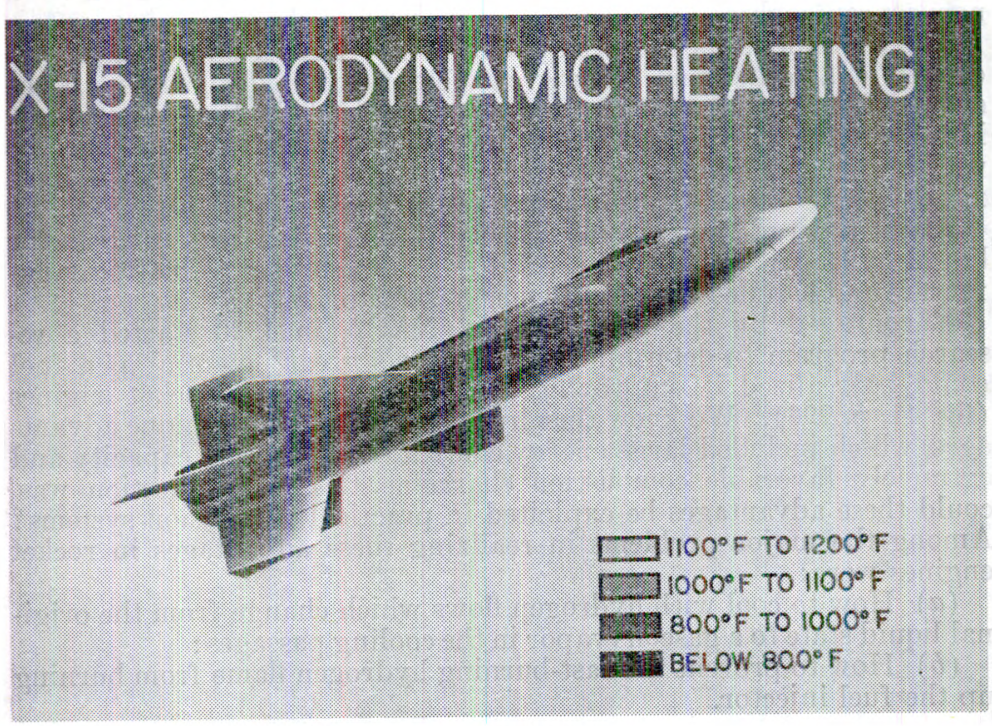

FIGURE 39

During the last year we have been cooperating with the Air Force and the contractor, North American Aviation, on the manufacturer's demonstration flights. It is expected that the first airplane with an interim engine will be accepted by the Air Force within the next week or 10 days and turned over to us for research flight testing in a cooperative program with the Air Force and Navy. The other two airplanes will also be available this year.

In defining our advanced research activities, I used the term "objective research." Some of the broad objectives of our research are indicated on this vehicle spectrum chart. We do not design vehicles at our research centers; however, as implied by the term "objective research," we do seek out the technical problems of missions such as those shown on this chart where sufficient knowledge does not exist to permit practical engineering solutions (fig. 40).

Then through theoretical and experimental investigations, we produce the information needed to reduce these problems to a point where good engineering solutions are brought within the state of the art of our Nation's engineering community.

This was the nature of our activity with regard to the X-15 project between 1952 and 1955. Our early research establishing the blunt body concept for ballistic missile nose cones and the Project Mercury concept was conducted mostly in the time period from 1953 to 1958. During this time period we also carried out studies leading to the Dynasoar I program. The other missions shown on this chart, such as space laboratories, space ferries, and the manned lunar vehicle, are examples of some of the possible future applications of our current research activity.

I would like to describe a representative example of how the research performed at our centers in recent years contributed the basic data required to breach formidable technology barriers and led us to new concepts which are currently being used in the space program.

The example is the research performed by NASA on the use of hydrogen as a rocket fuel. The great potential of hydrogen as a high-energy fuel has been recognized since far back in the last century. However, for all of these years, its inherent disadvantages, such as very low density and the apparent hazards associated with its use, have discouraged its consideration as a practical fuel.

About a decade ago Atomic Energy Commission requirements for liquid hydrogen resulted in studies which made it possible to manufacture and handle liquid hydrogens satisfactorily.

Encouraged by the AEC results, NACA in 1953 started a research program to determine if hydrogen's great potential as a fuel could be realized in improving the performance of rocket engines (fig. 41, p. 296). We knew that hydrogen had several unique advantages, which included large energy content, large cooling capacity and extremely favorable combustion characteristics. The question was, could these advantages be exploited in practical propulsion systems? Among the major problems in realizing these advantages in rocket engines were:

(*a*) How to cool with hydrogen flows which change from the original liquid state to a gaseous vapor in the cooling passages;

(*b*) How to prevent the fast-burning hydrogen flame from burning up the fuel injector.

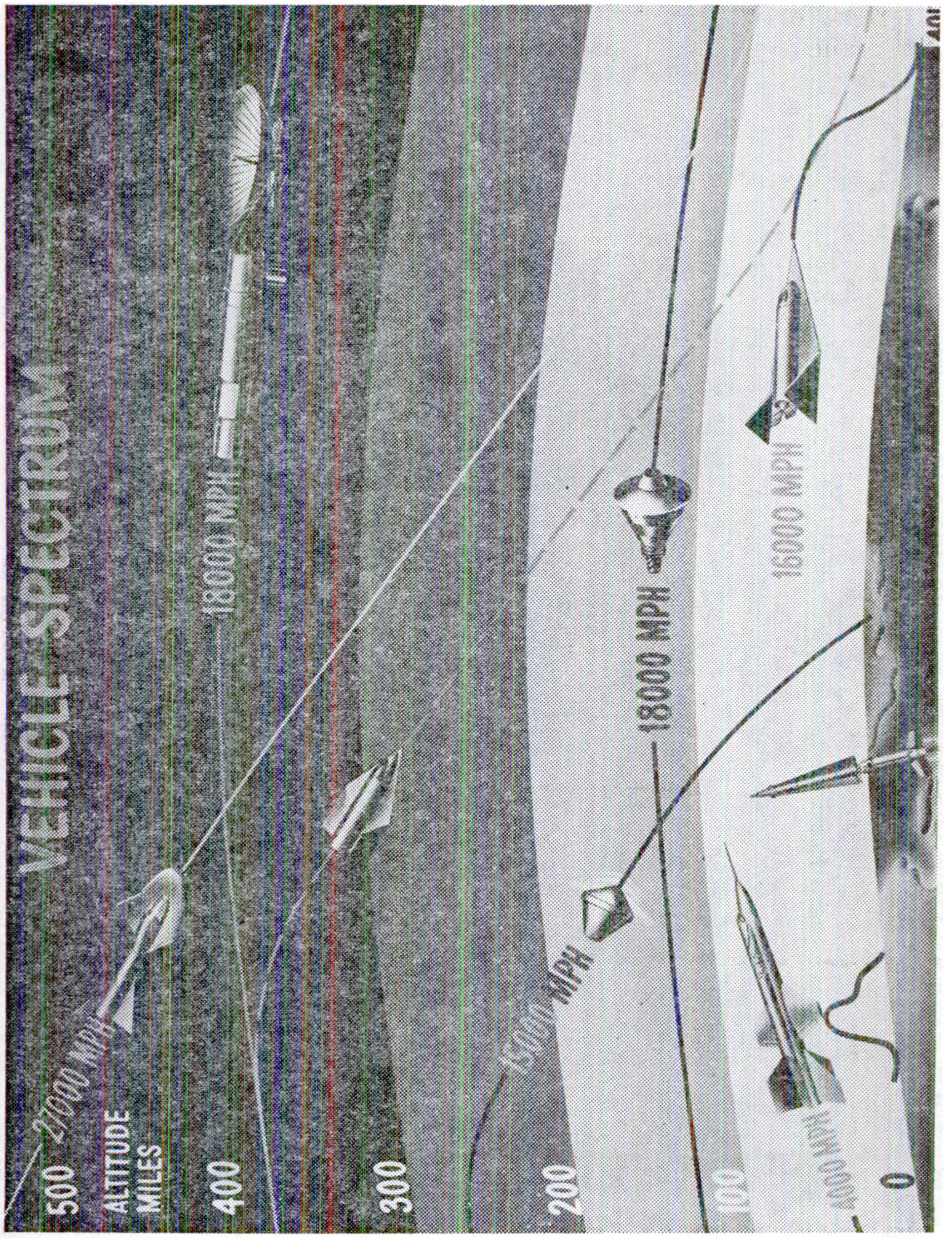
VEHICLE SPECTRUM
ALTITUDE
MILES
500
400
300
200
100
0
27000 MPH
18000 MPH
15000 MPH
18000 MPH
16000 MPH
4000 MPH

FIGURE 40

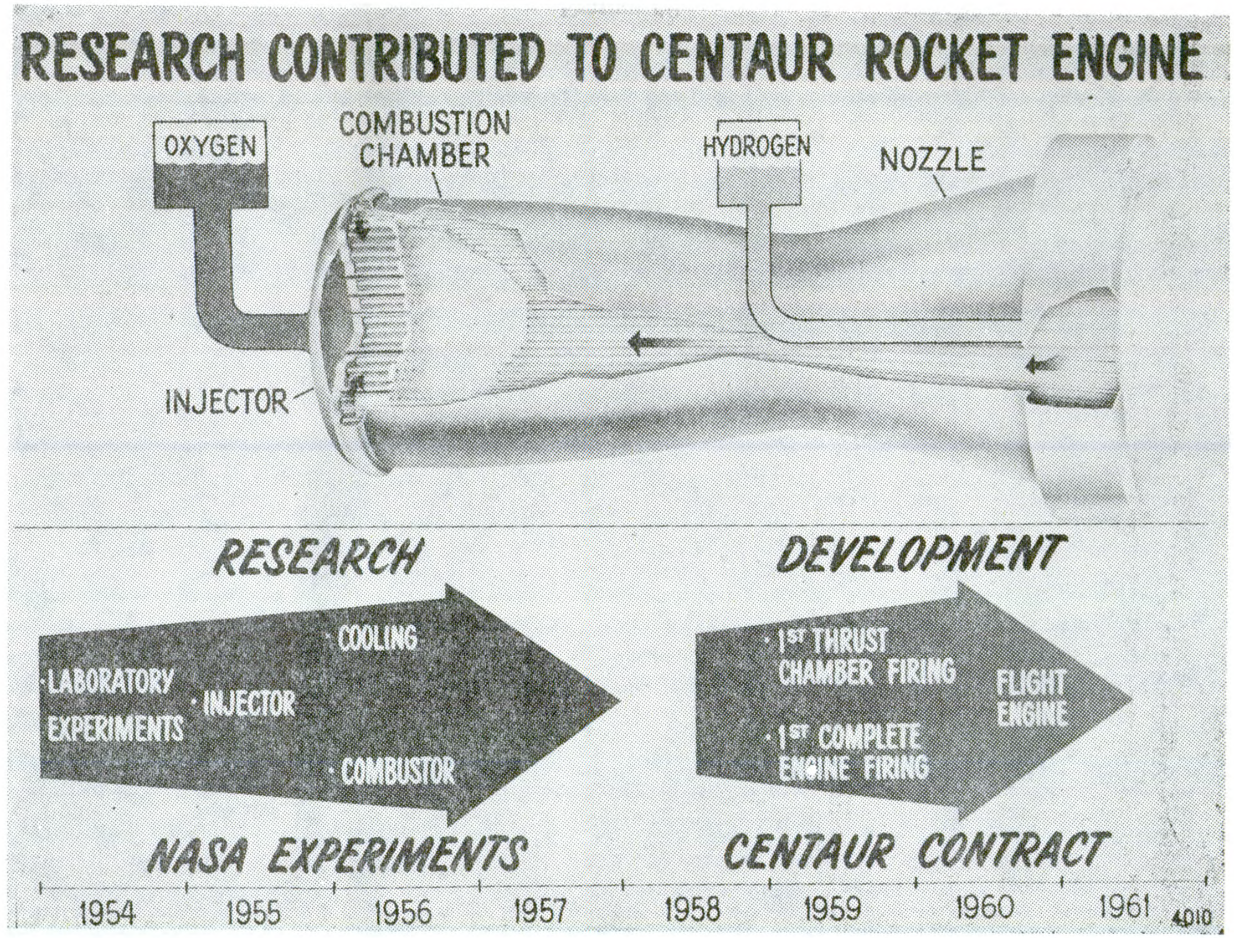
RESEARCH CONTRIBUTED TO CENTAUR ROCKET ENGINE
OXYGEN
COMBUSTION CHAMBER
HYDROGEN
NOZZLE
INJECTOR
RESEARCH
DEVELOPMENT
· LABORATORY EXPERIMENTS
· INJECTOR
· COOLING
· COMBUSTOR
· 1ST THRUST CHAMBER FIRING
· 1ST COMPLETE ENGINE FIRING
FLIGHT ENGINE
NASA EXPERIMENTS
CENTAUR CONTRACT
1954
1955
1956
1957
1958
1959
1960
1961
4010

Figure 41

Basic studies and experiments were required to determine the heat flow rates of liquid, boiling, and gaseous hydrogen. Using these results, our researchers developed a mathematical procedure for determining the size and shape of the passages required to permit the hydrogen to cool adequately the thrust chamber. Because gaseous hydrogen burns so rapidly, the first injectors based on the existing state of knowledge failed in laboratory experiments. Further laboratory studies of injectors were required to make effective use of the gaseous hydrogen and liquid oxygen to cool them.

Other studies showed that combustion chambers for hydrogen rockets could be reduced to approximately half the length of those using more conventional fuels. Finally, by November 1957 the Lewis Research Center successfully demonstrated in a laboratory setup a hydrogen-burning thrust chamber employing the concepts resulting from the research previously mentioned. Here it is on the table before you. It produced 5,000 pounds thrust. In view of the small scale of this experiment, a larger research thrust chamber capable of 20,000 pounds thrust was tested at Lewis in December 1957. As a result of the new concepts put forth by the research of the Lewis Research Center between 1953 and 1957, the Air Force awarded a contract to Pratt & Whitney in October 1958 to develop a hydrogen-burning rocket engine for the Centaur vehicle. This project was later transferred to NASA. As shown on the chart, the previous laboratory research enabled the contractor to make exceptionally rapid progress in the development of the engine. Many of our hopes for greater achievements in our Nation's space program are wrapped up in the potential of hydrogen-burning rockets.

The CHAIRMAN. Mr. Abbott, at that point will you explain to the members of the committee how this 5,000 pound thrust chamber model that you have here on the desk operates?

Mr. ABBOTT. I will be glad to, Mr. Chairman.

The CHAIRMAN. The members of the committee who can't see might come up closer if they wish. If you will, bear in mind, Mr. Abbott, some of the members are a considerable distance away.

Mr. ABBOTT. Well, as you can see, this is not a flight article, but a heavy laboratory experimental setup. It has been partially disassembled so that you can see it better.

The hydrogen burns in about the area I am indicating now, and the exhaust products flow out the nozzle at this end, thus producing a thrust in this direction.

The hydrogen is introduced into this ring which you see near the exhaust end.

The liquid hydrogen flows through passages which are contained within this surface so you cannot see them, to the back end of the thrust chamber and, in that way, the liquid hydrogen, through boiling and heating up as a gas, cools the thrust chamber to prevent it from melting.

The gaseous hydrogen is then introduced into this injector plate.

Liquid oxygen flows in through this hole on this end and into the injector plate. When assembled, these pieces come together in the same order in which you see them. Then the hydrogen and the oxygen flows through these holes in the injector plate and burn. You must appreciate this hydrogen-oxygen flame is extremely hot. It is hotter than the hydrogen acetylene flame. Consequently, the cooling problem is an extreme one in order that the material of which this rocket is made not be destroyed by this intense flame.

Of course, the reason the hydrogen is so efficient is partially associated with the fact that the flame is so intensely hot and partly associated with the fact that the combustion products, water vapor, have a low molecular weight compared with combustion products of more conventional fuels.

The CHAIRMAN. Thank you.

Are there any questions?

Mr. FULTON?

Mr. FULTON. The question comes up, how much water vapor discharge do you get?

Mr. ABBOTT. If we use a stoichiometric mixture of hydrogen and oxygen, just enough of each to burn completely, the entire combustion products consists of water vapor and nothing else.

However, if we use some excessive hydrogen, for instance, the combustion products will be mostly water vapor with some hot hydrogen. The hydrogen, of course, would burn immediately the hot exhaust products come out into the atmosphere, but this burning would do us no good.

Mr. FULTON. You have no problem with backup or anything of that type?

Mr. ABBOTT. No, sir.

Mr. FULTON. On hydrogen under such pressure and when you put it under such heat, how much does it impregnate or become imbedded in the metal?

For example, would hydrogen atoms or molecules as they might be, become forced by pressure into the various cells of the metal and then over a period of time build up so that you would get either a cracking or an explosive possibility there, that it might age the metal, crack it or else explode?

I am interested in the light of this vehicle. Does it become impregnated so that the metal loses its tensile strength?

Mr. ABBOTT. No, sir.

Hydrogen, of course, does have this tendency to leak into many metals. However, for the rocket engine, this is not a serious problem.

Mr. FULTON. It doesn't, then, by this impregnation of metals cause pockets that would cause an explosion with the continued use of this engine so that they might be dangerous, for example, to people?

Mr. ABBOTT. No, sir; we have not encountered any difficulties of that sort.

Mr. FULTON. How long have you used such type engine?

Mr. ABBOTT. Of course, we have been experimenting with these laboratory setups successfully since 1957.

Mr. FULTON. What is its life in hours? Could you give us that?

Mr. ABBOTT. Well, it would be short in terms of hours. The life of these engines, the satisfactory life, is measured in minutes. A laboratory setup such as this might have a life of a few hours at most, not continuously, but in successive experiments.

Mr. FULTON. So it would be just a booster-type engine and not a cruising-type engine in space?

Mr. ABBOTT. Yes; that is correct. The flight engine's useful life is measured in minutes.

Mr. FULTON. Are you able to control flows so that you do not get all the power at once and you get a controlled flow through this type engine so you get a gradual increase in velocity rather than a bullet bang, say?

Mr. ABBOTT. Yes, sir. Hydrogen has not been especially troublesome that way.

Mr. FULTON. Have you used any other fuels on this type engine, such as boron or things of that type? Have you tried any other mixtures? Lox?

Mr. ABBOTT. Not on this particular engine. This was designed specifically for hydrogen. However, in our research we are experimenting on small-scale setups with various types of advanced fuels.

Mr. FULTON. What kind of a specific impulse do you get out of this kind of an engine?

Mr. ABBOTT. I will have to rely on my memory now, but about 400.

Mr. FULTON. That is all.

The CHAIRMAN. Mr. Anfuso.

Mr. ANFUSO. Doctor, I believe that you intend to use this hydrogen thrust merely for the second stage. Is that correct? Not for the first stage?

Mr. ABBOTT. This is the current plan; yes.

Mr. ANFUSO. What is the biggest thrust that you expect or that you foresee?

Mr. ABBOTT. At any time in the future?

Mr. ANFUSO. Well, within the next year.

Mr. ABBOTT. Well, the immediate plans in the present Centaur engine is in the general thrust range between 15,000 and 20,000 pounds, and I would expect the next step to be about 10 times that.

Mr. ANFUSO. What could you accomplish by such a second thrust——

Mr. ABBOTT. What kind of a mission?

The advantage of the hydrogen engine is that the specific impulse is higher than the conventional fuels. Consequently, the advantage of using the hydrogen engine is that with the same total weight vehicle, one could accomplish either a bigger payload in orbit or a bigger payload into a deep space probe than with the conventional fuels. Alternately, to do the same mission, it would require a smaller total weight on the ground to start with.

I do not have any specific mission weights with me today.

Mr. ANFUSO. I have read somewhere, sir, that upon reentry into the atmosphere the capsule would burn, so if there was a man in there, he would fry to death.

Would the development of hydrogen fuel prevent that?

Mr. ABBOTT. No, I am afraid that the development of the hydrogen rocket does not speak directly to that problem. I have something to say on that problem a little later in my prepared talk.

Mr. ANFUSO. How do you get this hydrogen fuel?

Mr. ABBOTT. It is liquefied. There are a number of plants in the country, chiefly Government plants, that produce this liquid hydrogen. Hydrogen is produced in several ways, such as electrolysis of water.

It is liquefied in generally the same process one uses to liquefy air, except the temperatures are lower and it is a more difficult process.

Mr. ANFUSO. Any country can produce it?

Mr. ABBOTT. Any country can produce it.

Mr. ANFUSO. That is all; thank you.

The CHAIRMAN. Now, Mr. Abbott, you haven't finished your statement and the questions asked were just with reference to that particular machine. That is the reason we paused.

Will you proceed with your statement?

Mr. ABBOTT. I want to turn now to some examples of our current activities which will lead ultimately to new vehicles for the more advanced space missions of the future.

As mentioned by previous witnesses, flight by man through space to the Moon and return to the Earth is a goal that catches the imagination of many of us. However, much research must be undertaken to pave the way before our country can perform such an achievement.

Already the NASA's research centers are in the initial stages of research on a number of problems relating to manned lunar flight. For example, reentry into the Earth's atmosphere from lunar flight speeds poses much more severe problems of guidance and control, deceleration, and heating of the vehicle than will be experienced by the Mercury capsule on reentering the atmosphere at satellite velocities.

Our studies indicate that if we attempt this reentry from a lunar mission with a ballistic capsule, which would be based on a simple extension of our experience with Project Mercury, guidance will be a major problem. Perhaps you can visualize a ballistic capsule traveling from a distance of a quarter million miles out in space and heading toward the Earth at a speed of 27,000 miles an hour.

In order to decelerate and land safely in its first pass around the Earth, a capsule must enter a flight path corridor with an accuracy of only 3½ miles above or below the proper trajectory. For scale, this corridor width is less than 1/1000 of the diameter of the Earth. On this chart the width of the line representing this corridor has been exaggerated about 10 times to permit you to see it. Present guidance technology is not capable of meeting this stringent requirement in a practical way. If our capsule undershoots this corridor, it will be destroyed by aerodynamic heating. On the other hand, if it overshoots the corridor, our manned vehicle will make another excursion out into the radiation belts, involving the probability of several additional days of flight, if, indeed, return to earth can be made at all. We are, of course, extending our work on guidance and trajectory control to find means of meeting the severe accuracy requirements which are imposed by this type of vehicle (fig. 42).

We are also conducting research on other concepts, such as the use of lift during reentry. Results indicate that the permissible entry corridor width can be increased by the use of lift. This concept would, of course, greatly alleviate the guidance problem, and also reduce the accelerations experienced by the astronauts. In addition, the use of lift will provide much more operational flexibility in piloting the vehicle to preselected landing points.

However, we don't get all of this for nothing. The use of lift greatly aggravates the reentry heating problem, as shown on the next chart (fig. 43).

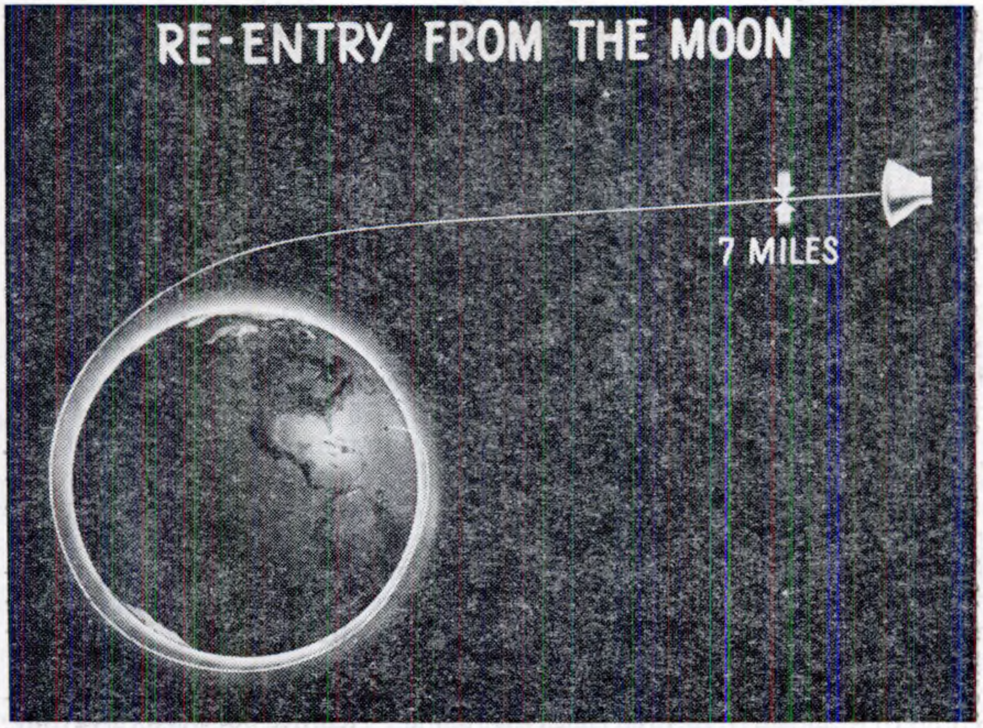

FIGURE 42

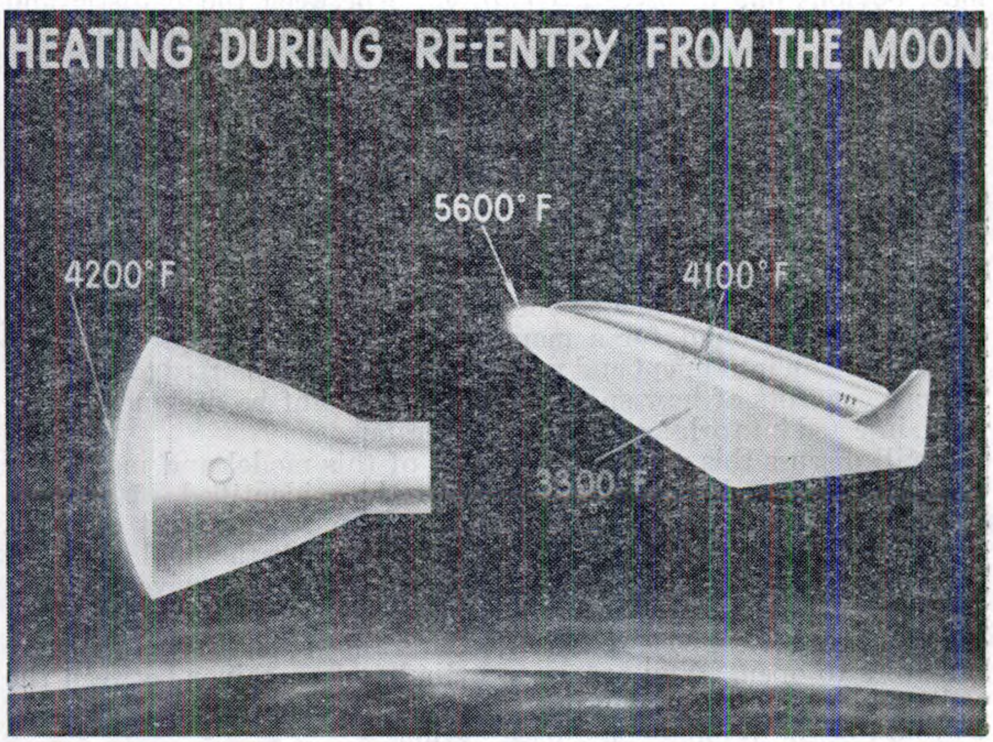

FIGURE 43

This chart illustrates the nature of the heating problem for both the ballistic and lifting entry configurations. In the case of the ballistic vehicle, severe heating is largely restricted to the front face. The maximum temperature would be of the order of 4,200° F. for relatively short times. We believe that the heating problem of the ballistic vehicle can be resolved by modest extensions of our present research. This is not the case with the lifting vehicle, however. The nose temperatures on lifting configurations, such as shown on the right of the screen, may reach as high as 5,600° F. Although this is the maximum temperature, the rest of the surface is also very hot. These high temperatures will also be experienced for a much longer time than for the ballistic vehicle. You will recall that in 1954 research information permitted us to propose the X–15 research vehicle, which would be capable of withstanding maximum temperatures of 1,200° F. Today we believe that the Dynasoar I vehicle can be developed to withstand maximum temperatures from 2,000° F. to considerably more than 3,000° F. This is about the present status of research information for structures for lifting reentry vehicles. You can see, therefore, that we have a long way to go in research on high-temperature materials and structures to permit a winged lifting vehicle to reenter from lunar flight speeds.

It is apparent that for the next few years much effort must be devoted to research to resolve these problems. In addition to the straightforward approaches of greatly improved guidance systems and heat-resisting structures, other approaches are being investigated. The most obvious one involves a compromise between the ballistic and winged lifting vehicles to retain the best features of each while minimizing their problems.

While the manned exploration of the Moon and planets constitute long-range objectives of space flight, it is not entirely clear at this time exactly what the next major step should be. It has been suggested by some that a manned orbiting space laboratory capable of supporting several men in space for a period of several weeks may be necessary in order that we might gain the knowledge and experience needed to accomplish longer range deep space objectives. Accordingly, we are now focusing some of our advanced research to provide technological background for a manned orbiting laboratory. In order to do this in an intelligent and realistic way, we have started to consider various concepts of how space laboratories might be designed, packaged, injected into orbit, erected, and operated.

I will discuss this work with the aid of this model and mention a few of the research problems which have been identified. I want to emphasize that this model represents only one of several concepts which are being considered. Our model represents the final stages of the rocket-launching system. When this configuration arrives in orbit, it is first pointed at the Sun by the stabilization system, then the nose cone is ejected [nose cone removed]. This allows the two semicircular radiators to open. You can see a cylindrical container between the radiators, which houses equipment for operation of the station. We will now begin to inflate our space station.

While our station is inflating, we can consider some of the research problems which must be studied before such a vehicle could be built. Obviously, the first problem relates to the characteristics of the inflatable wall. We are investigating materials which must be leakproof and strong. However, these materials must also withstand folding and packaging without damage, and be free of odors or toxic fumes in a closed pressure system. Even with a leak-resistant cell wall, we expect leakage through meteorite punctures. Hence our station which you can see inflating is made up in sections, with doors which would be closed in an emergency to seal off a punctured section. We would also expect micrometeorite punctures which would be small and hard to find; hence, it would be prudent to provide an automatic sealing system.

Now that the station is inflated, you will see that it may be considered to represent a 40-foot-diameter station which would have a total weight of between 12,000 and 15,000 pounds. Such a station could be launched with a Saturn launch vehicle.

The heating system of the space laboratory must have fail-safe features, hence we have considered using direct solar radiation to heat it. By adequate control of the reflective properties of the surface, an average temperature of 70° could be achieved. Thermal radiating properties of materials over a wide range of conditions in a hard vacuum environment must be known, as well as the effect of bombardment by high-energy particles. Ultraviolet and X-rays will also affect certain materials.

Such a station must have a source of power which can be provided by this solar collector which focuses the sun's rays on the boiler, which runs the turbogenerator to provide electricity. A zero or low g environment will affect heat transfer in the liquid and gaseous systems of this powerplant. We have considered that the station should be sun-oriented; that is, it spins about an axis directed at the sun. If we rotate our 40-foot-diameter station at six revolutions per minute, a small amount of acceleration of the order of one-fourth normal gravity may be provided for comfort of the occupants over long periods of time.

The principle of operation of this space laboratory is to erect it automatically and place it in operation by a programed sequence. Then, a space ferry containing personnel is sent up to rendevous with the station. The space ferry would approach the station and lock on here at the bottom to discharge personnel and cargo, and to be used as an escape or return vehicle as may be necessary.

In our work to date with such concepts we have identified many other research problems that require study.

In conclusion, I hope that these few examples of the many things we are studying in our research centers, have provided an indication of the nature of the NASA's advanced research work.

The CHAIRMAN. Thank you very much, Mr. Abbott.

You refer to a lift vehicle, as contrasted to a ballastic vehicle.

Mr. ABBOTT. Yes, sir.

The CHAIRMAN. Tell us a little bit more about the lift vehicle.

Mr. ABBOTT. Well, what I mean, of course, is a vehicle that would provide aerodynamic lift once it entered into the atmosphere.

The CHAIRMAN. In other words, return to the atmosphere circling the earth and using the power of the atmosphere to maintain its altitude?

Mr. ABBOTT. Using the life of the atmosphere to slow it down and support it, in a different manner than the ballistic vehicle.

You can see, if we have a lifting vehicle, the corridor in which we have to enter can be wider. If we enter too low, we orient the vehicle to go upward and go back to the right corridor. If we were too high it would be possible to lift downward and pull ourselves down into the atmosphere to the proper point.

The CHAIRMAN. Whereas your ballistic vehicle avoids the use of the atmosphere as a means of lift.

Mr. ABBOTT. Yes, sir. It uses the atmosphere only as a drag brake.

The CHAIRMAN. Now, this last vehicle that you have referred to. What value do you think it is going to have when and if you perfect it?

Mr. ABBOTT. You are referring to the space station?

The CHAIRMAN. Yes; the space station.

Mr. ABBOTT. I think a space station might have two types of values, one of which I mentioned in my prepared statement. That is, it would provide us with a great deal of experience in providing a habitable environment for people in space for a considerable period of time in an orbit not too far removed from the Earth's surface, where the people could be recovered by the use of space ferries if unusual, unexpected, things occurred. This would provide us with operational experience before sending people out into deep space missions to a point—well, the Moon itself is a quarter of a million miles from earth, which is quite a long distance.

The other utility that such a station might have would be as a base for actual laboratory experiments conducted in space. This is a question, the value of which can be debated.

For instance, in an orbiting astronautical laboratory a great many things can be done with instruments, but I am confident that one day we will want to put an astronomer up there along with those instruments in order that he may exercise the knowledge and judgment which only an astronomer has.

The CHAIRMAN. You may want to put a surveyor up there, too, to survey the world.

Mr. ABBOTT. Yes. I used only one example. There are many others.

The CHAIRMAN. I know that the Chief of the Army Engineers has made some statement about making a map of the Moon. Likewise, it would help us in making a map of the United States, would it not?

Mr. ABBOTT. I suspect that experience will indicate that one of the most valuable people who could be up there would be an electronics technician in some cases.

The CHAIRMAN. Why an electronic technician?

Mr. ABBOTT. He could make minor repairs on the equipment.

The CHAIRMAN. Repairs of that and other equipment?

Mr. ABBOTT. Yes.

The CHAIRMAN. It would be sort of like a service station for an automobile.

Mr. ABBOTT. Possibly. I really don't know how it will all work out.

The CHAIRMAN. Mr. Fulton?

Mr. FULTON. It is 17 minutes after.

The question is as to the kind of a reentry target area you would have when your space vehicle first approaches the atmosphere. What is that? Is that diameter of 1½ miles of a circle, that it can come in and aim within a circle, or must it come in and aim with an ellipse, or does it come in and aim within a crescent? Referring to your chart entitled "Reentry From the Moon," I can see unless it comes in on a certain trajectory and is aimed pretty well at a ballistic course around the Earth that you would get a kind of an ellipse, if you got a divergency out of an extreme angle, that, on Kepler's Second Law of Dynamics you would get a very short perigee and a longer apogee away from the Earth.

Mr. ABBOTT. Yes, sir. The figures which I gave relate only to the altitude width of the corridor.

Mr. FULTON. How wide could you get it, because I want to point out a difficulty you are getting into just on the ordinary Kepler's laws.

Mr. ABBOTT. I think you will realize it is more a question of the direction in which the vehicle is going than of the width, since there would be an annular area all the way around the Earth, of this altitude in which he could enter; but, of course, the direction in which he is going is important. I do not have figures with me about this and I don't believe they have been studied, as yet, to anywhere near the same degree as the altitude figures.

Mr. FULTON. Instead of an annular course, a circular course around the world, that would take, if you get a divergence on an angle one side or the other too much, then you get very little of the Earth's atmosphere that is being entered and you go back into a ballistic course much more quickly. So that is really an elliptical flight, not an annular flight. When you get an elliptical flight then you get Kepler's Second Law operating and you run into tremendous difficulties.

So I am saying, what amount of distance, right or left, can you then have as a toleration, on a reentry vehicle, when it comes to the point of entry in the atmosphere and comes to this 12½ miles, as you say, up or down—I don't know whether that is a good description or not. How much, we will say, east or west?

Mr. ABBOTT. I am not prepared to answer that question, Mr. Fulton. I recognize this is a very important thing. I am not prepared to respond to it in any numerical way because this whole subject has not yet been fully explored.

Mr. FULTON. Let's go on to another point. You say if we had our 40-foot-diameter station revolving at 6 revolutions per minute we get a small amount of acceleration and get about one-fourth normal gravity.

It would seem to me when you put your power station or your boiler right in the center around which this station revolves, you then are at zero gravity. It would be much better for you, instead of having one, have two, and put a meter out on the rim and have a mirror reflecting to those. Because at the rim of the space station you will get a quarter gravity, or if you go 20 feet further beyond the perimeter, you would get another 40-foot diameter. You would then, using the 3.11416 formula, probably get gravity at another 20 feet out, wouldn't you?

Mr. ABBOTT. You are quite correct about the arrangements.

Mr. FULTON. Then the question is: Why not put the two stations on arms out away from the perimeter, the outside of the station, and then you have full gravity and you have no trouble with your heat transfer.

Mr. ABBOTT. I think that you are quite right and that any practical vehicle would be designed in some such manner as that. I would like to point out that the only purpose——

Mr. FULTON. I felt that was a defect in this one here.

Mr. ABBOTT. I am sorry, sir, but this model is not intended to represent anything like a practical design but merely to indicate some of the research problems that are associated with it. It is a much more compact thing to bring into the room this way than with the other arrangement.

Mr. FULTON. How long would a station like this stay up?

Mr. ABBOTT. I really don't know. It should be capable of staying up for a long period of time.

Mr. FULTON. With what would you inflate it?

Mr. ABBOTT. I think it would be either air or oxygen.

Mr. FULTON. And there is no danger of the thing just going up in a puff, is there, with that kind of an inflating material?

Mr. ABBOTT. We always have danger of combustion wherever there is air or oxygen. That would have to be taken into account. I would like to point out, though, that I don't think the station would be inflated to full atmospheric pressure. People get along very well at pressures corresponding to 10,000 to 12,000 feet altitude and that is probably the pressure we would use.

Mr. FULTON. When you have that space station Sun oriented you expect it to be equatorial orbit, an annular equatorial orbit or a polar orbit? What kind of a declination would you expect?

Mr. ABBOTT. I think this would depend entirely on what the mission of the station would be.

Mr. FULTON. What is the best?

Mr. ABBOTT. Again, this would depend on the mission of the station.

Mr. FULTON. Suppose it was a communications satellite, what would you do——

Mr. ABBOTT. A communications satellite, I think probably would be best on an equatorial orbit, at a very considerable distance from the Earth.

However, if the station had a mission to examine the Earth's surface, it would be able to see all the Earth only in a polar orbit.

Mr. FULTON. That is all. Thank you.

The CHAIRMAN. Mr. Miller?

Mr. MILLER. Mr. Abbott, I notice on page 3 of your statement you discuss the activities of your agency. You mention the fact that you are doing work in connection with FAA.

Mr. ABBOTT. Yes, sir.

Mr. MILLER. In developing the peaceful uses of the air for the benefit of this country, I think it is one of the original objectives of your predecessor, NACA, and you are carrying them out?

Mr. ABBOTT. Yes, sir, we are. We have certain responsibilities in connection with research that relate to aircraft safety, navigational aids, and that sort of thing, although this primary responsibility rests in the FAA, and we cooperate with them on the research.

Mr. MILLER. Are your research and technical facilities at their disposal in this field, and have they been at their disposal in this field?

Mr. ABBITT. "At their disposal" is perhaps too strong a term, but we cooperate with them.

Mr. MILLER. Your knowledge has been available to them and you have been able to undertake any research that they need in this field when they request it?

Mr. ABBOTT. Yes, sir. Our knowledge is always available to them and where research is needed in a field, we get together with them and discuss how it should be done, and whether it should be done by us or by somebody else.

Mr. MILLER. Mr. Chairman, I think this is a very important facet that NASA has in this drive for outer space which we sometimes neglect. And the very great contributions they make and have made in the past, or their predecessor has made in the whole field of aviation.

I want to congratulate you, sir, on carrying out the work that has been assigned to you in the field of research. I would like to point out to some of my colleagues that some of the things you have told us here today, we read about as the great aviation companies' babies, whereas they were conceived and born in this Federal agency that has never received proper credit for the work that it has done. I believe at Ames right now you are doing certain work preliminary to perhaps getting an astronomer into space. Is that correct?

Mr. ABBOTT. That is correct.

Mr. MILLER. And the fine work that has to be done in this. The value of one of these stations, as I see it, would not only be in that field, but in the field of studying the radiation belts that we must penetrate before we can put a man onto the moon and bring him back again, in which field we are not too knowledgeable. Isn't that correct?

Mr. ABBOTT. That is correct.

I would like to thank you for those kind words. We have many years of experience as the NACA, of course, in working closely in teamwork with the industry of this country, with the Department of Defense and with the Civil Aeronautics Administration, now the Federal Aviation Agency, and we are continuing these activities.

Mr. MILLER. I would just like to close, Mr. Chairman, by saying that I again would encourage my colleagues at any time to visit one of the three laboratories of NASA. And I am certain that Mr. Moeller who saw one of them last year will join me in that.

Mr. MOELLER. Right.

Mr. MILLER. You get a far finer knowledge of some of the things we are trying to do if you take time out to see what this great agency is doing.

Mr. BROOKS. Thank you, Mr. Miller.

I think those words are well chosen and certainly appropriate. I don't think NACA was given proper credit for the fine work it did, as the predecessor to NASA.

I had the privilege of being at Langley during the fall and being briefed on the future development of aviation. I was impressed with the work which NASA is now doing in the aviation field as contrasted to the space field and I commend that briefing to my colleagues on the committee. I hope that we all have an opportunity to participate in such a briefing at some time or other.

Mr. ABBOTT. I hope you do, sir. We would be very happy to have you at any time.

The CHAIRMAN. Now, since we are so far behind on our schedule, if there are questions over here let us proceed. Do you have questions, Mr. Osmers?

Mr. OSMERS. Mr. Chairman, I wanted to make a suggestion to Mr. Abbott. There seems to be some doubt as to whether they should inflate this station with air, or oxygen. I thought I might suggest to them in a nonscientific way, that he use hot air because that has been found here in Washington to inflate earthly bodies and to keep them at high altitude without explosion for a good many years. That might be of some help to him in his program.

The CHAIRMAN. You can't eliminate the heat, though, in the case of Washington.

Mr. OSMERS. As my colleague, Mr. Miller, mentioned, in referring to a part of Dr. Abbott's statement, the top of page 3 relates to the work NASA is doing with regard to the civil aviation industry.

All over the Nation, Mr. Abbott, there are great discussions going on regarding the need for new, very large, very costly, very space-consuming jet airports for the future of the civil aviation program of the country.

Would you care to express yourself to the committee with regard to the imminence of practical vertical and steep landings and takeoff of commercial aircraft for commercial use?

Mr. ABBOTT. I think——

Mr. OSMERS. In order to narrow the question just a bit, sir, I am referring not to transcontinental, or transocean flights, but I am referring to flights between cities in the East and the Midwest, from the New York, Chicago, New Orleans, Miami, quadrangle—200-, 300-, 400-, and 500-mile hops.

Mr. ABBOTT. Thank you for clarifying your question. This makes it easier for me to answer, although I am afraid I do not have a good answer because timing of this sort depends on so many things in which I am not expert. It depends on the economics of the situation and upon how rapidly some organization with sufficient money to get into this venture wishes to push it.

At the present time, it looks to us as though vertical takeoff and landing aircraft will have to be heavier and more highly powered than conventional airplanes. About half again as heavy and about twice the power to do the same chore.

This means they are going to be more expensive to operate. This has to be balanced, on the one hand, against the difficulties of getting from the center of our metropolitan areas out to the large airports, on the other hand. Frankly, I don't know how this is going to end, but I would think that the current trends of metropolitan growth and location of airports would lead to some excellent opportunities for the new types of aircraft, but I cannot speak as an expert on this.

Mr. OSMERS. Do you feel, sir, that it might be possible—and I am sure this was very carefully thought out by your predecessor, NACA—that instead of making the aircraft heavier and more powerful, to use small rockets to help get them off the ground and up into the air high enough so that they can proceed under normal power—whether that be turbojet propellant, gasoline power or what ever.

Mr. ABBOTT. We have another problem here. There is an old saying that commercial aircraft have to support themselves in the air economically as well as aerodynamically. Rockets are very expensive things.

I am afraid the fares that would be charged for any short-haul flight where the aircraft was put into the air with rockets would be rather startling.

Mr. OSMERS. I am thinking more in terms of the roman candle type of rocket, rather than the rocket that is used to lift the Atlas into outer space.

Are you in a position to tell us, Mr. Abbott, approximately how much of the $800 million proposed NASA program for fiscal 1961 will be devoted toward the development of civil aviation projects, conventional projects.

Mr. ABBOTT. It is very difficult to arrive at such a figure because the very nature of research is such that it is often difficult to tell what the application is going to be. However, if I can do a little arithmetic out loud, the salaries and expenses account for the four research centers is in the neighborhood of about $74 million, of which about a third at the present time is applicable to aeronautics, or about $25 million. I would find it extremely difficult to break that down between civil and military because these are very closely intermingled and what is military today will often be civil tomorrow.

Mr. OSMERS. Do you feel that the future development of vertical takeoff and landing aircraft will lie along the lines of the helicopter of today or some of the other models which have engines which invert and turn and wings which change their character as the plane goes up? Do you feel that we will go along the lines of further development of the helicopter, or that we will go into newer, not necessarily newer, because I know some of the models have been under experiment for many years, but some of the other types?

Mr. ABBOTT. I would venture to predict that it will go both ways. Any time that you want to take off vertically with a very large load, the helicopter is far and away the superior type of aircraft for doing this. I think the helicopter is going to continue to be with us and that it will continue to be developed into a better and better vehicle.

However, the helicopter has many disadvantages, too, particularly with regard to efficiency of flight in forward speed and limitations on speed. For this reason, I think we will also see the development of the other types that you have mentioned.

Mr. OSMERS. Yes, I think that the general average low speed of the helicopter will narrow its use to commercial passenger transportation.

The CHAIRMAN. Mr. Anfuso.

Mr. ANFUSO. Mr. Abbott, one of the purposes of this space station is to study habitable environment in space. Is that correct?

Mr. ABBOTT. Yes, sir, that would be one of the purposes.

Mr. ANFUSO. It is true that man exposed to space could not live, could he?

Mr. ABBOTT. Without protection, he would die very rapidly.

Mr. ANFUSO. Are studies being conducted with respect to how man can navigate and survive in space? For example, could he possibly take off from the space station with a space suit on, like you see spacemen taking off into space? Do you think those things are within the realm of possibility, or could he take off from another smaller craft launched from the space station?

Mr. ABBOTT. I think it is entirely credible that a man might be able to exist in space for a short period of time protected only by an adequate space suit. These space suits are getting better all the time. I see no reason why this should not be done.

However, in thinking about the problems of assembling a space station, for instance, we have tended to consider rather impractical those comicbook impressions showing stations being erected out of prefabricated parts using a crew of astronauts dressed only in space suits floating around freely in space, equipped with a variety of hand tools. We don't think this is a very practical sort of thing.

Mr. ANFUSO. That is all.

The CHAIRMAN. Any further questions to the right? Mr. Karth?

Mr. KARTH. Mr. Chairman, just a couple.

I would like to ask the doctor if he knows how much money has been authorized or suggested in the 1961 budget for research work on this whole area of heat-resistant metals or compositions.

Mr. ABBOTT. This is a very difficult question for me to answer, because so many people are working on it. We will provide you the number, though.

(The information requested is as follows:)

The Federal Government is expected to spend about $125 million directly on basic and applied materials research in 1961. The NASA expects to spend about $6 million on materials research relating to NASA responsibilities plus $4 million for new facilities to expand this research in the future.

Mr. KARTH. Has this been assigned a rather high priority, Sir?

Mr. ABBOTT. Yes, sir.

Mr. KARTH. Do you feel the moneys being expended on it are sufficient to meet that priority in the shortest possible time?

Mr. ABBOTT. This is always a very difficult question to answer. I think I can answer best by saying that people who are better qualified than I am to determine such things, have determined the size of the program that should be done and that is going ahead. The question of materials is a very wide area.

Mr. KARTH. Is it your opinion sufficient progress is being made in this area?

Mr. ABBOTT. I would always be dissatisfied with the progress being made in any research area.

Mr. KARTH. This is the standard answer that we are destined to get, sir, or is this really your personal opinion?

Mr. ABBOTT. It is very difficult for me to say. There has been a tremendous upsurge in materials work in this country in the last year or two and there are plans for it to be increased still faster. My suspicion is that in this particular area any attempt to go much faster would run head on into the fact that we just don't have many more people who are really qualified to work in this field.

I think that one of our big problems in this materials area is to train more people and get them into it.

Mr. KARTH. Thank you.

The CHAIRMAN. Mr. Riehlman.

Mr. RIEHLMAN. Mr. Abbott, at page 2 of your testimony you refer to the cooperative program being carried on by the Department of Defense.

With respect to radar acquisition, identification, and predications of incoming ballistic missiles and warheads, as you say in your next statement, this is basic to our defense system.

Can you give us any idea how extensive and how successful this program is, up to this point at least?

Mr. ABBOTT. The program that is being carried on is in conjunction with our Langley Research Center although the actual work is being done at Wallops Island. The Department of Defense has erected there, or is now in the process of erecting, two very advanced radars which can be used to get this information from incoming objects which we will fire from Wallops Island.

I really can't go much further than that in this answer at the present time because we would be getting into a classified area.

Mr. FULTON. I have cautiously a couple of times suggested that trying to catch these missiles as they come down might be the wrong approach because it is like apples falling off a tree and one is going to hit you on the head.

I believe one should try to energize them or divert their course by applying energy of some sort. Because when they are at the height of their apogee in space it would take very little energy to either divert them or boost them and push them on.

If they are in the range of the United States give them a little push further, allowing them to just maintain the velocity they have and they would go on over and fall in the Pacific Ocean or fall in China.

So the question is, maybe, rather than to block these things and destroy their velocity completely, wouldn't it be much better just to maintain their then velocity and push them on?

It might end up like one of these games where you keep pushing the ball back and forth. Couldn't you divert them rather than try to knock them down?

Mr. ABBOTT. There is a subject that I don't think we can discuss profitably in open session. Anyway, it really is a Department of Defense problem.

Mr. FULTON. The second thing is this. Obviously, these space suits will not satisfy any women because these space ships are made by scientists and have no style at all. I think you will never get any women into space.

On this model, if you have no fins on it, it won't go anywhere.

Mr. ABBOTT. I think you are quite right, sir.

The CHAIRMAN. Mr. Hechler?

Mr. HECHLER. Dr. von Braun says we are exhausting our stockpile because of the emergency application of the research that we have done. I wonder whether you find this to be true as of now. Have we a great need for stockpiling additional basic research before we can move ahead?

Mr. ABBOTT. Yes, sir; I think I agree with Dr. von Braun. The only thing is, I would like to point out that this is not a new situation. I have never known any time in over 30 years when research information was stockpiled.

Mr. HECHLER. Isn't it more acute, though, at the present time, when we are trying to move forward in this emergency period?

Mr. ABBOTT. Yes, sir; but the point is that any time we find out something somebody is going to use it right then, and so it is no longer in the stockpile. The application is always right on the edge of what we are doing. Research information really cannot be stockpiled except by slowing down the application which is something that none of us would ever want to do.

Mr. HECHLER. Well, doesn't this then point to the absolute need for strengthening our educational system so that we can provide the basis for moving forward in research in the future?

Mr. ABBOTT. I agree completely. I think this is very important.

Mr. HECHLER. Thank you, Mr. Abbott.

The CHAIRMAN. Now, there being no more questions, Mr. Abbott, let me say we appreciate very much your appearance here and the able statement that you have made.

I want to say at this time now that we have four more witnesses from NASA to be heard. We hope that we can hear them this afternoon. We want the members of the committee to stand by. However, we must be on the House floor at 12 o'clock. It is 10 minutes until 12 now and, therefore, it seems proper that we adjourn and take up the next witness in the afternoon.

We will adjourn until 2:30 p.m.

I want to say this now: Tomorrow we will have Dr. Wernher von Braun. We have agreed to hear him at 10 o'clock. Then, following the testimony of Dr. von Braun and his group who will come up here from the Redstone plant, we hope to be able to take up Mr. Sisk's resolution and hear testimony on that.

The following morning we will have the Secretary of the Air Force, Mr. Sharp, who will be here in open session, and the Under Secretary, also, at the same time. I am sure they are going to consume all morning, perhaps even more time than that.

What I am getting to is this: We want to proceed with our hearings as rapidly as we can and we are behind at this time. My thought is this: We want to take up the authorization of NASA as soon as possible. We have a commitment to get it to the floor of the House as quickly as we can.

As soon as we can do so, we want to—unless there is objection—to follow the same procedure we followed last year, which is to give the subcommittees an opportunity to operate. In doing so, we would turn over portions of the NASA program to subcommittees 1, 2, 3, and 4, which would be Defense, Army, Navy, Air Force and NASA. They would have authority to go ahead and further run down and tie down these problems that are presented. There are so many, they are so numerous and so difficult that the subcommittees perhaps can handle that in excellent shape.

That is the situation before us. I thought I would just make the announcement. If we need to, we can go into executive session at this time. If there is no need to do so, we will just let the matter stand and meet here at 2:30. Do I hear any observations?

If there is no objection we will adjourn until 2:30.

(Whereupon, at 12 noon the committee adjourned to reconvene at 2:30 o'clock the same day.)

AFTERNOON SESSION

The CHAIRMAN. The committee will come to order.

Since we recessed at noon, the President of the United States announced at Denver, Colo., that he is recommending to Congress the authorization and appropriation of $113 million additional money for the 1961 fiscal year budget of NASA and $23 million additional for the current fiscal year.

Mr. HORNER. I think the $23 million mentioned in the press release, Mr. Chairman, is the supplemental appropriation which we have requested——

The CHAIRMAN. Now, tell me this, gentlemen, if you could, before we get back into the subject of the hearing: What will this do for the program?

Mr. HORNER. The $113 million is the result of our study which the President asked us to conduct on the 14th of January. It will be applied in three parts: $15 million to the F-1 engine; $8 million to the 200-K thrust liquid hydrogen engine which will ultimately be used——

The CHAIRMAN. How much is that?

Mr. HORNER. $8 million, to the 200-K thrust liquid hydrogen engine, which will be in addition to the money that is currrently in the fiscal year 1961 budget authorization proposal. This engine will be used as a component of the Saturn vehicle in its later versions and the balance of $90 million will be applied to the acceleration of the Saturn development program.

The CHAIRMAN. So it is mostly Saturn?

Mr. HORNER. Actually of the 113 million, there is a total of 98 which is applied to the Saturn, or components of the Saturn.

The $8 million being an engine for a later version of Saturn.

The CHAIRMAN. All of this was recommended by the study that you refer to?

Mr. HORNER. Yes, sir.

The CHAIRMAN. Now, the $23 million was not recommended by the study, was it?

Mr. HORNER. No, sir.

The CHAIRMAN. But that comes in the overall effort to speed up the program?

Mr. HORNER. That is right. That amount was submitted to the Congress as a request for supplemental appropriation within the authorization that the Congress provided us last year.

The CHAIRMAN. That will pretty much complete the authorization then, won't it?

Mr. HORNER. It leaves about $7 million, I believe, authorized, but not appropriated, largely in the "Salaries and expenses account."

The CHAIRMAN. Now, does that give you the money that you need? Of course, that question should be directed to Dr. Glennan.

Mr. HORNER. Yes, sir. The intent of this study was to provide an acceleration to the superbooster program which is compatible with the needs of the program. Of course, the bulk of the money is applied to Saturn as we have mentioned previously. As you know, Dr. von Braun is scheduled to be here and will discuss the Saturn program in some detail so the committee can judge for itself.

The CHAIRMAN. We will ask him tomorrow if this money will be sufficient for the program.

Mr. HORNER. I am sure that he will be expecting that question.

The CHAIRMAN. Now, may I say this before we get into the hearings, if there are sufficient members present when we finish the hearings this afternoon, I would like to ask the committee to go into executive session to consider a matter that I think we ought to push diligently. That is the one that you have already approved creating a panel of scientists as advisers to the committee. We approved that some time ago.

Since then, Dr. Sheldon has been working to arrange a meeting at an early date of this panel of scientists in Washington, with an agenda for a program in a meeting with the committee. He has done a fine job, I think, in working out an agenda and he has been assisted by Dr. Edward Wenk, Jr., senior specialist on science and technology, from the Library of Congress, who had been loaned to us by the Library of Congress to help on this work. Dr. Wenk will come here, provided we have enough members to take up that matter in executive session, and go over the program.

Mr. SISK. Mr. Chairman, if you will yield for a minute, I appreciate the urgency of this and I think it is fine. The only thing is, because of a previous commitment I have a later meeting this afternoon. I wondered if it is something we might put over.

The CHAIRMAN. We can't do that on account of Dr. von Braun coming in the morning. Tomorrow afternoon, we wanted to take up your resolution. We have a crowded schedule. While I am talking about the crowded schedule, I want to mention again the subcommittee on the 1961 authorization for NASA. I can tell you this, it is going to require us to burn the midnight oil, get up early in the morning to handle this program and get it out as it should be gotten out, as quickly as possible.

We have a commitment to report at an early date a bill covering NASA authorizations. We want to get it out. And while I am on that subject, I would like to ask you gentlemen this. The committee tells me the NASA backup books have not arrived yet on the authorization bill. Are they available so that the staff could look them over?

Mr. HORNER. Almost all of the backup information is available, Mr. Chairman, and, of course, the augmentation indicated by the President's announcement this morning will be submitted within the next few days.

The CHAIRMAN. So you have the backup books ready for the staff to look over or will have in the next few days?

Mr. HORNER. Yes, sir.

The CHAIRMAN. As you know, the committee can't very well take up something they haven't even seen the backup books on.

I think that covers what I had to say.

Mr. SISK. In view of the comment with reference to this, I might ask a question on where is the money. It is the money for the present proposed Saturn contract on which many of these companies are now preparing their bids with reference to the hydrogen engine. Is that in the 1960 money? Is that coming out of that 1960 money or is that a part of the new money being requested?

Mr. HORNER. There is money in the 1960 budget that has already been appropriated to initiate the Saturn upper stage which is currently being initiated. The augmentation we are proposing is for new obligating authority in fiscal year 1961 which is in addition to the obligating authority that we have requested within the $802 million.

Mr. SISK. Thank you, Mr. Chairman.

The CHAIRMAN. Any further questions on that?

Before we go into the testimony of Mr. Harold B. Finger, is there anything you could give us on the report that we get regarding the new Russian missile in the Pacific?

Mr. HORNER. I have no further information, Mr. Chairman, I would care to give in open session. I am sure you would want to get more specific information from the same source we get our intelligence information from.

The CHAIRMAN. We have Harold B. Finger on propulsion technology, and research.

You have been sworn, Mr. Finger?

Mr. FINGER. Yes, sir.

The CHAIRMAN. You have a prepared statement which the committee will be glad to receive from you. As I understand it, you would rather brief your statement and have the entire statement filed in the record.

Mr. FINGER. That is correct, Mr. Chairman.

The CHAIRMAN. If there is no objection, we will file the statement of Mr. Harold B. Finger in the record and then he will brief his statement for the committee.

(The statement referred to is as follows:)

STATEMENT OF HAROLD B. FINGER ON PROPULSION TECHNOLOGY AND RESEARCH

Mr. Chairman, members of the committee, it is the purpose of our propulsion technology programs to develop existing engine concepts for application to specific missions and to improve existing engine systems so that we may be able to deliver higher payloads over longer distances with these engines. In addition, it is a major objective of our propulsion technology program to evaluate the feasibility of the exciting new propulsion concepts that have been proposed. Not all of these new concepts will necessarily lead to useful applications; however, the potential of many of these concepts is sufficiently great that they must not be neglected.

When I speak of existing engine concepts, I am thinking of the chemical rocket engine systems such as the one shown schematically on the first chart (fig. 44). As you all know, in this system a fuel such as kerosene in our conventional engines and hydrogen in our higher performance engines, and an oxidant such as oxygen in our present-day engines, and possibly fluorine in advanced systems, are mixed together and burned in a combustion chamber. The resulting high-temperature gas is accelerated through a jet nozzle producing the thrust that propels the rocket. The specific impulse of the amount of thrust that can be developed for each pound of gas flowing out the jet nozzle is limited by the chemical energy contained within the fuels used in the chemical rocket. For the best chemical rockets, specific impulses up to approximately 450 pounds of thrust per pound of gas flowing through the jet nozzle are possible.

As examples of our propulsion work aimed at the development of particular engines that are required for our space missions, we are developing a million-and-a-half-pound thrust, single-chamber engine which will be used in vehicles following the Saturn vehicle. For example, this engine is intended for use in vehicles such as the NOVA concept. We are also developing a 200,000-pound-thrust hydrogen-oxygen engine which is intended for use in the Saturn development program.

In addition to development of specific chemical rocket engines to be applied in our space missions, we are doing work, as illustrated on the next chart (fig. 45), to improve the performance of our chemical rockets. For example, in our solid rocket research and development program we are studying ways of reducing the empty weight of the rocket, which is made up of such items as the pressure shell and the jet nozzle. Since these stages will generally be used in the last stage of the multistage rocket, every pound that we shave off the empty weight of the rocket permits an extra pound to be installed as payload. It has been found that we can operate the solid propellent space rockets with a low internal pressure so that we may be able to use lightweight structures and lightweight materials in the castings. For example, we may be able to use thin Fiberglas casings rather than heavy steel casings. In addition, we are studying methods of cooling rocket jet nozzles and of using suitable heat-resistant materials so that the jet nozzle, which constitutes a major portion of the empty weight of solid propellent rockets, may be made significantly lighter.

In addition to this work aimed at reducing the empty weight of our solid propellent space rockets, research and development work is being done on storable liquid propellent rockets. Methods of accurately controlling the path of our space missions using these storable propellent and solid propellent rockets are being studied. These two classes of propellents are particularly well suited for long-range missions because they are stable at room temperature conditions and will not boil off excessively during the long interplanetary trips.

In addition to our work on chemical rocket systems, a large part of our propulsion technology program is aimed at evaluating the feasibility and at developing advanced propulsion. One such concept that is of particular interest to us is the nuclear heat transfer rocket, the engine of which is shown on the next chart (fig. 46). In this system, liquid hydrogen is pumped out of the tank and is used to cool the jet nozzle. This hydrogen is then passed through a nuclear reactor where it is heated to high temperature. The hydrogen is then accelerated through the jet nozzle producing the rocket thrust. In this system the specific impulse is no longer limited by the chemical energy available within the hydrogen itself. The hydrogen is heated in the reactor by passing it over fuel elements. These fuel elements are made of uranium enclosed within a structural material capable of withstanding high temperature. The fission of the uranium produces heat which is transferred to the flowing hydrogen. The specific impulse is limited, in this case, by the maximum temperature at which we can operate the fuel elements. It may be possible to obtain 1,000 pounds of thrust per pound of hydrogen flowing through the jet nozzle for such a solid fuel element nuclear rocket system. It is essential that if this system is to be superior to our chemical rocket systems, we must be able to heat the hydrogen to high temperature and we must be able to build small, lightweight reactors.

Another new concept for space propulsion that is being extensively studied in industry, as well as within NASA, is the electric rocket shown on the next chart (fig. 47). Essentially, the electric rocket consists of a system for generating electric power. This electric power is then supplied to a thrust generator. In all of the electric rocket systems, the weight of the electric generator equipment is far more than the thrust that can be produced by the thrust generator. In fact, present estimates indicate that the thrust may be as low as one ten-thousandths of the weight of the rocket.

Because the thrust is lower than the weight, the electric rocket cannot be used to boost a payload from the surface of the Earth. It can only be used after it has been established in an Earth orbit by either the chemical rocket or the nuclear rocket system. As I will indicate later, there are many different kinds of electric generating systems. There are also many different kinds of thrust generators. In this diagram, I have indicated several ion accelerators, of the type being studied at our Lewis Research Center, clustered to give the desired thrust. A photograph of one of these ion-thrust generators operating in a vacuum tank test facility at Lewis Research Center is shown on the next chart (fig. 48).

Ions, which are atoms with electrons removed, are produced in the ion source. These positively charged ions are accelerated through an electrical accelerator producing the blue ion beam. The electron gun discharges electrons into the ion stream so that the jet will be neutralized and will not build up a positive charge in this region causing the jet to be slowed down.

Our interest in both the nuclear rocket and the electric rocket stems from the capability of these advanced concepts to perform missions, when combined with the chemical rockets, that are beyond the capability of the largest all-chemical rockets that are being studied. The important characteristic of the nuclear and electric rockets is that they are capable of giving much higher specific impulses than the chemical systems. This high impulse or high thrust per pound of propellant flow reduces the total amount of propellant that is required to accomplish a given mission. With this lower propellant weight, we have more room available in a certain gross weight vehicle for engine, structure, and payload.

When we insert estimated weights for the nuclear rocket and electric rocket engine and structure, the payload capabilities shown in figure 49 indicate the marked potential advantages of using nuclear rockets and electric rockets over our chemical rocket systems for space propulsion. In this case, I have assumed that the gross weight of each of these rockets established in an Earth orbit is 150,000 pounds. This 150,000-pound rocket would be either a chemical, a nuclear, or an electric rocket. It leaves the Earth orbit and goes out to a Mars orbit round trip. The payload that returns to an Earth orbit is shown on the chart. The nuclear and electric rockets are comparable with each other and both are far above the value shown for the chemical rocket. In addition to the payload advantage, the nuclear and electric rockets may do this job with one stage while the chemical rocket will require at least three and probably four stages.

Up to this point I have indicated the types of systems in which we are interested and the potential performance of these systems. I would like now to discuss some of our development work on these systems. I should also emphasize that the research and development program that we are supporting in industry in our propulsion program is backed up by fundamental research at our research centers on materials studies, flow systems, combustion studies, etc. These fundamental research programs are aimed at supplying industry with detailed information needed in design of advanced systems and components.

As you all know, the NASA is working with the Atomic Energy Commission on a research and development program on nuclear rockets. The broad objectives of this program are shown in figure 50. The AEC, through its Los Alamos Scientific Laboratory, has prime responsibility for the evaluation of reactor feasibility which will be achieved with the demonstration of breadboard engine operation. The broadboard engine is a system which contains all of the principal components of the nuclear rocket, but is not necessarily packaged so as to resemble an operational engine system. In addition, the components are not necessarily flight weight components. In support of the AEC prorgam, the NASA is supplying certain nonnuclear components and the hydrogen propellant that is required for the program. With the completion of the breadboard engine demonstration, prime responsibility for the following steps of the program transfer to NASA with the AEC supplying reactor support. The NASA is responsible for developing a flight test engine, the flight test vehicle system, and for application of the nuclear rocket to those missions for which it may be particularly well suited.

As you all know, the first step in achieving the breadboard engine goal was accomplished just this past summer when the Los Alamos Scientific Laboratory tested the research reactor called the KIWI-A at the AEC Nevada test site. This reactor is shown on the next chart (fig. 51) on its railroad test car. The reactor was moved by remote control from the assembly building to the test cell and after testing it was remotely moved back to be disassembled. The reactor was fired upward in order to simplify the test installation. The jet nozzle which is shown here was cooled by water for this test. The propellant used was gaseous hydrogen supplied from a gas storage tank farm. The gaseous hydrogen propellant and the water cooled nozzle were used in order to simplify the test facility and the text operations so that the required reactor information could be most easily obtained. The follow-on steps to this KIWI-A reactor test will be aimed at a logical development of the breadboard engine including all of the principal components of the nuclear rocket shown on the next chart (fig. 52). The breadboard engine will include a reactor, propellant tank, liquid hydrogen turbopump, a liquid hydrogen cooled jet nozzle, and an automatic controls system that will simultaneously control the reactor and all of the flow system. These major components will not necessarily be packaged or positioned as would be required of a flight system such as the one indicated here.

As I indicated earlier, the NASA is supporting the breadboard engine development by developing certain nonnuclear components. The NASA is developing, or will develop, all of these nonnuclear components shown on the chart. We are now funding the development of a suitable turbopump. This industrial development of the turbopump is backed up by a research program at our Lewis Research Center aimed at improving pump design methods and supplying data needed to improve turbopump performance. In addition, we are, during this fiscal year, initiating the development of a liquid hydrogen cooled jet nozzle to be used in the reactor test program.

This integrated AEC–NASA program will continue through the development of the flight test engine, development and operation of the flight test vehicle, and finally, the application of nuclear rockets to useful missions. Design studies are now underway at NASA and will be initiated in private industry to evaluate the best methods of flight testing nuclear rocket systems.

One possible flight test configuration is shown in the next chart (fig. 53). In this case, the two-stage Saturn vehicle is used to boost a nuclear rocket stage into an Earth orbit. After the stage is in orbit it could be started up and tested under conditions that simulate the conditions that would be encountered in accomplishing a useful, long-range mission. Such an orbital nuclear rocket stage could be a low thrust, low reactor power system. For example, on the Saturn vehicle, a reactor power of 200 megawatts would be sufficient. However, if we are to apply nuclear rockets as second stages rather than orbital stages, and if we are to apply them for useful missions to larger vehicles than the Saturn, then significantly higher powers will be required.

Another important area in our program is aimed at the development of systems to generate electrical power both for auxiliary power and propulsive power. The auxiliary power is needed in every satellite and space probe for collection and transmission of the data that are required. In addition, auxiliary power is needed for our applied satellites. I have already indicated the possible use of electric power for electrical propulsion.

Some of the many different types of electric power generating systems are shown on the next chart (fig. 54). In general, a power source supplies energy to a system for converting that input energy to electric power output. The power source may be a chemical system, a solar system, or a nuclear system. The chemical system could be a battery or it could be some kind of a chemical combustion system. In addition, the heat of the Sun may be used or the fission of uranium may be used to produce heat. There are also many different kinds of power-conversion equipment. Some of them, indicated here, are the turbogenerator system which directly converts from the input energy to the electric power. For example, the thermionic emitter is one of these direct conversion systems. In this system the cathode is heated by one of the power sources. This heat drives electrons off the cathode surface and forces them to flow to the cold plate (anode), producing an electric current. The thermoelectric system is the one that was used in the small SNAP–3 power generator which was demonstrated by the President and the Atomic Energy Commission a year ago. Any one of these power sources could be combined with any one of these power converter systems to produce useful electrical power output.

We are now initiating the development of one system using solar power and another one using nuclear power. The solar power system is a 3-kilowatt system and is called Sunflower-1. Proposals are now being invited from private industry for the development of that system. One possible configuration is shown on the next chart (fig. 55). This is a solar turboelectric power unit. In this case, the Sun's rays are collected by this large area collector or mirror. The rays are focused on a boiler in which some working fluid and very likely a liquid metal, is boiled. This vaporized liquid metal is then used to drive a turbogenerator which generates electrical power. It is necessary to package the collector during launch periods and then to erect it once we are established in the space environment. A 30-foot-diameter collector is required to generate 3 kilowatts of electric power. At 30 kilowatts of electric power a collector of upwards of 60-foot diameter is required. In order to generate power most efficiently, the collector must be oriented very accurately so that it faces the Sun. This is accomplished by this "Sun seeker" and attitude-control system. In addition, a heat-storage unit must be supplied in order to permit the system to continue generating electric power when the system is on the dark side of an Earth orbit. The Sunflower-1 system will be useful for supplying power to payloads that will be used in our Centaur and Saturn vehicle program.

For generation of large amounts of electric power, nuclear reactor power sources must be used to achieve lightweight systems. For example, nuclear power sources will be required to supply the power required for the high payload electric rockets that I discussed earlier. A schematic drawing of a nuclear electric rocket system is shown on the next chart (fig. 56). In this case, heat from this nuclear reactor is used to boil a liquid metal. The boiled metal is then used to drive a turbine which drives an electric generator and all the pumps needed in the system. The electric power may then be transmitted to an electric accelerator system such as the ion accelerator I described earlier, or it may be used as auxiliary power. Because the system is not 100 percent efficient (in general, a turbogenerator system will have an efficiency up to approximately 20 percent), at least 80 percent of the heat supplied by the power source must be rejected to the surrounding environment. In our ground power stations large condenser coils are set up in flowing water to reject this waste heat. In the space system, we must use a large radiator which will reject the waste heat out to the space environment. For large powers, these radiators may become as large as football fields and methods of packaging them during the launch period and then erecting them in orbit must be developed.

The NASA is now evaluating proposals for the development of a nuclear electric power generating system similar to this one shown here. This system will generate 30 electric kilowatts and is designated as the SNAP–8 system. This project is being conducted jointly with the Atomic Energy Commission. The AEC is developing the reactor for the system and the NASA will develop the equipment to convert from reactor heat power to electrical power output. The SNAP–8 system is the first electric generating system that will be capable of supplying both auxiliary power and useful propulsive power.

On the final chart (fig. 57), I have summarized the budget requests in the area of propulsion technology. For solid rockets, we are requesting $2.8 million during fiscal year 1961. Liquid rockets, which includes the development of the million and a half pound engine and the 200,000-pound hydrogen-oxygen engine, as well as some advanced technology, we are requesting $40 million. For nuclear systems technology, including both the nuclear electric generating systems and the nuclear rocket, we are requesting $10 million. For space power technology, including the development work being done on electric thrust generators and on nonnuclear electric power generating systems such as the Sunflower–1 system, we are requesting $8 million.

(NOTE.—The 14 charts cited in Mr. Finger's prepared statement will be found in his oral presentation, which follows:)

TESTIMONY OF HAROLD B. FINGER, CHIEF NUCLEAR ENGINES DIVISION, SPACE FLIGHT DEVELOPMENT, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. FINGER. Mr. Chairman and members of the committee, the NASA propulsion technology program is directed toward three principal objectives. First, we are trying to develop existing engine concepts for specific missions and specific applications.

Second, we are trying to improve these existing chemical rocket systems so that we can get more payload or greater range out of them; and third, we are trying to demonstrate and evaluate the feasibility of many exciting concepts that have been proposed for space missions.

I should point out that not all of these new concepts will necessarily be usefully applied, but their potential, their payload potential is so great that we must not neglect them.

Our first chart deals with chemical rocket systems, specifically liquid propellant systems (fig. 44, p. 321).

As you know, the oxygen and the fuel are mixed in a combustion chamber producing a high-temperature gas as a result of burning.

This high temperature is exhausted through the jet nozzle producing the thrust that propels the rocket.

In our conventional engines we use oxygen although we are doing research work for advanced systems where we might use fluorine as the oxidant.

In addition, in our present-day engines, we have been using kerosene and now, more and more, we are using hydrogen as the fuel.

As examples of our work in this system, as you already know, we are developing a million and a half pound thrust single-chamber engine for use in vehicles beyond the Saturn vehicle.

This engine is also intended for use in the Nova vehicle concept which Mr. Horner mentioned last week and which will be discussed later in these hearings.

We will also initiate the development of a 200,000-pound hydrogen-oxygen engine for application to upper stages in our Saturn vehicle and this engine I am sure will be discussed by Dr. von Braun, tomorrow.

In these chemical systems as you know, the specific impulse or the amount of thrust we get out of every pound of fuel flowing out of the jet nozzle in a second is limited by the chemical energy of the fuel. For the very best chemical rockets, we can expect up to 450 pounds of thrust per pound per second of flow out the jet nozzle.

As an example of our work aimed at improving these systems, I have selected the solid propellant research and development program.

This chart indicates some of our work in this area (fig. 45).

Specifically, we are trying to develop high performance solid propellent rockets. By "high performance" I mean that we are trying to develop rockets which have a very small empty weight. This empty weight is made up of such items as the propellent casing and the jet nozzle. In liquid rockets it is also made up of structural weight.

Since these rockets will generally be used in the last stage of our multistage vehicles, every pound we shave off the empty weight of the rocket permits a pound to be added to payload, or a pound to be added to propellant so we can propel the vehicle farther.

In addition to trying to reduce this weight, we are also trying to develop methods for steering these rocket motors and also for controlling the path of our vehicle. The solid and storable liquid propellent rockets are very well suited for these applications because these propellants are stable and don't boil off. We can use them for controlling our flight paths over the very long interplanetary trajectories.

With regard to lowering the empty weight of these rockets, we have found we can operate the solid propellent rockets at low internal pressure and, with a low pressure, we can go to very light weight structures in the propellent casing.

For example, we are talking about using fiber glass—thin fiber glass, plastic impregnated casings rather than steel casings.

In addition we are studying ways of cooling the jet nozzle. This is another way of reducing the weight of the jet nozzle which incidentally, in the solid propellent systems, makes up the largest part of the empty weight of the rocket.

I should also mention some work on solid propellent rockets, on analysis and research experimental work aimed at studying the applicability of these rockets to large ground boosting systems; that is, large thrust systems. This has been proposed, and we are studying the applicability of these systems to such application.

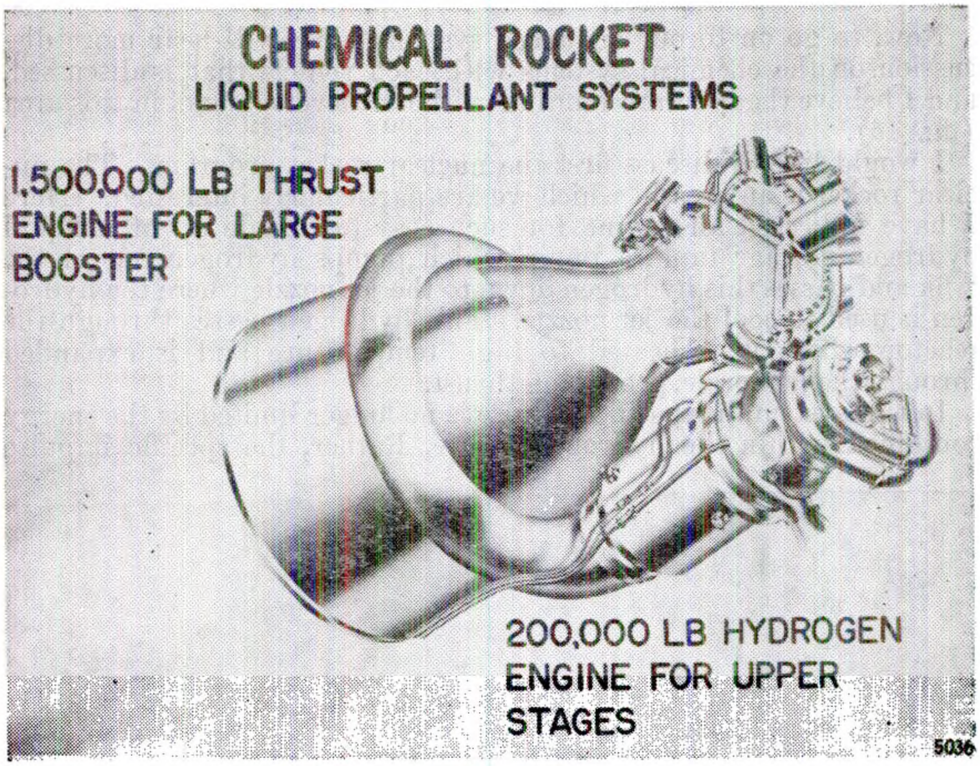

FIGURE 44

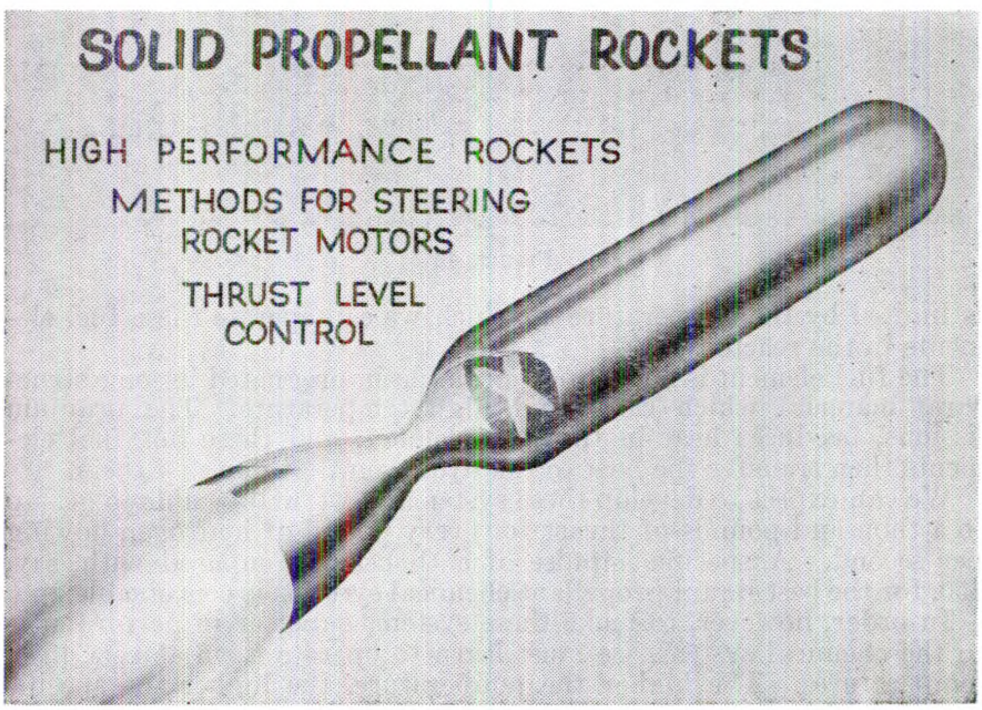

FIGURE 45

Now, to go on to our advanced systems. We will hear more discussion on the chemical systems with each vehicle that is discussed, and I believe that you are familiar with our developments in this area (fig. 46).

I would like to discuss first the nuclear rocket program. The nuclear rocket is an area in which we are particularly interested. Here I have indicated an engine for such a system made up of a liquid hydrogen storage tank, a pump which pumps hydrogen out of the tank and passes this hydrogen down to the jet nozzle where the hydrogen is used to cool the jet nozzle. This hydrogen passes through the reactor where it is heated to high temperature and is expanded through the jet nozzle, producing thrust.

In this system the specific impulse is no longer limited by the energy contained within the hydrogen itself. Rather, the specific impulse

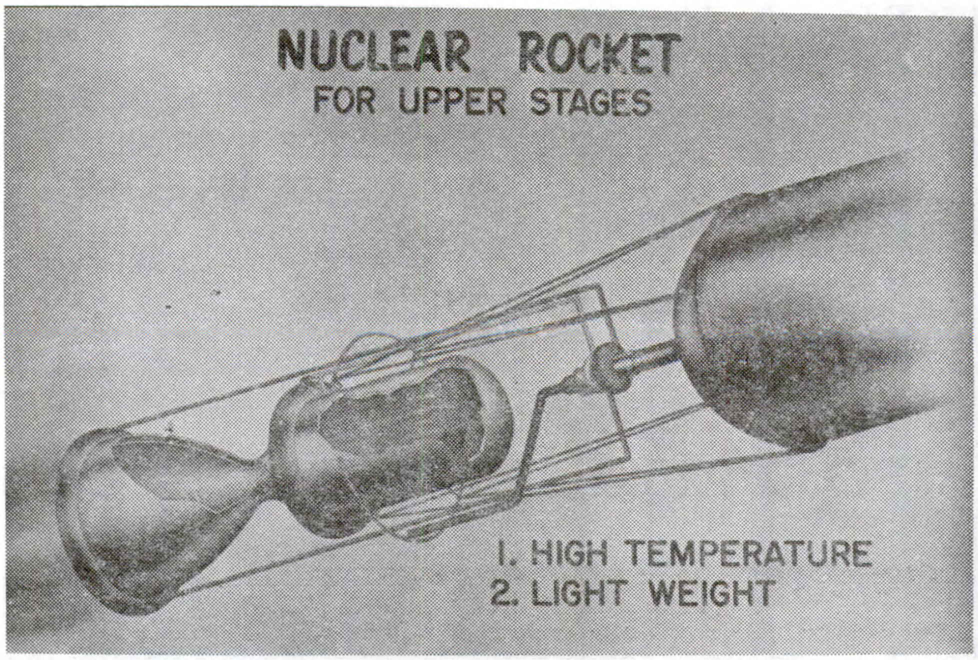

FIGURE 46

is limited by the temperature at which we can operate these fuel elements in the reactor.

The fuel element is made up of uranium impregnated in some structural material which can stand high temperature. The uranium fissions, produces heat in the fuel element, and these hot fuel elements then transfer the heat to the hydrogen that flows by them.

We can expect to develop these systems so we will be able to get up to a thousand pounds of thrust for every pound of hydrogen flowing per second. A specific impulse of a thousand compared with, say, 450, for the best liquid propellant chemical systems is conceivable.

In order, however, to make these systems superior in performance to the chemical systems we must learn to operate them at very high temperatures. The higher the temperature, the higher the specific impulse. If we want 1,000 specific impulse, we must go to extremely high temperatures.

In addition, we must learn to build reactors that are small and therefore light in weight.

Another propulsion system that has been proposed and is being worked on both in industry and NASA is the electric rocket.

Here I have indicated what this system might look like. It is complicated, and therefore a great deal of research and development must be done on this system (fig. 47).

In general it consists of a system for generating electrical power. This power is then supplied to an electric thrust generator. In all of these systems, the electric generating equipment weighs significantly more than the thrust that can be produced by the electrical accelerator.

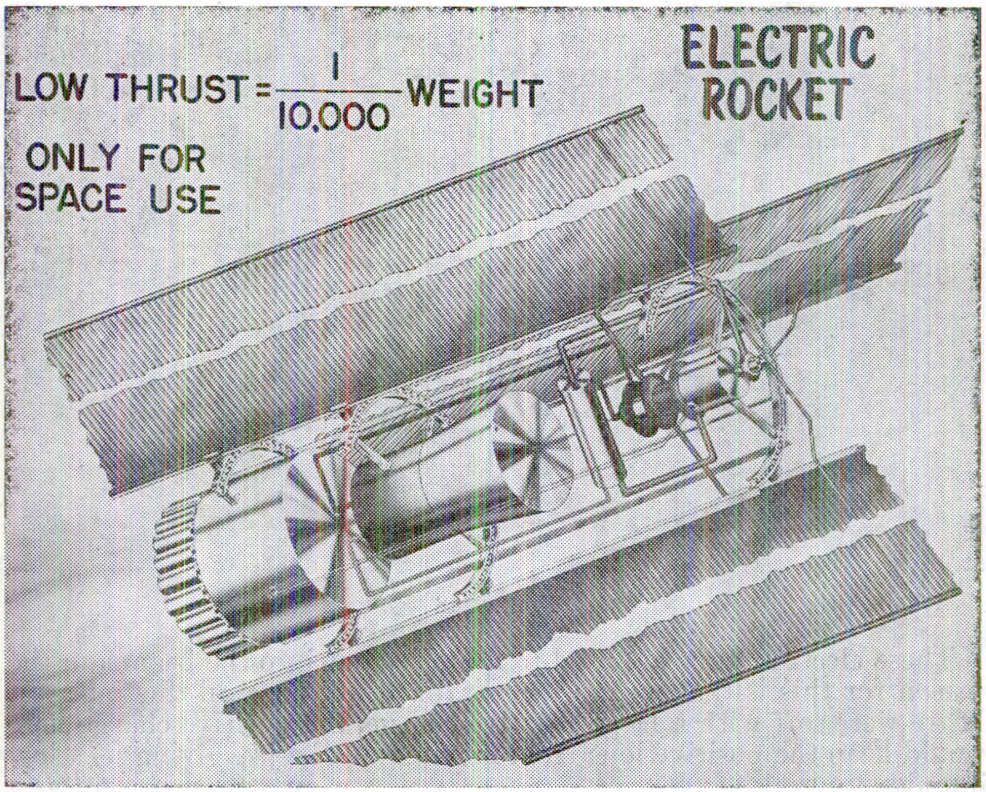

FIGURE 47

In fact, our present estimates indicate that the low thrust may be one ten-thousandths of the weight of the electric rocket. Since thrust is lower than the weight, this rocket cannot boost itself from the ground. It can be used once we are established in an orbit around the Earth. It may be raised by chemical or other means and once it is in orbit, it can use this small thrust to propel a spacecraft.

Therefore, this rocket is only applicable for space missions.

In this case, I have indicated several ion accelerators, such as those we are studying at the Lewis Research Center, clustered together to give the thrust desired. There are many kinds of electrical thrust accelerators and later I will show that there are also many kinds of electric generating systems.

On the next chart I have shown one of these electrical thrust accelerators, an ion-thrust accelerator, operating in a vacuum tank facility.

The area here is the ion source. Ions are positively charged atoms. Electrons have been driven off of the atomic structure. The ions are produced here at the ion source. They are then accelerated electrically through an electrical accelerator producing the blue ion beam (fig. 48).

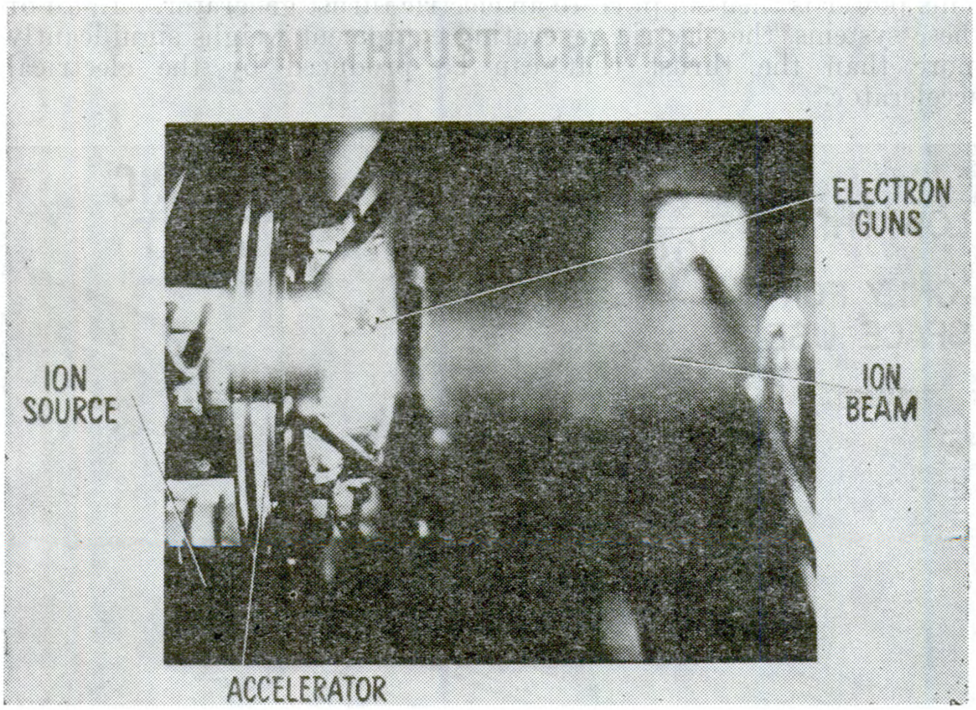

FIGURE 48

These electron guns are used to fire electrons into the beam and the reason for this is that we must neutralize the charge in this jet area. If we were left with a large positive charge, the positive charge here would keep the positive ions from moving out the jet, giving us a low impulse.

The reason we are particularly interested in both the nuclear rocket and these electrical rockets is that they give us the capability of performing missions that we can't do with even the large chemical launch vehicles we are studying.

We can get a large specific impulse out of the nuclear and electric rocket systems. In other words, we get a large amount of thrust for every pound of propellant flowing through the system, so we need a small total amount of propellant to do a specified job. This leaves us room for engine, structure, and payload (fig. 49).

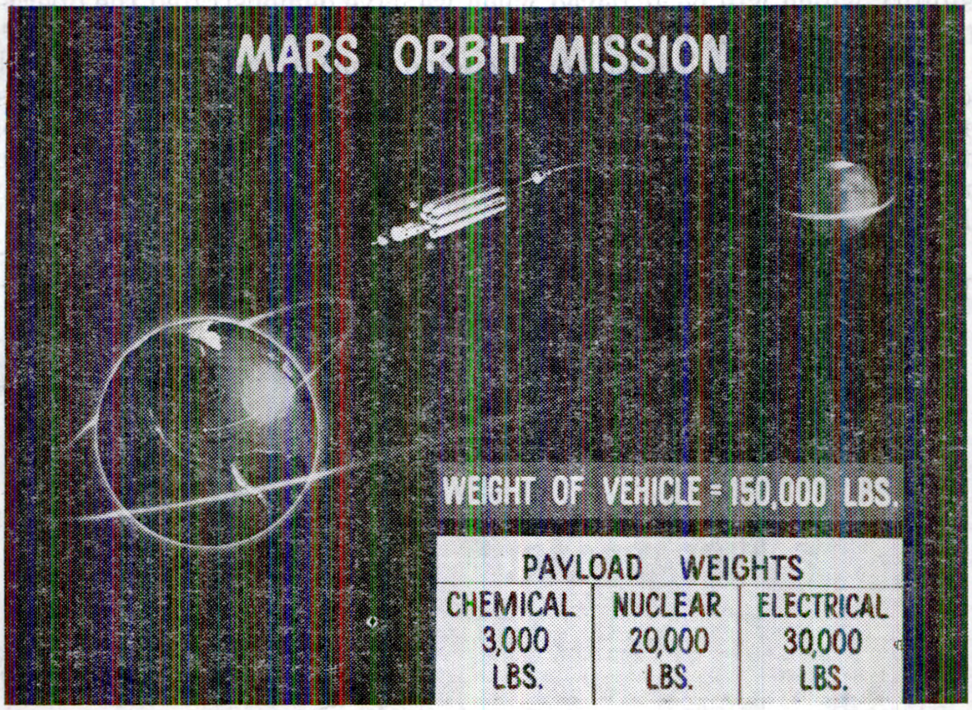

FIGURE 49

Here we have the payloads shown for these advanced systems. I have selected here, for example, a Mars orbit mission, in which case the space vehicle weighs 150,000 pounds. It may have been boosted there by chemical means or nuclear rockets combined with a chemical rocket.

This spacecraft vehicle takes off from the Earth orbit, goes out and orbits Mars and then returns to the Earth orbit.

Down here in the yellow block I have indicated payloads that can be returned to the Earth orbit using a chemical vehicle, nuclear or electrical. The nuclear and electrical can return significant payloads, 20,000 to 30,000 pounds, almost 7 to 10 times as large as the chemical rocket system.

In addition to this payload advantage, the nuclear and electrical system may be able to do this job with one stage while the chemical would be at least a three-stage vehicle, and very likely a four-stage vehicle.

Now, thus far I have discussed our proposed development program objectives. I have indicated some of the chemical rockets that we are developing. I have also indicated these advanced systems that we are working on.

Now, I would like to go into a further discussion of the development work on the nuclear and the electric systems and I will not dwell further on the chemical systems.

We are conducting a program jointly with the Atomic Energy Commission aimed at evaluating the performance capability of nuclear rockets (fig. 50, p. 326).

This chart indicates our nuclear project program goals.

The Atomic Energy Commission, through its Los Alamos Laboratory, is charged with the responsibility of investigating reactor feasibility which will be achieved when we have demonstrated the operation of a breadboard engine.

Now, this research breadboard engine is made up of the principal components of a flight nuclear rocket. However, these components may not be packaged as they would be in a true flight system. Also, they are not necessarily flight-weight components, but they do give us the interaction of all the principal components, so we determine how these engines will operate.

In developing this breadboard engine, NASA is supplying support to the Atomic Energy Commission. Specifically, we are supplying and developing certain nonnuclear components to the reactor tests and we are also supplying all the liquid hydrogen needed in the program.

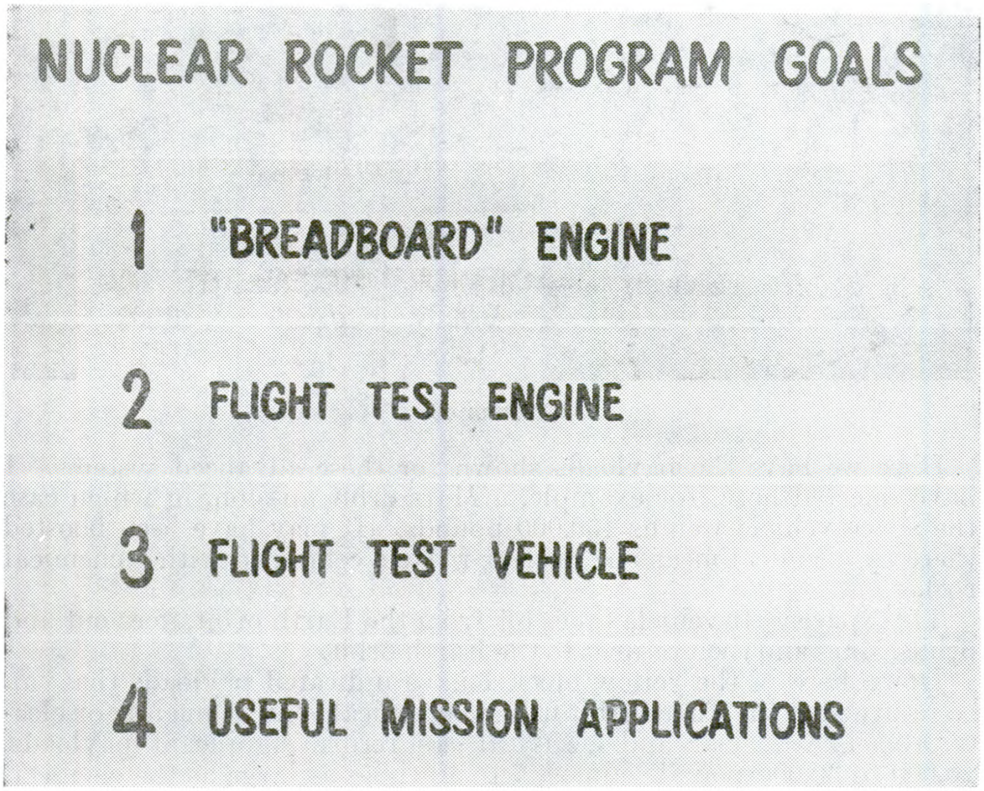

FIGURE 50

Beyond the breadboard engine development, prime responsibility for the program transfers to NASA in these following steps, with the Atomic Energy Commission supplying all of the reactor support to this program. Specifically, NASA is responsible for the development of the flight test engine, developing and operation of the flight test vehicle, and finally, application of the rockets for those applications to which it is particularly well suited.

As you all know, the first step in achieving the breadboard engine was taken just this past summer when the Los Alamos Scientific Laboratory tested the research reactor, the KIWI–A reactor.

This shows the reactor on its movable railroad test car. It was moved from the assembly building by remote control on this car. It was tested, and after testing was moved back for disassembly (fig. 51).

The reactor was fired upward in this case—this is the jet nozzle—in order to simplify the test facility.

In addition, this reactor is water cooled rather than liquid hydrogen cooled and the propellant was gaseous hydrogen rather than liquid hydrogen. The choice of water for cooling the jet nozzle and gaseous hydrogen for the propellant were dictated to keep the operations as simple as possible so we would be sure of getting the necessary reaction.

Mr. FULTON. Show us the breadboard engine.

Mr. FINGER. I don't have a picture of the breadboard.

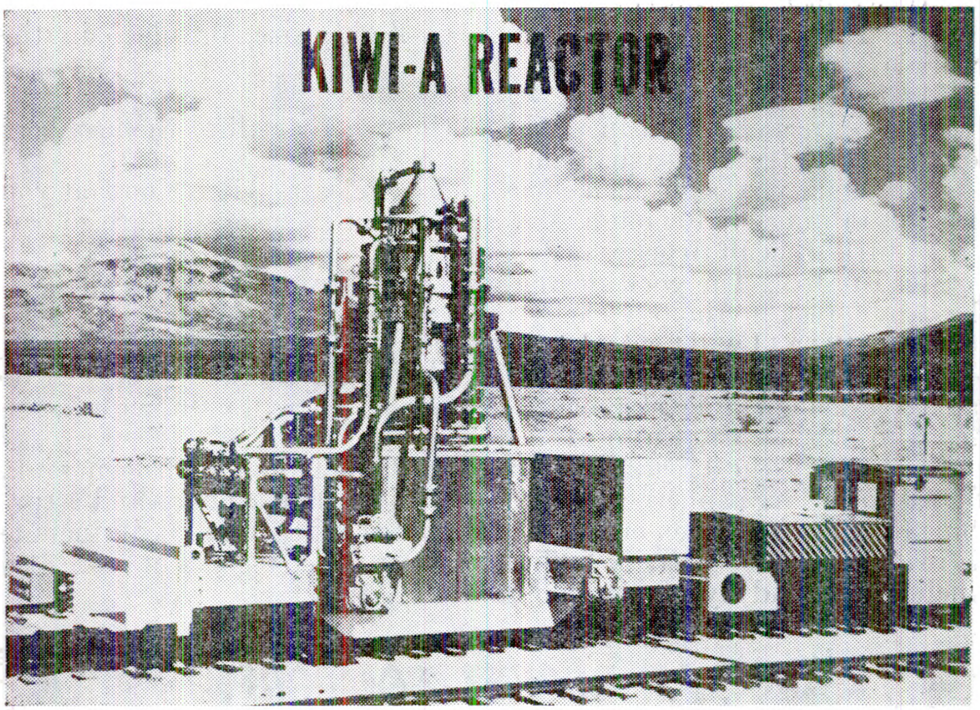

FIGURE 51

Mr. FULTON. Is the board to divide the various elements?

Mr. FINGER. "Breadboard" is really a term given to a system which tries to simulate operation of a true system, but doesn't necessarily put these in their proper relative position.

Mr. FULTON. It is the position of the various elements that are concerned in the word "breadboard" that I am trying to bring out.

Mr. FINGER. I am just not sure I understand your question.

Mr. FULTON. Go ahead.

Mr. FINGER. The KIWI–A project is aimed at developing the breadboard—I almost hesitate to use the term.

Mr. FULTON. Would you please define it?

Mr. FINGER. It is an engine having all the principal components of the engine unit, but not necessarily utilizing flight weight components or necessarily packaging these components as they would be in a flight system. It is a simulated engine.

Mr. FULTON. Go ahead.

The CHAIRMAN. Is that clear to all the members?

Mr. FULTON. Really, you could call it a prototype?

Mr. FINGER. No; a prototype is an early flight engine. A breadboard is earlier than a prototype.

The CHAIRMAN. It is a design engine?

Mr. FINGER. No; it is not even that. A prototype is a design engine.

The CHAIRMAN. A drawing board engine?

Mr. FINGER. Yes; but it includes hardware so that it is more than that.

Mr. FULTON. Actually it is a mockup then that is workable and is not just a drawing board engine with hardware on it?

Mr. FINGER. That is correct.

Mr. FULTON. It has no relation to flight, size, or place in the vehicle?

Mr. FINGER. That is correct.

The CHAIRMAN. Mr. Finger, I question whether all of the members of the committee are hearing you.

Why don't you gentlemen come on down closer? It is not that you are not talking loud enough, Mr. Finger, but the acoustics are so bad it is a little difficult to hear you.

Mr. FULTON. The good doctor wants to know whether breadboard has any Greek mythology background in the naming of it.

Mr. FINGER. I will try to determine that.

The followon steps to this KIWI–A reactor are aimed or will be aimed at a logical development program which will culminate in the mockup engine Mr. Fulton referred to.

Specifically the breadboard engine will include a hydrogen tank. It will be a large sphere actually. It will include a pump and a turbine to pump hydrogen out of the tank into the reactor; it will include a reactor—not necessarily a flight weight reactor—and it will also include a liquid hydrogen jet nozzle (fig. 52).

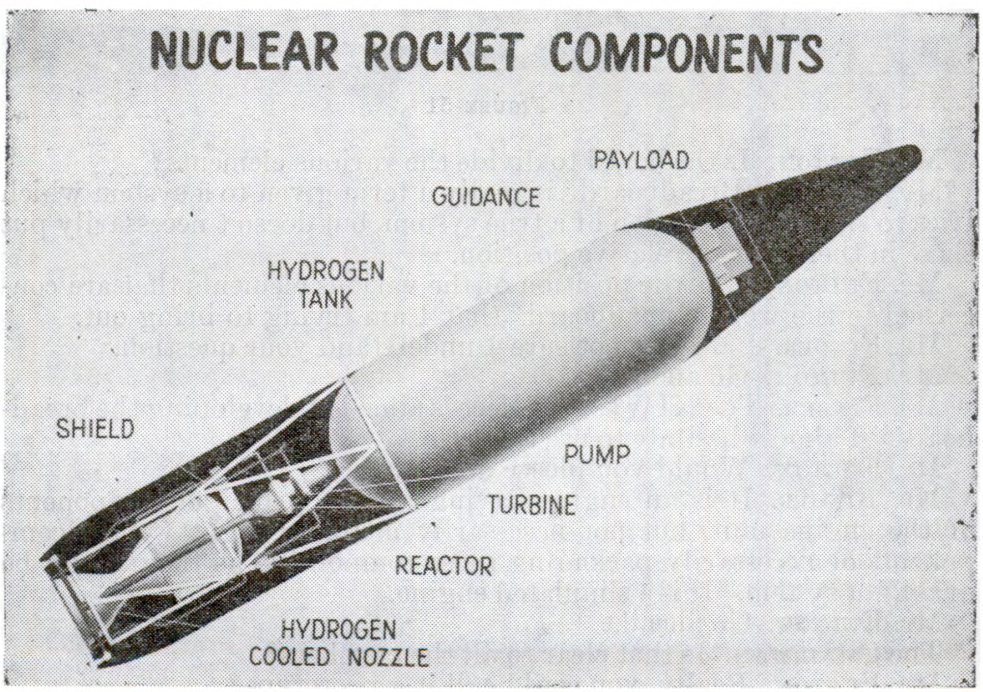

FIGURE 52

The NASA is developing all of these nonnuclear components. Specifically, we are funding the development of the pump and turbine to be used.

This year we will undertake the development of a hydrogen-cooled nozzle, also to be used in the reactor tests.

Not shown on the chart is an automatic control system which will automatically control both the reactor and the flow system. This, too, will be developed and studied by NASA.

Now, in addition to the work in the breadboard engine development we are already initiating work to study the flight test system that may be used for the nuclear rocket program.

This is one of the possible flight test vehicles we might use. In this case I have shown the two-stage Saturn vehicle which will be discussed by Dr. von Braun. This vehicle could be used to boost a nuclear stage rocket into orbit around the Earth. Once it is established in the orbit, this stage will be fired up and it will be tested under conditions that simulate the operation of a nuclear rocket on a useful space mission. This will be an orbital rocket test (fig. 53).

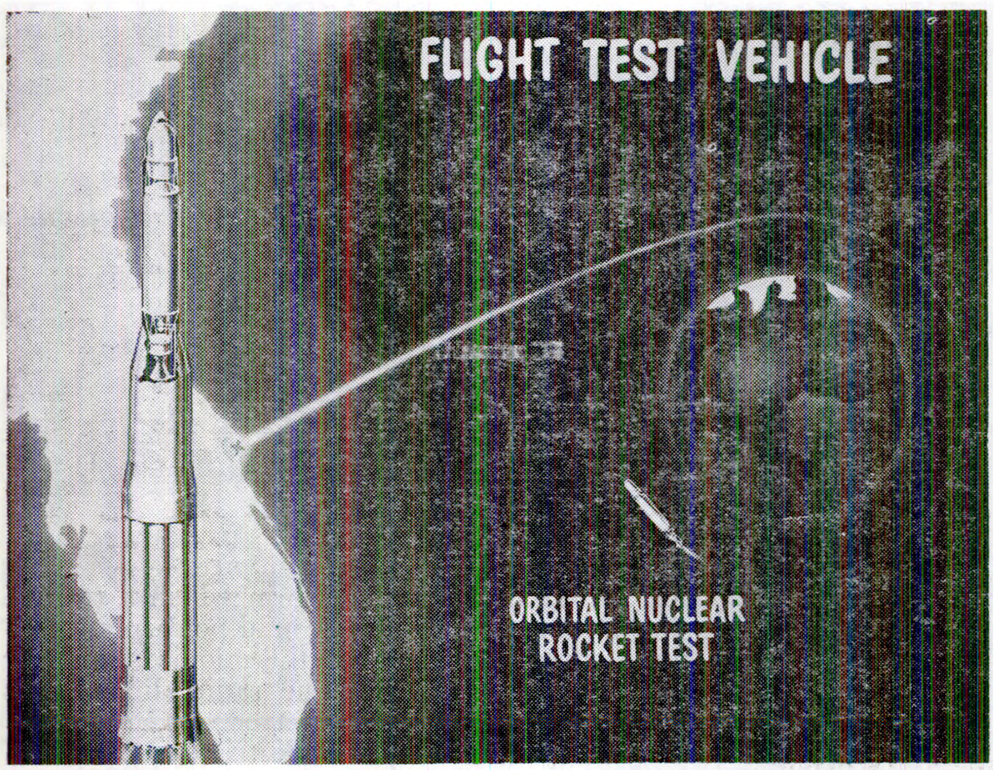

FIGURE 53

In this kind of a test, an orbital test, we can operate with low values of thrust and therefore low reactor power. For the Saturn vehicle in fact, we could get by with a reactor power of only 200 megawatts, 200 million watts of thermal power.

However, if we are to apply nuclear rockets to much larger vehicles or to second stages, then we will have to go to much higher powers than 200 megawatts.

In addition to our work on the nuclear rocket, we are studying various methods of generating electric power in space.

We want power for rocket systems and also on every one of our satellite space probe missions in order to collect data and transmit the data back to Earth. All of these electric power generating systems are made up of some kind of a power source which supplies energy—it might be heat—to systems that convert that energy to electric power output (fig. 54).

We have chemical, solar, or nuclear power sources. The chemical could be a chemical battery, or we may use the heat of the Sun, and we may use the fission of uranium.

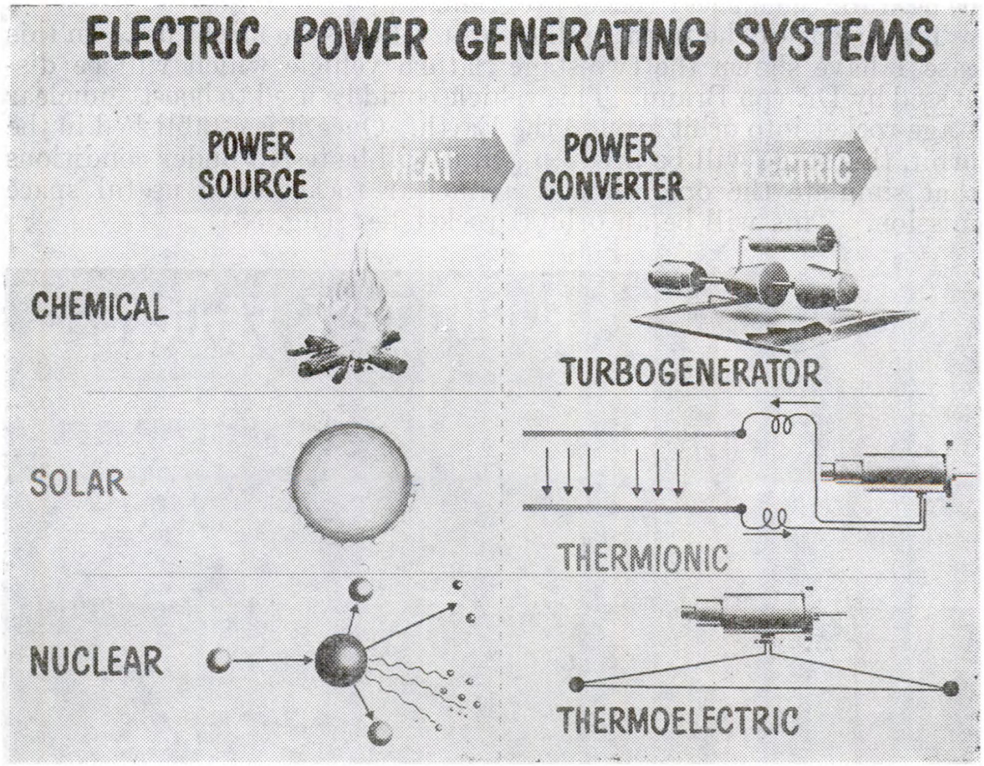

FIGURE 54

The power converter can be a turbogenerator in which a turbine runs a generator like our steam turbines in a ground powerplant.

Or, we may use direct conversion systems, thermionic system or thermoelectric systems. This is much like our radio diode tubes where the electrons are transmitted between electrodes from the hot to the cold plate. Or we may use the thermoelectric system which was the one used on the SNAP–3 power generating system demonstrated by the President and the Atomic Energy Commission about a year ago.

Any one of these power sources can be combined with any one of these power converters to generate electrical power.

Chemical systems give low power or a short duration of power, so we prefer the solar and the nuclear power for longlived systems.

We now have being initiated a solar-powered generating system and a nuclear system.

Mr. FULTON. Before you leave that, are you working on the electromagnetic system to be operated in the Van Allen radiation belt?

Mr. FINGER. Yes, there is study being done on using the motion of charged particles through such a magnetic field to produce an electrical output.

Mr. FULTON. With reference to your word "solar" there, are you working on a solar sail system? Actually, is there a program of research and development underway or is that just an indication that you could use it for electric batteries?

Mr. FINGER. This is specifically aimed at generating electrical power. The solar sail is a propulsion device and requires solar collector areas acres in size. This kind of a system has been reviewed in our NASA research centers. Specifically, our Lewis Research Center has made some analytical studies. There are also other people working on it.

Mr. FULTON. Apart from the ordinary equipment, such as generators and batteries, have you carried on any research in rockets as a separate program?

Mr. FINGER. Yes, sir.

Now, one possible configuration of the solar turboelectric system is the one that Dr. Abbott showed this morning. He had a model of it, with a collector, turbogenerator, and the Sun seeker to keep the collector oriented in space (fig. 55).

In addition, in order to supply power when this solar system goes around to the dark side of the orbit, we have a heat storage unit which would be used on the dark side. This is a boiler which supplies hot vapor to a turbogenerator.

One of the problems here is that, in order to generate electric power with a solar system, we must be able to package this collector into the nose cone of our vehicle and then erect it once we are up in space.

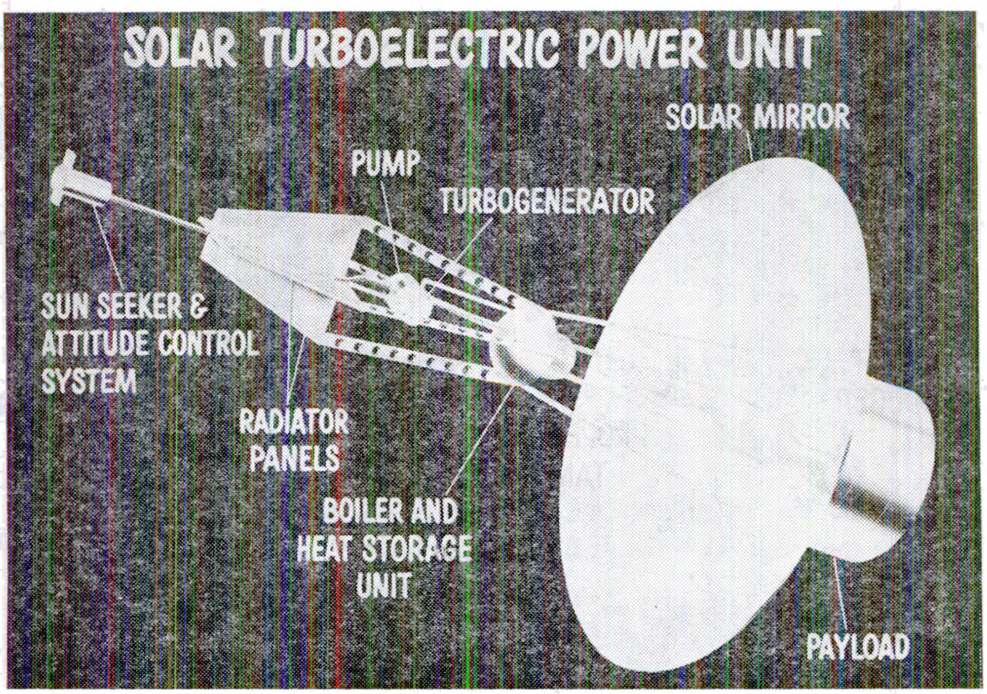

FIGURE 55

For 3 kilowatts of electric power, the diameter of this collector must be 30 feet. If you wanted to generate 30 kilowatts, then we have to go to something in excess of 60 feet in diameter.

This first solar system will be called the Sunflower–1.

If we want more power, we must go to reactor power systems, such as the one shown on this slide.

In this case the heat is supplied by a reactor which transfers the heat to a boiler and a working fluid. The working fluid, rather than being water and steam as in our ground stations, will probably be vaporized metal in these space systems. These vaporized metals drive a turbine which drives a pump and a generator in the system (fig. 56).

This generator electric output may be used for an electric thrust producer or to produce ordinary power.

Now, this system is not 100 percent efficient. In fact, it is only up to 20 percent efficient and therefore it is at least 80 percent of the heat generated in the reactor which must be rejected to space. In our ground power systems we usually reject this waste heat in a condenser set out into a flowing river.

For large powers we need a large area and the radiator may become almost as large as a football field. This radiator will have to be packaged in the launch vehicle and then erected in space.

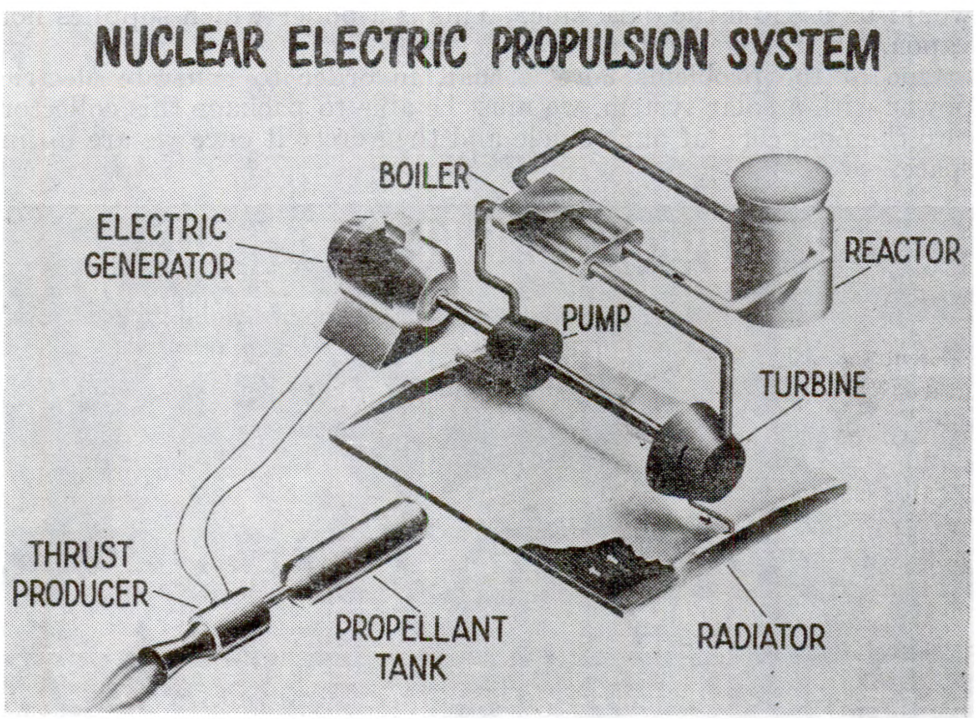

FIGURE 56

We are now initiating the development of a nuclear electric power generator capable of developing 30 kilowatts of electric power and this is called the SNAP-8. This program is being operated jointly with the Atomic Energy Commission. Specifically, the AEC is developing a reactor and the NASA is developing the conversion equipment, the equipment to convert the thermal power to the electrical power.

Mr. FULTON. Could I ask you why have you such a low rate of efficiency on the conversion of the heat into actual power? What is your trouble?

Mr. FINGER. All of these thermodynamic cycles have a maximum efficiency. There are no practical cycles of higher efficiency. You must reject waste heat due to the cycle and component inefficiency. This Carnot maximum cycle efficiency is of the order of 25 percent.

Mr. FULTON. That is just the same as it is in the atmosphere. I thought you could do better in space.

Mr. FINGER. No. This is a closed loop system that keeps working on the same fluid all the time. For example, in this primary loop if you didn't reject heat to the boiler, the temperature would continue to rise. Similarly, if you didn't reject heat through the radiator, the temperature in this loop would continue to rise to higher and higher levels. In order to maintain a stable operation, we must reject the waste heat of the thermodynamic cycle and the inefficiency of all of the components.

The CHAIRMAN. You say you use the same material over and over again?

Mr. FINGER. Yes, sir.

The CHAIRMAN. How do you recapture it then?

Mr. FINGER. It is not released at all. You will notice that this is a closed loop.

The CHAIRMAN. You release your heat and that permanently takes something away from the material, doesn't it?

Mr. FINGER. No, it just drops the temperature of the material.

The CHAIRMAN. Doesn't that take something away from it?

Mr. FINGER. It takes energy away.

The CHAIRMAN. It takes energy out of the material?

Mr. FINGER. Yes, but then the material itself, the mass of material, continues to flow.

The CHAIRMAN. How do you reenergize the material?

Mr. FINGER. Through the reactor energy which supplies heat to the boiler. The reactor keeps producing energy while we are using it here.

The CHAIRMAN. It is a nuclear reactor then?

Mr. FINGER. Yes, sir.

The CHAIRMAN. That is where you get the basic energy?

Mr. FINGER. And it keeps developing energy for a very long life, continually.

Here I have indicated fiscal years 1959, 1960, 1961. In my final chart I have indicated our budget requests for propulsion technology (fig. 57, p. 334).

For liquid propellent rocket we are requesting $40 million plus additional funds just mentioned at the start of this session. Specifically, rather than only $25 million for the million-and-a-half-pound

SPACE PROPULSION TECHNOLOGY BUDGET

	1959	1960	1961
LIQUID PROPELLANT ROCKETS	**15.98**	**30.30**	**40.00**
1500 K ENGINE	10.00	24.20	26.00
165 K LIQUID H_2-O_2 ENGINE		1.70	8.00
ADVANCED TECHNOLOGY	5.98	4.40	6.00
SOLID PROPELLANT ROCKETS	**.62**	**3.79**	**2.80**
NUCLEAR SYSTEMS TECHNOLOGY	**3.80**	**6.00**	**10.00**
NUCLEAR ROCKET	3.00	4.10	5.50
NUCLEAR ELECTRIC GENERATING SYSTEMS	.80	1.90	4.50
SPACE PROPULSION & AUXILIARY POWER UNITS		**4.82**	**8.00**
SPACE PROPULSION		1.60	2.90
AUXILIARY POWER UNITS		3.22	5.10

FIGURE 57

thrust engine, we will now have $41 million with this supplemental money, with the additional request that the President has just announced.

For the 200,000-pound liquid hydrogen-oxygen engine we will now have $16 million. For the other advanced technology work, which is the work aimed at improving the performance of our chemical rocket systems and learning more about advanced systems; $6 million.

In the solid propellent rocket program, we are requesting $2.8 million. For nuclear systems, including the nuclear rocket and the nuclear electric generating systems, we are requesting $10 million.

And finally, for space propulsion and auxiliary power units, including the electrical thrust accelerator and the nonnuclear auxiliary power units such as the Sunflower–1 solar system, we are requesting $8 million.

Thank you.

The CHAIRMAN. Thank you very much, Mr. Finger. We appreciate your very learned explanation.

Now, are there any questions from the committee?

Mr. FULTON. I have one.

The CHAIRMAN. Mr. Fulton has a question.

Mr. FULTON. Why don't you, when you are trying to get rid of your heat—you only have 20-percent efficiency—try to combine some sort of an ion emission system and use your heat and discharge to come up with a positive ion emission and that will give you a propellant? It would be useful in space, but it wouldn't be much here.

I wonder, since your efficiency is so low, why don't you use it?

Mr. FINGER. What you are suggesting is certainly feasible. We could put thermionic emitters on the radiating surface, but it would then turn out that we would lose more through added weight than what we gain in power. We could end up with a lighter system if we build a higher powered system to begin with and just lose this heat. It would be a lighter system.

Mr. FULTON. Well, isn't there some better way than just radiation from an exposed surface in space of dispelling heat in?

Mr. FINGER. This is really something we are looking for. It introduces many problems. We haven't found any other way except to just have tubes and fins connecting the tubes, giving us a hot surface radiating heat away.

Mr. FULTON. Your exposed surface likewise gets solar heat, compounding your own trouble by making exposed surfaces.

Mr. FINGER. That is correct, but we have a net heat loss because of distance from the sun, reflection, and the radiator orientation.

In other words, the sun delivers 125 watts per square foot most of which is reflected and we would radiate more than that at the temperatures at which we would operate.

Mr. FULTON. Would it be possible to have some sort of an electrode set up where you could discharge it in the form of a spark. You would just have a pink-bluish spark emitting out into the vacuum.

Why couldn't you do that?

Mr. FINGER. You really don't use energy that way unless you have something flowing with it. In other words, this spark has to heat something. It has to heat a mass in order to lose the energy.

Mr. FULTON. Doesn't the fact that the spark has a pressure cause a thrust which would then cause a loss of energy?

Mr. FINGER. Yes, sir. If it has a pressure and produces thrust then it will cause loss of energy. This will be the energy of the propellent moving out.

Mr. FULTON. That is all.

The CHAIRMAN. Any further questions? Mr. Hechler?

Mr. HECHLER. Mr. Chairman, on behalf of my eminent colleague, Mr. Fulton, and myself I would like to ask this question: Have you ever done any research on the possible use of derivatives of coal as a propellant?

Mr. FINGER. If you are thinking of hydrocarbons and so on——

Mr. FULTON. Preferably Pennsylvania and West Virginia coal.

Mr. HECHLER. I mean this question quite seriously.

Mr. FINGER. For the systems we are talking about, they wouldn't have high enough energy per pound. We are looking for very high energy systems or low molecular weight systems. For example, in the nuclear rocket we want hydrogen because it is the lowest molecular weight fluid and gives us a high specific impulse.

The CHAIRMAN. Any further questions? Mr. Roush?

Mr. ROUSH. I was wondering if, in your original request for funds the additional amounts the President has authorized for your F–1 engine and your liquid hydrogen engine were included.

Mr. FINGER. Originally?

Mr. ROUSH. Originally.

Mr. FINGER. Yes: I believe they were; on the F–1 engine, I believe so. I am not sure of the hydrogen-oxygen engine.

Mr. HORNER. The numbers shown on the chart did not include the augmentation of the budget announced by the President.

Mr. ROUSH. I realize that and that is the reason for my question. I was wondering whether, when you made your original request for funds, you limited it to the figures I saw on the chart or whether you included that which the President finally has authorized.

Mr. HORNER. This goes back to the discussion we had the day before yesterday concerning the request we had made of the Bureau of the Budget in the budget authorization process.

The answer to your question is that there was additional money in our original request upon the Bureau of the Budget, on the F-1 engine, but at that time we did not have responsibility for Saturn, so this problem wasn't treated as a whole at that time.

Mr. ROUSH. That is all.

The CHAIRMAN. Any further questions?

Mr. FULTON. I have one.

The CHAIRMAN. Mr. Fulton has a question.

Mr. FULTON. From what you say, it appears that the development of plasma propulsion is not a part of your program. Where do you fit that in?

Mr. FINGER. The example I chose was the ion accelerator and it is only one example of the many electrical thrust producers that are possible. We are investigating them all, including plasma.

Mr. FULTON. So you do have a broad program of plasma propulsion?

Mr. FINGER. Plasma propulsion is one and electrically heating a plasma is another.

Mr. FULTON. A Russian scientist has come up with the idea of using the magnetic field as a propellant. For example, you have a positive pole and a negative pole. He would change the emissions and thus get an attraction or a repellant.

Have you done anything on that the way the Russians are saying they are doing?

Mr. FINGER. Do you mean using the Earth's magnetic field?

Mr. FULTON. Yes.

Mr. FINGER. Of course, this would then require that you launch in certain directions and maintain this kind of a direction all the way.

It also means that you have a problem of worrying about the change in the magnetic field intensity, with mission location.

Mr. FULTON. Are you doing anything on that the way the Russians say they are? They are going to have a vehicle that will operate just on magnetic fields as propellants.

Mr. FINGER. No, sir. There may be something going on in our research, but I don't know of it myself.

Mr. FULTON. That is all.

The CHAIRMAN. Thank you, Mr. Finger. We appreciate your fine statement very much.

The next witness we have here is Dr. Homer E. Newell, Jr. Dr. Morris Tepper is here too, isn't he?

Mr. HORNER. Yes, sir.

The CHAIRMAN. And Richard Rhode, is he here too?

Mr. HORNER. They are all here.

The CHAIRMAN. Then they can all be sworn en masse.

Do you, and each of you, solemnly swear the testimony you are about to give on the subject under discussion by this committee is the truth, the whole truth, and nothing but the truth, so help you God?

Mr. NEWELL. I do.

Mr. TEPPER. I do.

Mr. RHODE. I do.

STATEMENT OF DR. HOMER E. NEWELL, JR., ASSISTANT DIRECTOR, SPACE SCIENCES DIVISION, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The CHAIRMAN. As members of the select committee will remember, Dr. Newell was one of our friends and supporters and advisers on the select committee. We are happy to have you again here, sir, upon this occasion.

Dr. NEWELL. Thank you, Mr. Chairman.

The CHAIRMAN. Do you have a prepared statement, Doctor, or would you just like to give us a verbal statement like Mr. Finger did?

Dr. NEWELL. I have a written text which may be distributed but I would like to talk——

The CHAIRMAN. Fine. If there is no objection, we will place Dr. Newell's statement in the record.

(The statement referred to follows:)

STATEMENT BY DR. HOMER E. NEWELL, JR., ON NASA SPACE SCIENCES PROGRAM

This presentation answers four important questions:

(1) Why must NASA do research in space?

(2) What are the objectives of space-sciences research?

(3) What is this agency's space-sciences research program?

(4) How much will this space sciences research program cost in fiscal year 1961?

Now, why must NASA do research in space? The many reasons can be summarized by the observation that such research contributes materially to each of the eight objectives enumerated by the Congress in the National Aeronautics and Space Act of 1958 and, in fact, constitutes the very first objective: the expansion of human knowledge and phenomena in the atmosphere and space. Furthermore, before man ventures into this new and hostile environment of radiation belts, solar winds, cosmic radiation, and meteorites, we must learn enough about this environment to insure man's safety.

Next, what are the NASA space-sciences research objectives? In the past, man was limited to observations which could be made at or near the surface of the earth. Now, the scientist can send his measuring equipment on sounding rockets and satellites throughout the earth's atmosphere and into space beyond the moon on lunar and planetary probes. Even those regions of the universe which instruments cannot reach have been opened up to more penetrating study; for telescopes and satellites coursing above the earth's atmosphere can observe the radiations in all of the wavelengths which arrive from the vast depths of space. Unobscured and undistorted by the earth's atmosphere, these radiations may be expected to reveal a hitherto inaccessible wealth of information about the universe.

Seizing upon the new opportunities, scientists the world over are busily investigating a wide range of phenomena. The geophysicist is using sounding rockets and earth satellites to study the properties and behavior of the earth's atmosphere, ionosphere, magnetic field, auroras, and other phenomena in space close to the earth. Cosmic rays, radiation belts, and the solar wind are under intensive investigation thousands of miles above the earth. The moon, the sun, and the stars received their due share of attention. Cosmic experiments to study gravity and relative theory, to observe physical processes and materials in the environment of space, and to probe the mysteries of life in space are in preparation. Manned flight away from the earth into the hostile environment of space is imminent. In support of this worldwide quest for knowledge and experience, hundreds of sounding rockets and more than a dozen satellites and space probes are to be fired each year for the foreseeable future.

At first glance, this broad range of activities may seem disconnected and random. But in all this activity there is one simple, coherent pattern. One clear-cut, concise set of objectives ties together and motivates all of this activity. These objectives are:

(1) To understand the nature of the control exerted by the Sun over events on the Earth;

(2) To learn the nature and origin of the universe, including the solar system; and

(3) To search for the origin of life and its presence outside the Earth.

Let us consider the first objective. The Sun affects every aspect of human activity. If its radiation were to increase or decrease by a small fraction of 1 percent, our present mode of existence would undergo marked changes. Knowledge of the Sun and its influence on the Earth has direct bearing on our daily activity and our very existence.

Actually, we know that the total solar energy output does not, and should not be expected to, change appreciably. It is for this reason that the solar energy reaching the Earth's surface per square centimeter per minute is called the solar constant. It is this energy in the visible and infrared regions of the spectrum which furnishes the driving power for our winds, storms, and the other manifestations of weather.

But one small part of the Sun's energy does undergo important fluctuations. This part comprises the gusts of X-rays, ultraviolet light, and charged particles which are emitted from the Sun at times of unusual surface turbulence. The radiations travel at the speed of light, reaching the Earth some 8 minutes after leaving the Sun. They are absorbed in the higher levels of the atmosphere, well above our "weather sphere," and produce heating, chemical reactions, and electrical charging of the very thin area. It may be said that they give rise to a sort of upper atmospheric weather whose storms produce heating, chemical reactions, and radio blackouts. The charged solar particles travel at the more modest speed of some 1,000 miles per second, reaching the earth in 1 or 2 days. Upon arrival, they are seized by the Earth's magnetic field and funneled into the polar latitudes, producing magnetic field storms, modifying the radiation belts, augmenting the auroral displays, and producing longer lived radio and telephonic communications breakdowns.

One of the most exciting chapters in the history of Sun-Earth relationships concerns the discovery by James Van Allen of the radiation belts which bear his name. These belts consist of charged particles which are trapped and guided by magnetic lines of force many thousands of miles above the Earth's surface. Although the possible radiological effects of these particles are well known, their geophysical role in transferring energy from the Sun to the Earth, accompanied by heating, auroras, and communications disturbances, may well prove to be more significant.

Experimental evidence obtained during 1959 shows the importance of the Van Allen belts in Sun-Earth relationships. Pioneer IV, launched in March after 5 days of unusually intense solar and auroral activity, detected a belt population some 10 times greater than that observed by Pioneer III during a period of solar quiet. In October, Explorer VI radioed back counting rates 5,000 times lower than those of Pioneer IV; but several weeks later, after some intervening solar activity, Explorer VI counter showed a return of the particle population nearly to its Pioneer IV level.

These fragmentary measurements have led to strong disagreements between the scientists themselves concerning the interpretation of the results and their geophysical importance. Consequently, it is important to measure the populations of such energetic particles over long periods of time and to many tens of thousands of miles from the Earth. One entire satellite to be launched in 1960 will be devoted to the observation of these trapped particles, using more complex detectors which will separate the particles by type and by energy. Particularly important will be the first measurement of the very low energy protons [hydrogen nuclei] having energies of less than 10,000 electron volts, which is only half the energy of the charged particles in the average home TV picture tube. Due to their potentially large population, such particles may even be dominant in producing geophysical effects.

The second approach to the measurement of charged particle activity is the use of a space probe in orbit around the Moon, to detect the clouds of solar particles as the sweep across the Moon's orbit, and, in cooperation with measurements from an Earth satellite, to measure the velocity of the solar particles. Still another approach to be followed in 1960 is the rocket launching of recoverable film, or nuclear emulsions, into the polar atmosphere during unusual solar activity, so that the responsible particles may be identified by studying their photographic tracks. Such identification is as positive as that of an individual by his fingerprints.

Such effects have a practical aspect. It has been suggested that the arrival of large numbers of solar particles may trigger major weather disturbances. For example, on February 10, 1959, a large solar flare was followed by magnetic storms, radio disturbances, a red aurora visible as far south as Washington, record high temperatures in the Arctic, and freezing snow throughout large areas of the South. Although this one event could have been coincidental, a study of weather statistics for other years has shown a definite correlation between magnetic storms and rising polar temperatures 5 days later. Tree rings and wheat price index both show an 11-year cyclic weather variation, corresponding to the sunspot activity cycle. More knowledge of such phenomena could lead to the future use of data transmitted from a distant satellite observatory to predict the arrival of a cloud of solar particles in time to light the smudge pots in Florida.

The importance of the Sun to man, and the immediate value of the knowledge of Sun-Earth relationships, is clear. But, underlying such relationships is an even more fundamental matter, that of the nature of the entire universe. Science is based on the assumption that all activity is governed by universal laws which apply both near at hand and in the remotest part of the universe. These laws form the basis for the origin and development of living matter.

All the achievements of science in the last century have been applied to the development of a remarkable description of the universe and its elementary constituents. The development begins with the neutron, proton, and electron; these are the fundamental building blocks of the universe. Neutrons and protons are bound together tightly to form the atomic nucleus. Atoms consist of electrons bound to the nucleus and circling around it at some distance, like a planetary system in miniature. Atoms combine to form molecules, which in turn are cemented together to form visible matter as we know it. Our Earth is a collection of such matter, circling around the Sun along with the eight other known planets. The Sun is one of the 100 billion stars of our disc-shaped galaxy whose cross section we know as the Milky Way. In turn, the galaxies tend to collect in huge clusters which together make up the universe. This entire hierarchy is built on three basic forces:

(1) Nuclear force, the most powerful force known, which clamps together the nucleus of the atom so tightly that 1 cubic inch of nuclei (such as is found in white dwarf stars) weights 1 billion tons.

(2) Electromagnetic forces, which bind electrons to nuclei, atoms into molecules, and molecules into gross matter. These forces are some 100 times weaker than nuclear forces.

(3) Gravitational force, which gives many weight and holds the solar system together. This force is 10^{40} times weaker than the nuclear force.

The weakness of the gravitional force can be illustrated by the smallness of an electromagnet which will lift a 1 pound iron bar, compared with the tremendous size of the earth which generates 1 pound of gravitational force on the iron.

Strangely enough, the formation and evolution of stars depend upon the interplay between the weakest and strongest of these forces. Initially, stars are probably formed out of condensation of the interstellar dust in space. Once begun, gravitational attraction accelerates the condensation process until the pressure and temperature at the center are high enough to initiate a thermonuclear reaction whose heat prevents further attraction. The rest of the star's life history depends only on its initial mass and on the relative amount of different elements present; i.e., its chemical abundance. The determination of this chemical abundance of stars is one of the most basic problems in the study of stellar evolution.

Perversely enough, the light which contains the best information on chemical abundance on stars is beyond the visible portion of the spectrum in the ultraviolet; but such wavelengths cannot penetrate the Earth's atmosphere. Thus, for the first time, man can obtain this vital information from an observatory located on an artificial or natural Earth satellite. The very first ultraviolet experiments, flown by scientists of the U.S. Navy in rockets, disclosed many sources of ultraviolet light, some at locations where there is no visible emitter of light. The nature of such ultraviolet sources is still a mystery. Their further study from an orbiting astronomical observatory is an objective of the highest scientific priority which may be expected to produce new information concerning the structure of the universe.

Just as stars may have formed by the condensation of interstellar matter, so planets may have formed by the condensation of smaller pockets of matter left over from the stellar formation. If this condensation theory is the correct one, then planets such as ours must be very commonplace in the universe. On the other hand, it is possible that our planets were born catastrophically, in a rare collision between our Sun and a second star. Since the probability of such a collision is extremely small with the existing stellar population, the catastrophic theory implies a small probability of other planets in the universe, and a correspondingly small chance of life existing outside of our solar system.

If we can determine what the temperatures of the Moon and planets were at the time of their formation, we will have gone far toward discriminating between the condensation and catastrophic theories of the origin of the solar system. For if these planets were formed by the cooling of hot masses of solar gas, they must have passed through a molten phase; while if they were formed by the condensation of relatively cool gas or dust, they may never have existed in the molten stage. This is particularly true of the Moon, which is small enough so that the heat produced by decay of radioactive uranium can be lost to its surface rapidly enough to keep the temperature below the melting point. In this respect, the Moon is of greater interest than either Mars or Venus.

Another reason for concentrating on lunar observations is the uniqueness of the Moon as the only major accessible body whose surface has been unchanged for a major portion of its life, some 3 billion years. This is due to the combined lack of mountain building and lack of erosion by air or water.

Thus, our first need is to come close enough to read nature's handwriting on the lunar surface. Television cameras in orbit about the Moon or en route to a crash landing can radio back detailed information of the lunar surface characteristics, while observations of a lunar satellite orbit can detect whether the Moon has a "raisin bread structure" of iron chunks embedded among lighter rock, which would indicate a process of accretion from small cool masses. Television reconnaissance can also be used to select a location for the first soft lunar landing, and to obtain information concerning the nature of the surface.

Once a soft landing is feasible, instruments such as the seismograph can be placed on the lunar surface to detect Moon quakes produced internally or by meteorite impact. A gravimeter can measure minute changes in the lunar shape produced by the Earth and Sun, thus measuring the elasticity and viscosity of the Moon's interior. Measurement of the surface heat flow and radioactivity would fix the temperature history of the Moon within narrow limits, thereby further defining its mode of initial formation.

Again we find a coherent pattern in our search for the origin of the universe. Experiments on the interaction between radiation and matter, on relativity theory, and on gravity, lead to an understanding of the working of the universe today. Exploration of the Moon and planets, together with observations of the Sun and the rest of the universe, will help determine how the universe began and how its stars and planets were formed. All of these diverse activities and many others contribute to the one great inspiring objective: to understand the universe of which man is such an infinitesimal, but important, part.

One of the most exciting possibilities of space research is the opportunity to search for life outside the Earth and its atmosphere. Were one to discover life forms on another planet like Mars or Venus, the philosophical implications would be tremendous. Working on the earth and in the laboratory, the bioscientist has progressed toward an understanding of how material life may have formed on Earth. Our understanding of the origin of life might make gigantic strides forward if we could discover and study, at the same time, different life forms that have developed and currently exist under different conditions.

The primitive atmospheres of Venus and Mars were doubtlessly similar to ours, but not identical with it, and the development of life on these planets, if it did occur, may be presumed to have proceeded along somewhat different lines.

The practical consequences of this research of planetary biology will require a longer time to develop because the acquisition and interpretation of the basic facts are both very difficult. But in the long run, such research can be expected to have a greater influence on human welfare than any other area of the space sciences program. Most diseases today are regarded as essentially metabolic, that is, as due to aberrations in the normal pattern of molecular interactions. It is precisely these interactions which we hope to understand better through our biological studies of other planets.

Mars and Venus are the solar planets, other than the Earth, which appear to offer the greatest probability of the development of life. The manned landings required for thorough exploration of these planets will not be possible for many years to come. Meanwhile, a progressive program of instrumented planetary explorations will be undertaken as rapidly as the necessarily sophisticated guidance, communications, and soft landing techniques become available.

At present, balloons capable of lifting heavy infrared spectroscopes to altitudes 10 to 20 miles above the Earth can acquire valuable information on Venus and Mars atmospheric constituents and on the nature of some Martian surface compounds. During 1959, an Office of Naval Research sponsored experiment discovered water vapor in the atmosphere of Venus. Early space probes will develop long-range communications techniques, measure the characteristics of the interplanetary environment, and observe those features of the planets, such as their magnetic fields and radiation belts, which may be expected to extend into space many times the planetary diameter.

During the past year, as shown in table 1, a number of important scientific discoveries have already resulted from the NASA space sciences program. With regard to the Van Allen radiation belts, it has been discovered that the extent and intensity, particularly of the outer belt, fluctuates over a very wide range. These fluctuations show a distinct correlation with activity on the Sun, and a complex structure which varies with time. As usually occurs in scientific research, such discoveries raise as many or more questions than they answer.

TABLE 1.—*Recent discoveries in space sciences*

Area	Discovery	Questions raised
Radiation belts	Outer belt extent and intensity fluctuates	Causes.
	Correlation with solar activity	Mechanism.
	Complex structure	Explanation.
Magnetic field	Deviations from expected values	Source.
	Fluctuations with time	Causes.
Upper atmosphere	Very strong wind shears at 70–100 miles	Cause.

The last of the Vanguard satellites has disclosed deviations from their expected values of the Earth's magnetic field, and some fluctuations in the measured magnetic field intensity with time. Again, such results raise questions regarding the sources and causes of these deviations and fluctuations. It should also be recalled that three successful satellites were launched during the latter half of 1959 and, since 6 months to a year is usually required for thorough data analysis, most of these data will be translated into new discoveries in 1960. If all goes as planned, Explorer VII will continue to radio back data for another 9 months.

Several important results also resulted from the NASA sounding rocket programs during 1959, table 2. Perhaps the most notable of these resulted from the Wallops Island launching of rockets carrying sodium, which was visible over a wide area of the east coast. The resultant sodium vapor clouds showed very strong wind shears at altitudes between 70 and 100 miles, and wind velocities at slightly higher altitudes in excess of 400 miles per hour. During 1959, there were also several very successful tests of new satellite instrumentation for direct measurements of the structure of the charged region of the atmosphere which is called the ionosphere.

TABLE 2.—*Scientific sounding rocket launchings, 1959*

Date	Vehicle	Experiment	Comment
August	Nike-Asp	Sodium vapor, dawn	High winds, 400-500 knots, 150 kilometers.
September	Aerobee-150 (2 rockets).	Ionosphere measurements Instrument development	Successful tests of new satellite instrumentation, new ionospheric data.
November	Nike-Asp	Sodium vapor, twilight	Powerful wind shears around 110 kilometers.

Table 3 summarizes the planned NASA rocket launchings through the end of fiscal year 1961. Since each sounding rocket is generally devoted to only one or two scientific disciplines, it is convenient to divide them according to their scientific purpose. The planned level of activity of approximately 100 sounding rockets per year is only slightly less than that reached during the peak of activity during the 18-month International Geophysical Year, when 200 sounding rockets were launched by this country.

TABLE 3.—*Sounding rockets*

	Fiscal year 1960		Fiscal year 1961			
Quarters	3	4	1	2	3	4
Atmosphere	3	4	4	4	3	3
Synoptic atmosphere	2	2	9	9	6	6
Ionosphere	2	2	2	2	2	2
Energetic particles	2	6	2	1	3	2
Magnetic field		5	1		2	3
Astronomy	6	8	8	8	6	6
Special	10	3	3	1	2	2
Total	25	30	29	25	24	24

During 1959, four scientific satellites were launched successfully (table 4). Two of these utilized the Vanguard launching vehicle, one the Thor-Able combination, and one the Juno II vehicle. These launchings completed our participation in support of the International Geophysical Year by means of scientific satellite research.

TABLE 4.—*Scientific satellites, 1959*

Name	Month	Vehicle	Experiments
Vanguard II	February	Vanguard	Cloud cover.
Explorer VI	August	Thor-Able	Radiation belt, magnetic field, micrometeorite, radio propagation, cloud cover.
Vanguard III	September	Vanguard	Magnetic field, solar X-rays.
Explorer VII	October	Juno II	Composite radiation.

During 1960, the Juno II scientific satellite program will be completed with the planned launching of four additional satellites (table 5). The first and fourth of these missions represent follow-on studies to earlier exploratory experiments. The second and third of these missions are first exploratory experiments.

TABLE 5.—*Juno II scientific satellites*

Fiscal year	Quarter	Mission
1960	3d	Radiation belt studies.
1961	1st	Ionosphere properties.
1961	2d	Gamma and cosmic rays.
1961	2d	Ionosphere beacon.

The five scientific satellites listed in table 6 are planned to be launched with the use of the Thor-Delta vehicle system over the next 2 years. The last three of these missions represent first exploratory satellite experiments in their respective scientific fields, and will be launched in orbits across the polar regions.

TABLE 6.—*Delta scientific satellites*

Fiscal year	Quarter	Mission
1961	2d	Solar spectroscopy.
1961	3d	Radiation belt studies.
1962		Atmospheric structure.
1962		Geodetic flashing light.
1962		Ionosphere topside sounder.

By fiscal year 1962, it is expected that the solid-propellant Scout satellite launching vehicle will have been developed for routine use in the scientific satellite program. This vehicle will be put to frequent use in support of our international cooperative program in space sciences (table 7). Like the Delta satellite system, most of the Scout scientific satellites will be launched in orbits over the Earth's polar regions, with the exception of those satellites primarily devoted to the astronomical program.

TABLE 7.—*Scout scientific satellites*

Fiscal year:	*Mission*
1962	International.
1962	Polar ionosphere studies.
1962	International.
1962	Polar radiation studies.
1963	International.
1963	Polar atmospheric structure.

The satellites which have been discussed thus far are all limited to maximum payload weights of the order of a few hundred pounds. Beginning in 1962, the Atlas-Agena and Thor-Agena vehicle systems will be capable of placing into orbit scientific satellites weighing 1,000 pounds and more. Two such satellites are planned to be launched into orbits over the polar regions of the Earth for various geophysical studies, as shown in table 8. A Thor-Agena satellite will be used in a relatively low altitude orbit of several hundred miles, while an Atlas Agena will be used in a highly eccentric orbit reaching many tens of thousands of miles from the Earth's surface at its highest point. The other two Agena satellites will be launched into orbits of relatively low inclination to the equator, one to correlate relations between solar activity and phenomena in the Earth's atmosphere, and the other to make astronomical observations using a highly precise stabilized astronomical platform. This last satellite will weigh several tons.

TABLE 8.—*Agena scientific satellite*

Fiscal year	Booster	Mission
1962	Thor	Polar geophysics.
1963	Atlas	Geophysical observatory.
1963	Thor	Sun-Earth relations.
1963	Atlas	Astronomical observatory

During 1959, the first U.S. space probe to escape the earth's gravitational control and go into orbit about the Sun was launched on March 3. This payload produced valuable information regarding the radiation belts, and was tracked to a distance of 407,000 miles from the Earth (table 9).

TABLE 9.—*Space probe, 1959*

Pioneer IV.
March 3.
Juno II vehicle.
Energetic particles experiment.
Communications tests.
Tracked for 82 hours to a distance of 407,000 miles.
Now in orbit about the Sun.

During the next 2 years, in addition to their use in the scientific satellite program, four Scout vehicles will be used to launch scientific probes which are intended to reach altitudes of from 5,000 to 10,000 miles. These probes are listed in table 10.

TABLE 10.—*Scout scientific probes*

Fiscal year	Quarter	Mission
1961	2d	Ionosphere structure.
1961	3d	Nuclear emulsion recovery.
1961	3d	Ionosphere structure.
1962		Outer atmosphere winds.

These comparatively short-range scout probes which fall back to the earth should be distinguished from the longer-range lunar and interplanetary probes which are scheduled during the same time period, as shown in table 11. Initially, relatively lightweight space probes will utilize the Thor and Atlas boosters with the Able and Delta upper-stage systems, for preliminary research on the interplanetary environment and for tests of long-range communications. Beginning in 1961, the heavier Atlas-Agena system will also be available for this important program. The first two Atlas-Agenas will be used for the twin purposes of measuring the interplanetary environment and for developing the necessary technology for more advanced missions. The last three of these vehicles will concentrate on the measurement of the surface properties of the moon.

TABLE 11.—*Lunar and interplanetary probes*

Fiscal year	Quarter	Vehicle	Mission
1960	3d	Thor-Able	Interplanetary environment and communications tests.
1961	1st	Atlas-Able	Lunar orbiters.
1961	2d	Atlas-Able	Lunar orbiters.
1961	2d	Delta	Interplanetary plasma and field.
1961	4th	Atlas-Agena	Interplanetary environment technological development.
1962		do	Interplanetary environment technological development.
1962		do	Lunar surface properties.
1962		do	Lunar surface properties.
1962		do	Lunar surface properties.

In fiscal year 1963, using the Atlas-based Centaur vehicle system, we will be ready for our first attempted orbit toward the planets Venus and Mars. The objectives of technological development for later, more advanced missions and an investigation of both the planetary and interplanetary environment will be served by these missions.

In summary, the space sciences program over the next several years will include approximately 100 sounding rockets per year, some 9 satellites and Scout probes, and approximately 4 deep space probes for lunar and planetary explorations (table 12). Nearly half of the requested funding in the space sciences area will be devoted to lunar and planetary explorations, while the sounding rocket program will require less than 10 percent of the total (table 13).

TABLE 12.—*Space sciences vehicle summary*

	Fiscal year 1960	Fiscal year 1961	Fiscal year 1962	Fiscal year 1963
Sounding rockets	55	102		
Scientific satellites and scout probes	[1] 4	9	9	
Lunar and planetary explorations	[2] 2	4	4	

[1] Includes 3 in orbit.
[2] Includes 1 launch failure.

TABLE 13.—*Space sciences budget summary*

[In millions of dollars]

	Fiscal year 1959	Fiscal year 1960	Fiscal year 1961
Sounding rockets	3.9	8.8	8.0
Scientific satellites	21.3	22.8	41.7
Lunar and planetary explorations	30.2	49.0	45.0
Total	55.4	80.6	94.7

The CHAIRMAN. All right, Doctor, now you may proceed in your own manner.

Dr. NEWELL. Mr. Chairman and members of the committee, this afternoon I should like to address myself to four important questions. First, why must NASA do basic research in space?

Second, what are the prime objectives of space science and research?

Third, what is the NASA program designed to meet those basic objectives, and then finally, what is the proposed cost for this program in the fiscal year 1961?

Now, as to the first question—namely, why must NASA do basic research in space—I believe I do not need to dwell long on that subject, since the Congress itself has set forth these reasons in the Space Act itself.

Basic research in space contributes to all eight of the stated objectives of the United States in space activities and in particular the very first objective; namely, the expansion of human knowledge of phenomena in the atmosphere of space.

Moreover, before we send any men out in space we must certainly know as much as we can about the hazards that are to be encountered.

With these few remarks about the first question let me proceed to the second question; namely, what are the prime objectives of space science research?

Last year in these hearings you heard us describe a rather complex series of subjects that were to be studied in space science and during the year you have seen these things written about in newspapers and spoken about in different kinds of discussions. You have heard us talk about the Earth's atmosphere and the complexity and the dynamics of the Earth's atmosphere; the pressures, the temperatures, the density, and winds; and about the Earth's ionosphere. Then you have heard us discuss the possibility of extending these studies to the planets and to the Sun. We spoke of energetic particles, the cosmic rays, auroral particles, the plasmas in space, and so on. We have spoken about the magnetic field of the Earth and the gravitational field of the Earth, and the fields of the planets and of the Sun.

We have spoken about astronomy and the new dimension that satellites and space probes give to astronomy, until I am sure you have come to wonder just what is the pattern here. Is this just a disconnected random series of investigations carried on by scientists who have no coherent objective at all?

Well, the answer is "No," this is not the case. There is a coherent pattern. There are three principal objectives which tie together all of these activities. These are:

1. The study of the Earth and Sun, and the Sun-Earth connections. Here we tie together many of these observations.

Secondly, to look for the fundamental nature of the universe and the origins of the universe, including the origin of the solar system (fig. 58).

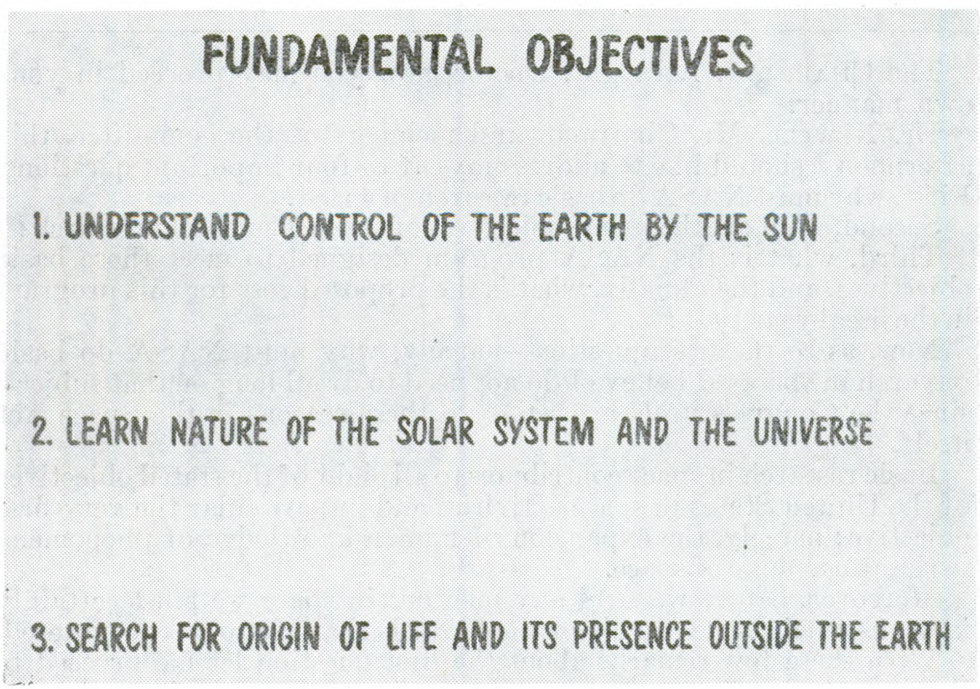

FIGURE 58

Thirdly, to search out the origins of physical life, and to look for the presence of life beyond the Earth itself.

Now, as to the understanding of the Sun-Earth relationship I should like to point out to you that the Sun has an influence in our everyday life on practically everything we do.

If in the total solar energy that comes to us daily from the Sun, a change of even a fraction of a percent were to occur, then our lives would undergo marked changes. One might say violent changes. Yet we know from experience and past observations that this radiation does not change, and has not changed to any great extent in our history and should not change for millions of years (fig. 59).

The main portions of this solar energy lies in the visible and infrared regions and it is this part of the energy that affects our weather, the growth of plants, our own growth, and provides the basic heating of the lower atmosphere.

But there is a small portion of the total solar energy that does undergo fluctuations, sometimes quite dramatic fluctuations, and these are the energies that are contained in ultraviolet light and X-ray radiations and particles that are emitted by the Sun during times of unusual activity.

The X-rays and the ultraviolet light travel from the Sun to the Earth in about 8⅓ minutes. This is the velocity of light. When

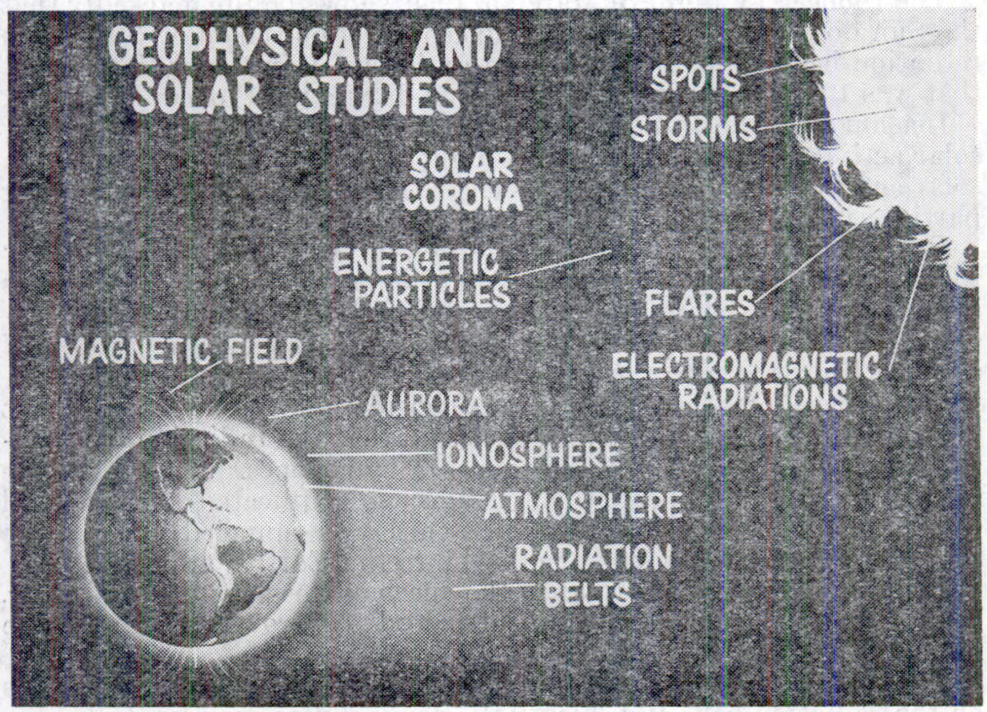

FIGURE 59

they arrive at the Earth, they are absorbed in the Earth's upper atmosphere and they give rise to heating, electrification of the upper atmosphere, affecting communications, providing the basis for our normal shortwave communications and sometimes interfering with that shortwave communication.

Since they are absorbed in the upper atmosphere we don't get to see them in the lower atmosphere.

We might say that these X-rays and ultraviolet radiations cause a weather of the upper atmosphere which is electrical and chemical in nature, in contrast to weather of the lower atmosphere which is based on water vapor.

The particles, the charged particles which are also emitted by the Sun travel at a more modest speed of about a thousand miles per second and they arrive at the Earth a day or 2 days after they are emitted by the Sun. Now, when they get to the Earth they are seized by the magnetic field and funneled into the northern and southern latitudes and give rise to magnetic storms, interfere with radio communications, sometimes even with telephone lines; give rise to aurora, heat up the upper atmosphere and so on.

I may illustrate this subject by a topic which has become familiar to you by now; namely, the Van Allen radiation belts. The discovery of this belt was, as you know, one of the most exciting events of the IGY. At the time of this discovery, people thought of the Van Allen radiation belt mostly in terms of the hazard to space flight. However, it may well turn out that these belts are far more important in the light of their role in transferring energy from the Sun via these belts into the Earth's atmosphere.

The Pioneer IV flight of March 5, 1959, showed quite markedly that the Sun does indeed have a pronounced effect on the outer Van Allen radiation belt. This flight showed an intensity in the radiation belt that was 10 times the intensity observed during the Pioneer III flight.

Inasmuch as the Pioneer III flight occurred during a time of low solar activity, whereas the No. IV flight occurred after 5 days of high solar activity, the conclusion was clear that the Sun must be pouring particles into the outer radiation belt.

In addition, the Explorer VI satellite, in October, at a time of low solar activity, showed intensities in the radiation belt 5,000 times lower than those that had been observed in Pioneer IV.

Yet a few weeks later, after some solar activity, the rates had climbed back again to the rates shown in the Pioneer IV flight.

Well, these facts have given rise to considerable discussion as to just what is going on. You will hear it said that the radiation belt consists of two zones or maybe three zones or more zones. The fact of the matter is that the radiation belt is a very complicated and diffused region just as shown here, in which energy is funneled in from the Sun and then in some way or other, into the Earth's atmosphere.

Just how this happens, what the mechanisms are, are not clear. There are discussions, arguments, and controversy over these mechanisms.

For this reason, it is important for us to continue with observations on the radiation belt, and during the coming year we plan to have a satellite devoted just to this subject, in which the instrumentation is a step beyond that which has been used in the previous satellites, in which the types and energies of the particles will be pinned down in much greater detail.

Furthermore, the satellite will observe in the lower energy regions, electrons and protons, for example, of less than 10,000 electron volts. This is less than half of the energy in the electrons in the normal home television picture tube.

In addition, if we are successful, a satellite about the Moon, a satellite of the Moon, will be used as an anchored space station as it were, to make similar observations. These observations can give us a measure of the solar clouds out at the distance of the Moon. Simultaneous observations at the Earth, on the ground, or in a satellite of the Earth, can be used to study the transit time effects, and the time it takes the solar clouds to sweep across the intervening space between the Moon and the Earth.

Also in the polar regions, nuclear emulsions will be sent aloft at a time of high solar activity to study the particles that arrive at the Earth following this activity. The tracks left by these particles in nuclear emulsions identify these particles just as a fingerprint will identify a man.

Now, these observations planned are of great interest to the scientists. I should point out they have a great practical value, also.

There is a considerable likelihood that the energies brought in by these particles to the radiation belt and then fed into the atmosphere have a great effect on our weather. We certainly know they have an effect on our communications.

Back in February of 1950 at a time of the great solar disturbance, it was noticed on the Earth that we had marked magnetic storms, marked interference with radio communications. There were large auroras, and red auroras seen as far south as Washington.

There was marked and unusual heating of the arctic atmosphere and yet at the same time freezing rain and snows in great portions of our own South.

Now, of course, this might have been an isolated instance, but an analysis of weather statistics over many years shows that there is a relationship between magnetic activity, which is certainly associated with the Sun, and heating of the arctic regions, a heating which almost always occurs 5 days after such magnetic activity.

Moreover, the tree rings, the growth rings in trees, and, of all things, the wheat price index, both show an 11-year cycle. This corresponds with the 11-year sunspot activity.

The CHAIRMAN. Would you amplify that, the wheat price index?

Dr. NEWELL The wheat price index was analyzed statistically over the last 350 years from all the records that were available, and interestingly enough, the only variation in this thing that lasted consistently over 350 years was the 11-year component, the ups and downs that seemed to follow the sunspot cycle ups and downs. Now, this presumably tempts one to think that there must be some connection with weather, one thing that you think of as affecting the wheat price index.

The connection with weather, then, must be in some way connected with solar activity that is associated with the sunspot cycle, and that is magnetic, particle activities.

The CHAIRMAN. So the growing of wheat would be traceable to your reaction that you referred to?

Dr. NEWELL. Yes. The wheat crops and the successes and so on may be traceable to——

Mr. FULTON. Ask the question again. I don't think the witness understood you.

The CHAIRMAN. I said the growing of wheat, I should have said perhaps the production, but growing would cover it, of wheat, then, has a direct relationship with the reactions you referred to, from the sun?

Dr. NEWELL. This is an obvious conclusion one might jump to. However, as all of you know, the wheat price index is a very complicated thing which depends upon economic situations, trade conditions, agricultural situations and so on. But the fact that this

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11-year cycle component existed through 350 years would lead you to guess that many of these other factors wash out in this analysis, and there must be some weather and some solar connection.

Now, I would make the immediate point that this is something that requires study. This is something that requires further research, both in the basic physics we are talking about and in the effects that I have mentioned.

The CHAIRMAN. Well, if it isn't the weather that produces more wheat, then would it be that this activity would result in the merchant becoming more active during those 11-year periods? That represents a period of activity on the part of the individual, rather than on the part of the wheat, does it not?

Dr. NEWELL. This is the sort of question that one must look into and in fact, in order to pin down just what the real meaning is behind the fact that I have pointed out, one must ask all the possible questions as to what is the cause of this and look into all sources and until this is done—this will take a long time—one can't state conclusively the variations are caused by the solar radiation.

Yet I suspect that when one has gone through that whole process, one will find that the solar particles do have an effect.

Mr. FULTON. Will you yield?

The CHAIRMAN. I yield to Mr. Fulton.

Mr. FULTON. The thing that caused an abrupt start was when your question and answer changed quickly from price to production. That is what caused me some trouble. I used to be a fellow in economics, studying it. Possibly, rather than spend your time on trying to follow that research out, you might find it might be the effect of the radiation on the human energy that made the farmer plant and harvest more wheat. Or, you might find that, if it is the price, it was the way the particular farmer or the middleman looked at his medium of exchange or his pocketbook.

Or it might also have been that the energy made more wars and, therefore, the human energy went off in a different direction and had an effect on price.

I think it would not be too productive for the taxpayers' dollars to try to go into quite a program on trying to correlate price and electromagnetic radiations.

Could I finish with this? On the electromagnetic storms on the Sun's surface, isn't there about a 30-day lag in the Earth's weather pattern?

Dr. NEWELL. There is a 27-day pattern. Following a solar outburst, there is a magnetic storm or some such terrestrial effect within a few days; then 27 days later, often times another effect; and then 27 days later sometimes another; due to the 27-day rotational period of the Sun which brings the sunspots that caused the thing in the first place, back again.

The CHAIRMAN. Well I can say this, though, and I think it is correct. Dr. Reichelderfer, head of the Weather Bureau, testified before the committee about a year and a half ago that the ability to judge long range weather accurately would save this country $3 billion a year and save the lower Mississippi Valley in which I am particularly interested, of course, about $1 billion a year.

Now, could you go so far in your statements as to say that this radioactivity from the Sun might result in the weather forecasting being set up like Dr. Reichelderfer referred to?

Dr. NEWELL. Yes. The point I was about to make was not that we should investigate the wheat price index. This was only an interesting side point that was quite remarkable, but that all of these facts that I brought out suggest that we have here something that may be of great value in forecasting events on the Earth.

It is not unreasonable to think that some day we will have a satellite away out beyond the Earth that detects the approach of these solar particle clouds, radios this information back to the Earth—to use a homely suggestion—in time to be of value.

In other words, it is an area of research that man must pursue from a scientific point of view in order to lay the groundwork for these future practical applications.

Mr. FULTON. Could I ask you this. Of course, there are these energized particles all around the world in the magnetic field. The first question is, do those energetic particles travel from the Sun or do the rays themselves simply energize particles that are already there in the magnetic field and make them bounce? If they do bounce, how long do they keep bouncing from one of those electromagnetic storms on the Sun?

Dr. NEWELL. The energetic particles we are talking about travel directly from the Sun, and, arriving in the vicinity of the Earth, are caught, as it were, by the magnetic fields.

Mr. FULTON. How long does it take?

Dr. NEWELL. About a day to 2 days, depending on their speed.

Mr. FULTON. They don't come at the speed of light then?

Dr. NEWELL. No; about a thousand miles per second.

The light, the X-rays and ultraviolet radiations come at 8⅓ minutes, so those effects are observed first. Then the particles, the charged particles arrive about a day after the solar activity, sometimes 2 days.

Mr. FULTON. When they energize other things, coming like a bunch of pool balls, how long do they keep bouncing around the outer edge of the Earth's magnetic field?

Dr. NEWELL. This depends upon their energy. Some particles are trapped in orbits that dip away down in the Earth's atmosphere. Those will stay in their orbits a matter of days only. Other particles are trapped in places where they may stay a year or more.

Mr. FULTON. I hope you do work out some correlation for the Earth's weather so we can forecast it better.

Dr. NEWELL. This, then, presents to you a picture of one of the areas in which Sun-Earth relationships may produce some things of very practical value, and certainly of great scientific interest. But underlying all of this is something even more fundamental; namely, the nature of the universe.

It is an assumption we make that the laws we observe to operate on the Earth also operate elsewhere in the universe, to the remotest distances.

The science of the last century has been directed toward developing a remarkable picture of this universe based on the number of fundamental particles and a number of fundamental force laws (fig. 60).

Now, these fundamental particles are the neutron, the proton, and the electron. As you know, the neutron and proton combine together in various numbers and make up the different nuclei of our atoms.

If you have electrons revolving around this nucleus, you get an atom. Atoms join together to form molecules and molecules adhere together to form matter as we observe it; and the Earth, of course, is a large collection of such matter.

As we go up in the scale, we have the solar system. The Sun is one of 100 billion stars in our galaxy; and ours is one of billions of galaxies, as we know, in the universe.

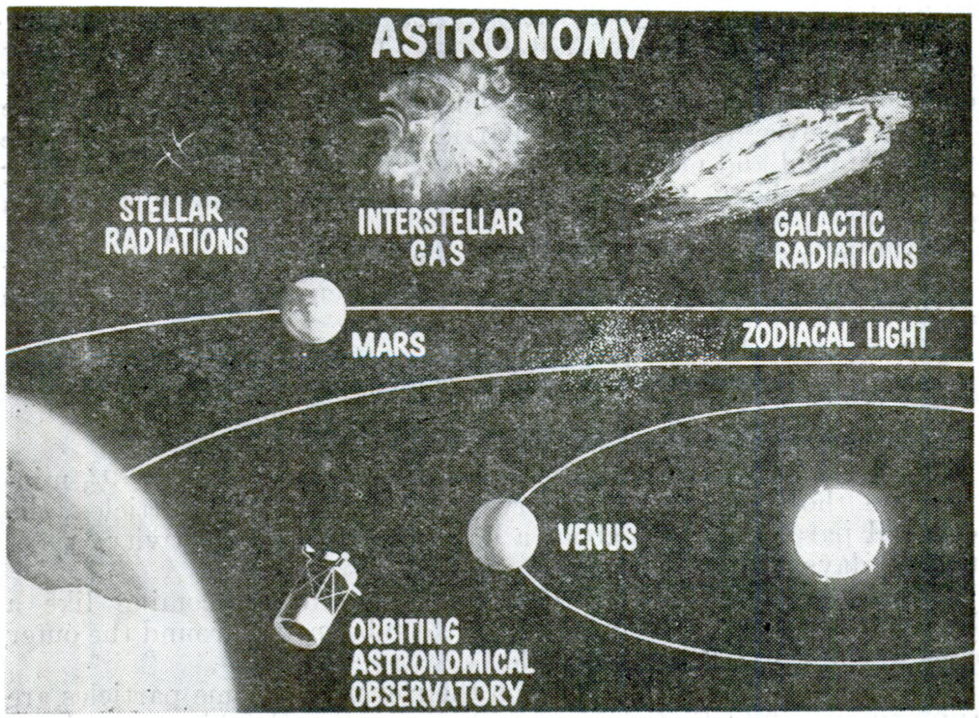

FIGURE 60

Operating with these particles are three fundamental force laws. These three forces are the nuclear forces, the atomic forces, and the gravitational forces.

The nuclear force is the strongest of all. It combines together the neutrons and the protons in the nuclei in such density that 1 cubic inch of this material would weigh 1 million tons. Of course, we have nothing like this on Earth, but matter approaching such a density is observed in what we call the white dwarf stars.

The atomic forces are electromagnetic in nature, and are a hundred times weaker than these nuclear forces. It is these forces that combine together the electrons to the nuclei, and the atoms together to form molecules, and molecules to form ordinary matter.

The gravitational force is the weakest of the three, and it is 10^{40} times weaker than the nuclear forces. That is 10,000 trillion trillion trillion times weaker than the nuclear or atomic forces.

To give you some idea. so you can visualize what this means, consider a pound of iron. When you say you have a pound of iron, you mean the earth pulls on that piece of iron with a force of 1 pound. It takes a whole earth to pull on that iron to make a force of 1 pound; but a very small electromagnet will produce a force to hold that pound of iron. In fact, it doesn't take a large magnet to pick up tons of material.

This gives you an idea of the weakness of the forces of gravity.

There is the interaction between the weak forces and the strong forces that give rise to the birth and life of stars, for example. A star is born presumably by the condensation of interstellar dust. As this accumulation begins, the gravitational forces accelerate the process, the dust accumulates together, and finally pressures are built up in the interior of the star that is being born. These pressures give rise to high temperatures and eventually the temperatures and pressures are high enough that a thermonuclear reaction is started.

Now, this thermonuclear reaction can release additional energy which balances the gravitational force and this collection of material in the star stops and the star has been born.

Now, the life history of the star depends on only two things—the original mass at the time the star was born and the abundance of the chemical elements in the star. In order to study the life history of this star, then, the scientist has to observe, to learn about what these chemical abundances are.

And, perversely enough, the information about the chemical abundances in these stars is contained mostly in the ultraviolet light that doesn't get through to the surface of the Earth.

So if we are going to continue our study of the nature of the universe and the origins of things in the universe, we must get our equipment up into observatories above the Earth's atmosphere.

Now, there is another subject of the origin of the universe that is important to us and rather dear to our heart and that is, how was the Earth born? How was the solar system originated? It may be that planetary systems are born from materials left over from the birth of stars, accumulations left over, we will say, from the birth of our star.

If this is the way planetary systems are born, then it is very, very likely that there are millions and even billions of other planetary systems throughout the universe. This is a very likely process, you see. This means then that there is a great likelihood of finding life elsewhere in the universe.

On the other hand, it may be that the planets were born in a catastrophic sort of process in which one star collided with another—our solar system perhaps was born because of collision of our sun with another star, in which masses of material were pulled out of the sun and left to condense into the planets.

Now, if this is the way planetary systems are formed, this has a low probability of happening and implies a low probability of other planetary systems in our galaxy and hence a low probability of life as we know it elsewhere in our galaxy.

Well, how can we test for this? Well, the Moon gives us a very significant object to study and test for this. The Moon is small enough that if it were accumulated out of the relatively cool gases left over from the formation of the Sun, the Moon itself may never have been molten. If we can get to the Moon and study the surface and learn as much as we can about its past temperature history, and so forth, we may be able to tell whether or not the Moon and hence the Earth and the other planets were formed from the accumulation of cooler gases (fig. 61).

On the other hand, if we find from study of the Moon that it was at one time molten, then we may have to conclude the planetary system was made by the catastrophic process.

Mr. FULTON. Or a third process; formation of new matter.

Dr. NEWELL. Yes; but this is a slow process compared with the time involved in the formation of the Moon and Earth.

Mr. FULTON. Do you favor a static universe or a different one?

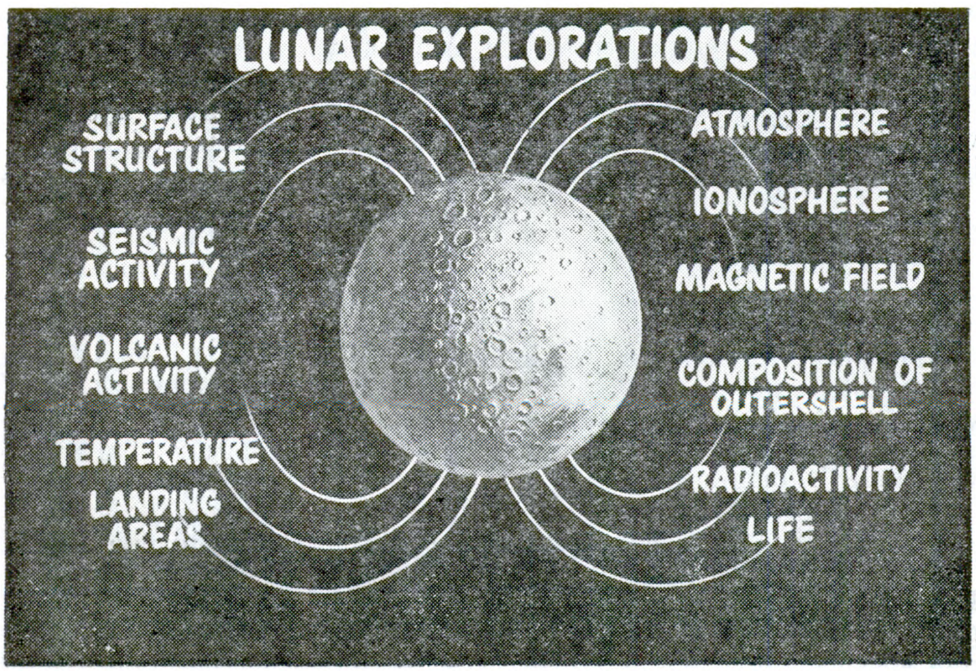

FIGURE 61.

Dr. NEWELL. I think the expanding universe theory is probably a good one.

Mr. FULTON. How about the dimensions of space? What are they to you?

Dr. NEWELL. I suspect that Einstein's theory of relativity will turn out to be correct, in which case space time is what we should speak of. In other words, a four dimensional space time rather than space and time.

As you know, the NASA program has in it an experiment to check this theory of relativity.

Well, in the study of the nature of the universe and the origins of the universe, we have come back to our own back door, so to speak, to the nearest object in space, to the Moon. But even closer to us, right here on the surface of the Earth we have the most exciting, the most fundamental thing: physical life.

This brings us to our third objective: the study of the origins of life and possibly its presence beyond the Earth.

In the study of the origins of life——

Mr. FULTON. Before you get into that, while you are just on space, do you have any experiment that proves whether there is ether through which matter moves in space? Aren't you trying to do that, too?

Is there anything there through which all matter moves? Don't you have an experiment on that?

Dr. NEWELL. We have no such experiments specifically planned. Our present thinking runs along the following lines: To check the Einstein theory of relativity; to compare whether gravitational clocks and nuclear clocks—by this I mean whether the motions of large masses around each other like the Moon around the Earth, or satellites around the Earth, follow the same type of time as vibrations of electrons in atoms.

This is a fundamental topic and one that we hope to include in our programs, but beyond this we haven't gone any further at the present time.

Mr. FULTON. You don't favor the theory that neutrons are being formed all the time?

Dr. NEWELL. You are thinking of the continuous creation of matter?

Mr. FULTON. Yes.

Dr. NEWELL. I don't, but no one is in a position to reject that absolutely and it has to be looked into. It has to be checked in the course of our program sometime.

Mr. FULTON. You are one of the believers in the theory that 5 billion years ago there was an explosion through which all these motions of matter and planets and stars can be checked back to? A tremendously compressed mass, and an explosion occurred and we are just 5 billion years after that explosion occurred?

Dr. NEWELL. When I say that I favor the expanding universe theory, that automatically implies that I must then trace back to this explosion. This seems to me, at least at the present time, to be the best theory explaining the facts that we know.

Mr. FULTON. But you don't think that was a progression, coming back in by attraction, getting so dense nuclear forces got into play, exploding, so that we have a 5-billion-year alternating thing—that it goes out for 5 billion years and comes back for 5 billion?

Dr. NEWELL. We really don't know. Many scientists are trying to trace things back through an initial "egg" as you might want to call it, to what happened before; but there is apparently no way through which they can do it. It is something they can't get their hands on. So, for the time being they are content with starting with this initial nucleus, and an ensuing explosion, and seeing what they can develop there.

Mr. FULTON. Do you have any time study on the radioactivity of various matter in the universe?

Dr. NEWELL. We have radioactivity measurements included in our lunar program.

Mr. FULTON. That is all.

The CHAIRMAN. Just proceed, Doctor, with your statement.

Dr. Newell. Thank you.

In laboratories on the Earth, it has been shown that certain types of atmospheres which may be called reducing atmospheres, are different from our present atmosphere which is an oxidizing one.

In these, lightning discharges will always give rise to formation of amino acids. Amino acids are building blocks of the self-replicating molecules which are probably precursors of living matter.

Now, we can continue this sort of research in the laboratories on the Earth to seek out the origin of physical life on the Earth. However, if we can get our equipment up to some other regions, Venus and Mars, where the atmospheres are different and presumably were different in their life history, although perhaps similar to that of the Earth, then we may be able to find some life processes and life forms that are similar to, but different from, those on Earth (fig. 62).

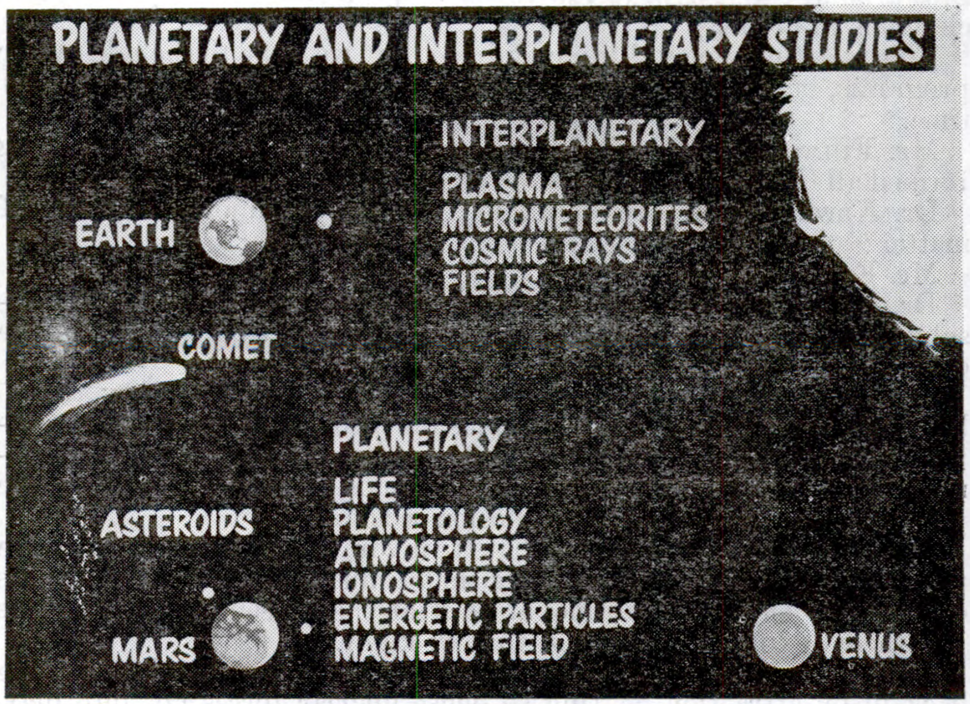

Figure 62

If this is the case, then we will have the very powerful way of searching for the origins of life. Whenever you can follow two slightly different processes, that are sufficiently similar to compare them, but sufficiently different to highlight fundamental things that are going on, then you have an extremely powerful tool to work with. Well, in our current researches we will have a planetary program and an interplanetary program leading to the study of Mars and Venus and the medium in between, but looking forward eventually to the search for life on these planets and even beyond that, to the search of the origin of this life.

This may well have by far the greatest impact on our everyday living, although it may be well into the future before we feel this impact.

Now, I have given you the three principal objectives of space sciences.

Let me run through quickly the program that has been developed to support these objectives.

First we have the results in 1959. There were three significant areas that led to important discoveries: Radiation belts. We found, as I mentioned earlier, that the radiation belt is an extremely complex thing, not at all as simple as we first thought and, as always seems to be the case, the discovery of these things raises more questions than it answers. So the program goes on. (See table 1, p. 341.)

In the case of the Earth's magnetic field, work done in Vanguard–3, it shows deviations from expected values. Now, this is always interesting scientifically. If you find what you expected, that is not half as exciting as when you find deviations. Then, of course, you have to find out the course and causes of those deviations.

In the Earth's upper atmosphere many measurements have been made. One significant one has shown that the Earth's upper atmosphere is even more dynamic than we thought. Very strong wind shears exist in the ionospheric regions.

Sounding launchings show that sodium vapor (table 2, p. 342), launched between evening and dawn, show high winds in the upper atmosphere; 400 to 500 knots at 150 kilometers and very powerful wind shears—I mentioned this on the previous slide.

The CHAIRMAN. What is a wind shear?

Dr. NEWELL. A wind shear is one wind going this way and the other going in either the opposite direction or in a cross direction. Remarkable wind shears have been discovered. As much of a change in velocity of 100 kilometers per second in 1 kilometer change in height. It is a tremendous shear and, of course, it raises the question as to how it occurs.

Mr. FULTON. Is there a general correlation to the turning of the Earth or the movement around the Sun, or heat? Much more around the Equator and less around the poles?

Dr. NEWELL. There appears to be such a correlation. The winds appear to be strong and from the west in winter—west and winter both beginning with "w."

Mr. ANFUSO. And weak in the summer.

We extend these to higher altitudes and this will be part of our program to follow.

Mr. FULTON. Do they have any effect on weather?

Dr. NEWELL. Probably not. The atmosphere at this point is only one one-millionth of the density of the atmosphere on the Earth.

Now there may be a connection. There may be things that happen simultaneously, or perhaps things happening in the upper atmosphere that precede things happening in weather, in which case it would be important to know about these because then they would be signs of things to come.

Mr. FULTON. Do the jetstream winds have an effect on weather?

Dr. NEWELL. Yes, indeed, but these, of course, are fairly low down compared with the altitudes we are mentioning here.

Mr. FULTON. Thank you.

Dr. NEWELL. This is the sounding rockets program, and you will note about 100 rockets per year is the program and that there is a fairly good distribution among the different subjects that might be studied. (See table 3, p. 342.)

This "special" here means things like those sodium vapor experiments.

In the next chart we have the satellites in 1959. Vanguard II, Explorer VI, Vanguard III, and Explorer VII. These launchings were all successful. The data from these three will continue to be analyzed and we expect discoveries announced in 1960 that will be based on these satellites. In addition, Explorer VII will continue if it is successful, to transmit for another two-thirds of a year, so we will have additional data coming from that. (See table 4, p. 342.)

Mr. FULTON. Do you have in those programs exploration of the oxygen radical belt that is about 60 miles up?

Dr. NEWELL. Not in these particular satellites, but in the sounding rocket program, yes.

The measurements of the atomic oxygen is one of the most important items in the atmospheric composition studies.

Mr. FULTON. Thank you.

Dr. NEWELL. I might point out with the launching of those satellites in 1959, this country performed every experiment that it planned to perform for the IGY. There was one slight variation. Our upper air densities were not measured by the 30-inch sphere, but they were measured by other techniques.

So there was no measurement planned for IGY that we did not make.

Following on with this chart, we have the Juno II scientific satellites, at the times indicated. The radiation belt studies and the Ionosphere Beacon, which carries several transmitters radiating frequencies back to the earth for observing the ionosphere, are follow-ons of previous work. The other two will be firsts, exploratory, opening new fields. (See table 5, p. 342.)

The Thor-Delta vehicle will be used for a series of experiments, at the times shown here [indicating]. (See table 6, p. 343.)

The last three here will again open up new fields. The geodetic flashing light satellite will open up an important field, previously touched on by the Vanguard I.

The ionosphere top side sounder was described last year, and we have agreement with Canada for a joint effort in this experiment.

Mr. FULTON. When will you be able to put a telescope in space?

Dr. NEWELL. This will come up in the chart after this.

The Scout vehicle should be ready for use in the near future. We plan to use it as the principal vehicle for our international program and to use it in our solar studies. (See table 7, p. 343.)

With this we will be able to put up the heavier payloads, the previous payloads being a hundred to several hundred pounds. With the Agena, based on the Thor or Atlas, we will pursue geophysics studied and with these Thor and Atlas vehicles, Sun-Earth relations and the Precision Astronomical Observatory, which I personally regard as one of the most exciting prospects. (See table 8, p. 343.)

Mr. FULTON. So do I.

The CHAIRMAN. Doctor, where do you pick up that word "Agena"?

Dr. NEWELL. I got it from the Department of Defense. I don't know where they picked it up.

Mr. FULTON. I can answer that. It is a star in the constellation Centaur near the Southern Cross and, I think, one of the 6 or 10 brightest stars in the heavens.

The CHAIRMAN. The gentleman might be correct. I am going to ask the Department of Defense though, when they come down here, and not rely entirely on the gentleman from Pennsylvania.

Mr. FULTON. Isn't there anyone here from the Air Force? Weren't they going to have a polar orbit from Vandenberg Field and they picked out the brightest star toward the South Pole and said, "That is what we are aiming at." How about that, Mr. Horner?

Mr. HORNER. I think that is correct.

The CHAIRMAN. Is that correct? That is what the Agena is?

Mr. HORNER. I believe so.

Dr. NEWELL. You will recall Pioneer IV was launched in March of this year. We discussed the results of this in detail earlier. (See table 9, p. 344.)

The Scout will be used for near-Earth probes; namely, probes reaching out 5,000 to 10,000 miles. (See table 10, p. 344.)

Following the Scouts, other vehicles will be used for probes reaching to greater distances with relatively small payloads.

We will make communications tests with the Thor-Able, Atlas-Able, and the Delta. (See table 11, p. 344.)

Then, the heavier payload vehicles, the Atlas-Agena for interplanetary environment, technological developments, and a study of the Moon.

This is what is planned for 1962. This is for technological developments of payloads in interplanetary space and preliminary planetary measurements (fig. 63).

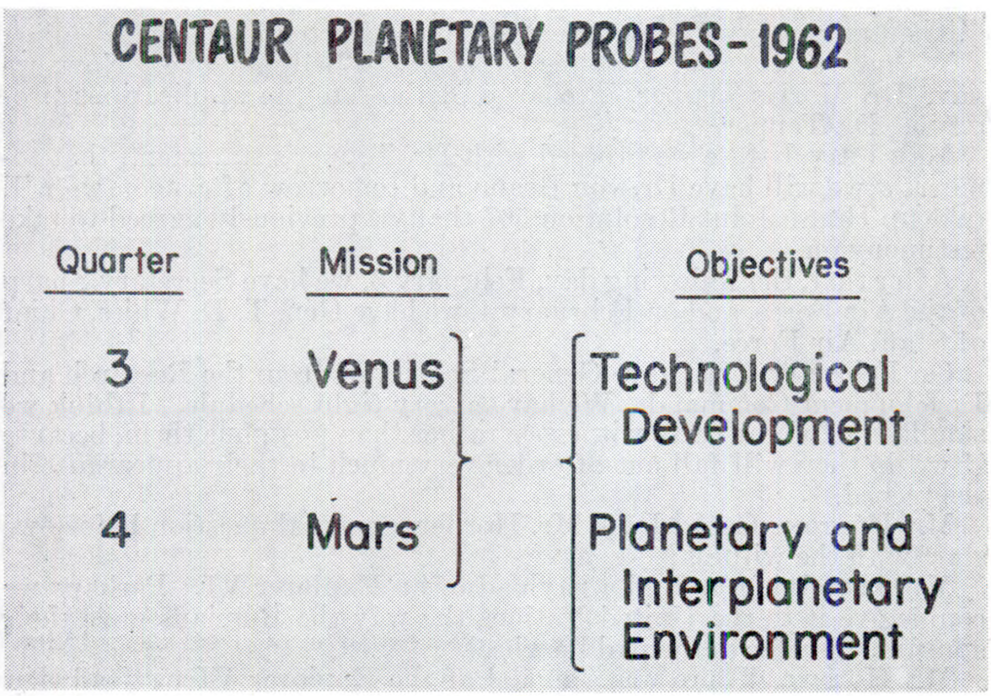

FIGURE 63

In summary, the program goes through about 100 sounding rockets per year. The scientific satellites, about eight or nine a year. These figures here are incomplete. When we develop our program next year, the 1963 figure will probably go up to eight or nine. The lunar and planetary explorations will be about four per year. (See table 12, p. 345.)

This will be divided as follows: Slightly less than half for lunar and planetary explorations. Less than 10 percent for sounding rockets. The remainder for scientific satellites. All total $94.7 million. (See table 13, p. 345.) Thank you.

Mr. FULTON. Mr. Chairman, could we have these charts all put in the record?

The CHAIRMAN. If there is no objection, it is so ordered. All of these charts are more or less a part of the statement. I want to take this opportunity to commend Dr. Newell on the exhaustive statement he has presented to this committee. The charts are most interesting.

Dr. NEWELL. All of the charts except the pictorial ones are in the material handed out.

Mr. FULTON. May I add, it is interesting and not exhausting.

Dr. NEWELL. Thank you.

Mr. FULTON. Could we have a statement from you as to what the Russians are doing in this field? If you don't want to give it now, put it in the record.

Dr. NEWELL. I will be glad to put it in the record. You may have seen an analysis that NASA drew up recently which I think is still up to date.

Mr. FULTON. I would like to have that in the record.

(The information appears on p. 256.)

The CHAIRMAN. Thank you very much, Doctor.

We appreciate your statement. It was a brilliant one. Now, we have Dr. Morris Tepper, in charge of the satellite applications program. Dr. Tepper.

May I say, before we proceed with Dr. Tepper's statement, that tomorrow we will have Dr. von Braun and tomorrow afternoon we will take up House Joint Resolution 567 that we previously agreed to take testimony on.

After that, the following day, February 3, we have Secretary Sharp of the Air Force, and on February 4, we have Gen. T. D. White, Chief of Staff, Air Force.

On February 5, we have General Schriever, from the Research and Development Command. We have a very tight schedule. I think we should try to hear these witnesses, rather than postpone them, because if we do they will fall out of order very much in their appearance in the record.

Mr. FULTON. Could I ask Mr. Horner a general question before we start with the witness?

You have lying around a payload of an Explorer VI. Perhaps we could give it to the United Nations the way the Russians gave their sputnik. I refer to the paddle wheel.

Mr. HORNER. There was a model of the Explorer VI payload that was used by USIA in various exhibits in foreign countries.

Mr. FULTON. Where is that?

Mr. HORNER. I just don't know at the moment. The last I knew about it was in Italy, but I will find out where it is.

Mr. FULTON. That is all.

The CHAIRMAN. Thank you. We will proceed, Doctor.

STATEMENT OF DR. MORRIS TEPPER, CHIEF, METEOROLOGICAL SATELLITE PROGRAM, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. TEPPER. After having heard the presentations so far, you may be wondering somewhat whether the exploration of space does not have a more practical side, something closer to our activities as individuals.

The CHAIRMAN. Doctor, may I interrupt you. Would you like to give us a verbal statement like Dr. Newell's? If so, we will place your written statement in the record.

Dr. TEPPER. Just as you prefer.

The CHAIRMAN. I believe the committee would be more attentive than if you read the statement.

Dr. TEPPER. Surely.

(The prepared statement is at the end of the day's hearing.)

Dr. TEPPER. There are three general fields of application which I would like to discuss today, those of meteorology, communications, and navigation.

The objectives are: In the meteorological field, to develop a satellite capability for providing worldwide meteorological information; in the communications field, to develop a satellite capability for making possible worldwide communications; in the navigational field, to develop a satellite capability for making possible all-weather navigation at low cost (fig. 64).

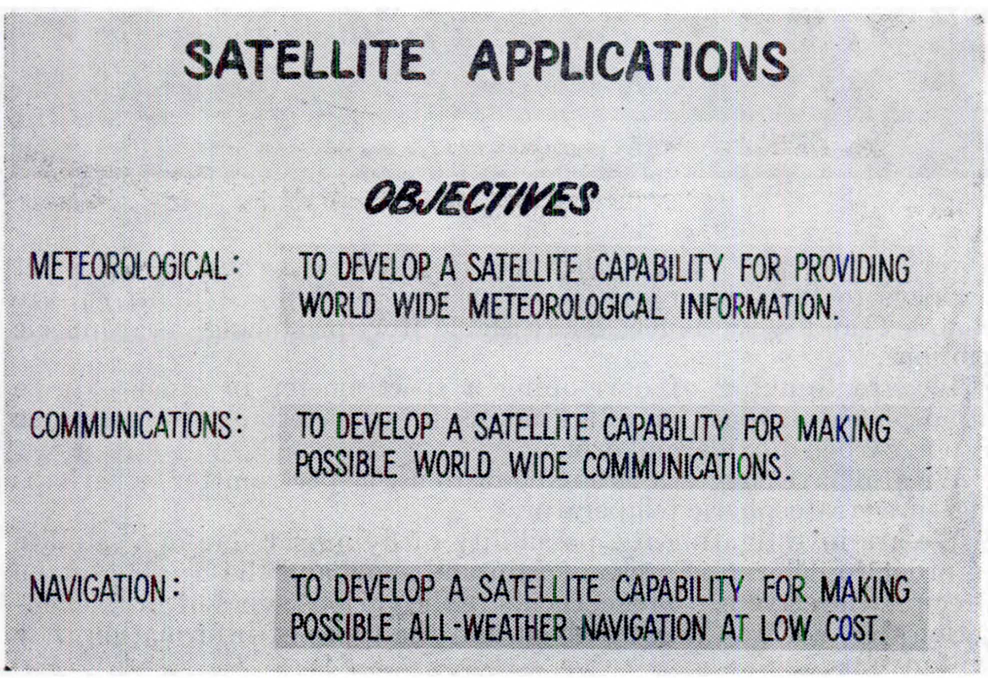

FIGURE 64

I will discuss these three fields in turn.

First, the meteorological satellite: The meteorologist requires certain information in the performance of his duties. The objective of the meteorological satellite program is to provide this information for the meteorologist. How this will be done, I will show in the next slide.

In the upper right-hand corner we see that photocells and television will provide cloud cover information, storm location, description of the various clouds, their amounts and general types (fig. 65).

The scanning infrared detectors are being designed to measure temperatures—average surface temperatures and temperatures of the atmosphere; and temperatures of the cloud tops.

There are nonscanning infrared detectors which will give information on the gross heat budget of the Earth's atmosphere. This is

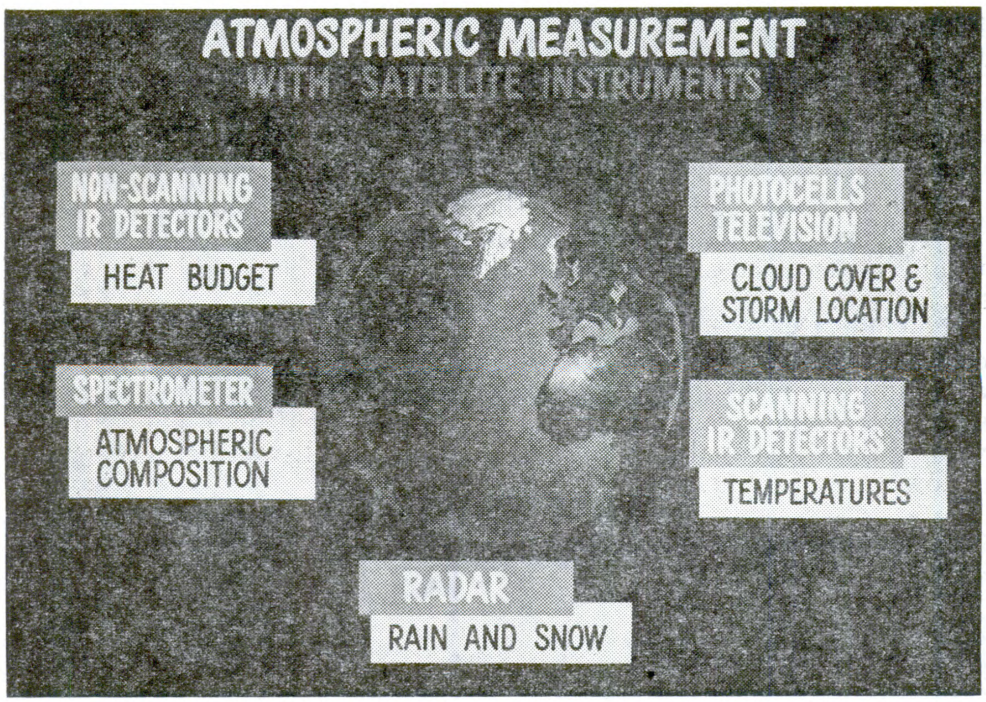

FIGURE 65

a very important quantity because it gives an accounting of what happens to the solar radiation after it enters the earth-atmosphere complex and how much is available for producing atmospheric motions.

We are thinking of developing a spectrometer in order to give atmospheric composition of a kind, useful to meterologists, like water vapor, carbon dioxide, and ozone.

We also have suggestions as to how to use a spectrometer to perhaps measure stratospheric temperatures.

We are investigating the possibility of flying a radar in a satellite in order to determine areas of rain and snow and the heights of the precipitation layers. These, then, are the various types of instrumentation that we are thinking about and the types of information they will give us.

Mr. FULTON. Are you not going to have any of those nuclear explosion detectors?

Dr. TEPPER. Not in this program. Their relationship to meteorology has not been demonstrated as yet. Our experiments are designed more to provide the meteorologist with the type of information he is using currently.

This is our progress, past, present, and future. During the past we launched two satellites which had significant meteorological instrumentation. Vanguard II, contained a photocell, and I believe the committee is well acquainted with the history of that satellite. We have not abandoned the possibility of reducing that data, however. We hope that we will be able to get useful information from this satellite (fig. 66).

METEOROLOGICAL SATELLITES

PAST	VANGUARD II	PHOTOCELL
	EXPLORER VII	NON-SCANNING IR
PRESENT	TIROS I	TELEVISION
	TIROS II	TELEVISION SCANNING IR NON-SCANNING IR
FUTURE	NIMBUS	IMPROVED TELEVISION SCANNING IR, NON-SCANNING IR
		SPECTROMETER } LATER RADAR } VERSIONS

FIGURE 66

Explorer VII, which is still in orbit, contains a nonscanning infrared radiation detector and is giving us information on gross heat. This data is not completely reduced but is being worked up. The information that I have is that the data looks very good.

Currently—and I want to talk about this at greater length later—our current program relates to Tiros I and Tiros II. These are two satellites to be launched this calendar year. Tiros I will contain a television system containing two cameras to photograph cloud cover. Tiros II will contain a television system also and will contain a scanning infrared radiation system and a nonscanning infrared detection system.

In the future, is a series of satellites which we have designated Nimbus, and these will contain instrumentation of the kind we have been working with and in addition the spectrometer and the radar developments.

I will mention a little bit later, when I discuss Nimbus, some of its important improvements over Tiros I and II.

This chart shows an artist's drawing of the Tiros satellite. Tiros will be spin stabilized. In other words, it will rotate and maintain its aspect fixed in space throughout its life history. It will be covered with solar cells to provide energy for its operation (fig. 67).

In addition, it will have batteries in order to run the satellite whenever it is in darkness.

This shows one of its cameras, the wide angle camera and the narrow angle camera is back here. I show this to show the complicated equipment that the satellite has.

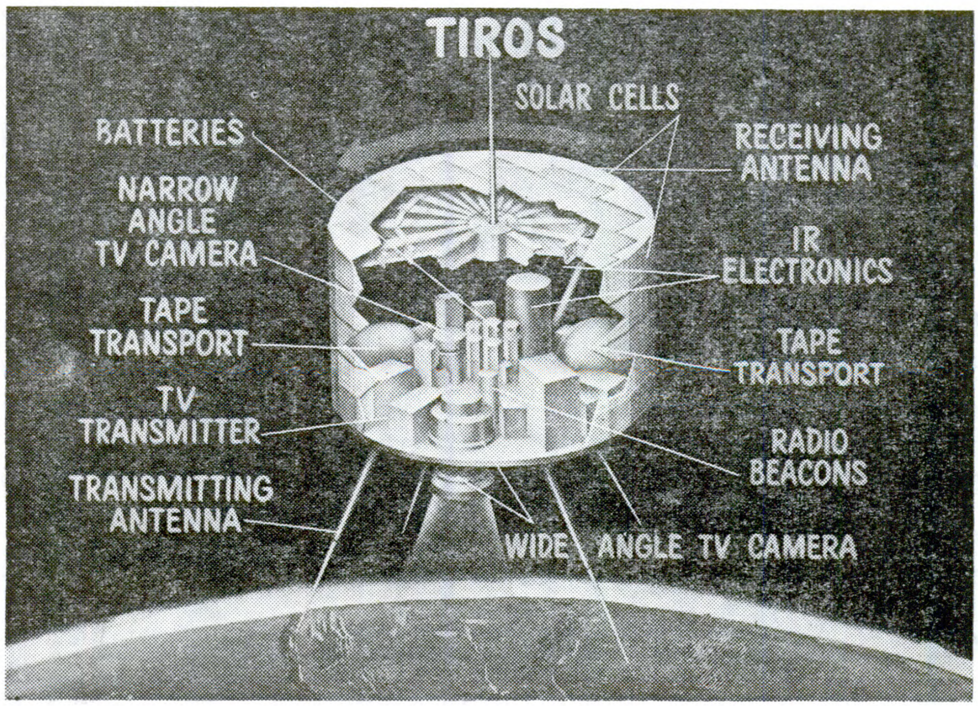

FIGURE 67

It will be launched in an inclined orbit and will reach approximately 50° north and 50° south during its transit around the Earth. It will be at approximately 380 miles elevation. Insofar as its shape, weight, and size are concerned, it weighs about 270 pounds; it is 42 inches across here and 19 inches tall.

Mr. FULTON. Why do you have a 50° inclination? Why don't you have it equatorial?

Dr. TEPPER. The meteorologist would like to have as much coverage over the entire Earth as possible so that the optimum orbit would be one that would go pole to pole. As the Earth rotates around it would see everywhere during its orbit.

Mr. FULTON. Why don't you then make a polar obit?

Dr. TEPPER. We couldn't start with a polar orbit and this will be one of the differences between the Tiros launch and the Nimbus launch we will talk about a bit later.

Energy considerations prevented us from launching the Tiros directly northward and also the fact that we have been launching from the Atlantic Missile Range rather than the Pacific Missile Range.

Mr. FULTON. When you get a 50° orbit and then get your scanners, how much of the Earth's surface can you then cover? How much of a slope do you get?

Dr. TEPPER. There are several things that are involved. Picture taking is essentially restricted to daylight. Another factor is whether the satellite looks at the Earth. Sometimes it looks out in space or has a glancing view of the Earth.

These are the two essential features. Percentagewise, I don't have this information.

Mr. FULTON. Put it in the record later.

Dr. TEPPER. All right.

(The information referred to is as follows:)

The portion of any orbit useful for photographing the Earth's cloud cover is variable, ranging from 0 percent under the worst conditions to about 33 percent under the most favorable. An overall average figure is perhaps 17 percent per orbit.

Areawise, it is possible to photograph up to 40 percent of the Earth's surface per day under the most favorable conditions.

Dr. TEPPER. Tiros originally began in the Department of Defense and was transferred to NASA during the spring of the past year (fig. 68).

In Tiros, NASA has responsibility for overall direction and coordination. The U.S. Army—specifically the U.S. Signal and Research Laboratories at Fort Monmouth, and contractors from industry, particularly the Radio Corp. of America, had responsibility for the development of payload and selected ground equipment, data acquisition, and data transmission.

PARTICIPATION IN TIROS

NASA	OVERALL DIRECTION AND COORDINATION
U.S. ARMY AND CONTRACTORS FROM INDUSTRY	DEVELOPMENT OF PAYLOAD AND SELECTED GROUND EQUIPMENT, DATA ACQUISITION, DATA TRANSMISSION
U.S. AIR FORCE AND CONTRACTORS FROM INDUSTRY	DEVELOPMENT OF LAUNCH VEHICLE, MATING OF VEHICLE AND PAYLOAD, LAUNCH, DATA ACQUISITION. ASSISTANCE IN DATA ANALYSIS AND INTERPRETATION
U.S. NAVY :	ASSISTANCE IN PHOTO ANALYSIS
U.S. WEATHER BUREAU	DATA ANALYSIS AND INTERPRETATION, DATA DISSEMINATION, HISTORICAL STORAGE

FIGURE 68

50976—60——24

The U.S. Air Force, BMD, and contractors Douglas and Lockheed, had the responsibility for the launch vehicle itself—the mating of vehicle and payload, launch, data acquisition. AFCRC is assisting in data analysis and interpretation. The U.S. Navy, particularly the Navy Photographic Interpretation Center, is assisting in the photoanalysis.

The U.S. Weather Bureau has a very major role in the Tiros program and that is in the data analysis, data interpretation, and dissemination.

Mr. FULTON. Is this program one done with international cooperation and under the extension of the International Geophysical Year? What are you doing in connection with other countries?

Dr. TEPPER. As of now this particular Tiros program and the follow-on program of Nimbus are restricted to activities within the United States. The cooperation with other countries in the meteorological satellite field has not really begun.

Mr. FULTON. When do you expect to begin that? I think that is one of the things the Space Act points out. These programs are to be done when they are for the benefit of mankind and extensions of practical programs for peaceful purposes with these other countries and in conjunction with them.

It was apparent to me from your statement that it seemed to be limited to just the United States.

Now, the second thing is, our statutes of 1958 require the dissemination of this information so I would rather not have it now, but put in the record what your plans are on that. It is to be made public and disseminated.

Mr. HORNER. Mr. Fulton, we have had activity in that area.

Mr. FULTON. Put in a statement on that.

Mr. HORNER. We will provide it for the record.

(The information requested is as follows:)

A cooperative program with other nations for the use of application satellites is an objective of the National Aeronautics and Space Administration. When the technology of meteorological satellites has advanced sufficiently, a detailed plan for such cooperation can be prepared. The Tiros satellite is an initial experiment to develop the technology. Experiments with Tiros and the second generation satellites, Nimbus, will provide us with much of the information needed to make engineering selections of the type of data to be collected, the methods for storing and coding the data, the type of ground receiving and data recovery systems, and the methods for processing the data.

Although a detailed plan for international cooperation in a weather satellite system cannot be prepared now, it will be desirable to call upon other countries to aid in some of the experiments. Our first task, however, is to produce a successful satellite for conducting the experiments.

Dr. TEPPER. In our program we have established a Joint Meteorological-Satellite Advisory Committee, jointly with the Department of Defense and the Weather Bureau, where the military requirement in the field of weather is being coordinated with ours so that we can develop a national program responsive to the needs of the military and the civilian as well.

This meteorological data will be quite different from anything the meteorologist has had before (fig. 69).

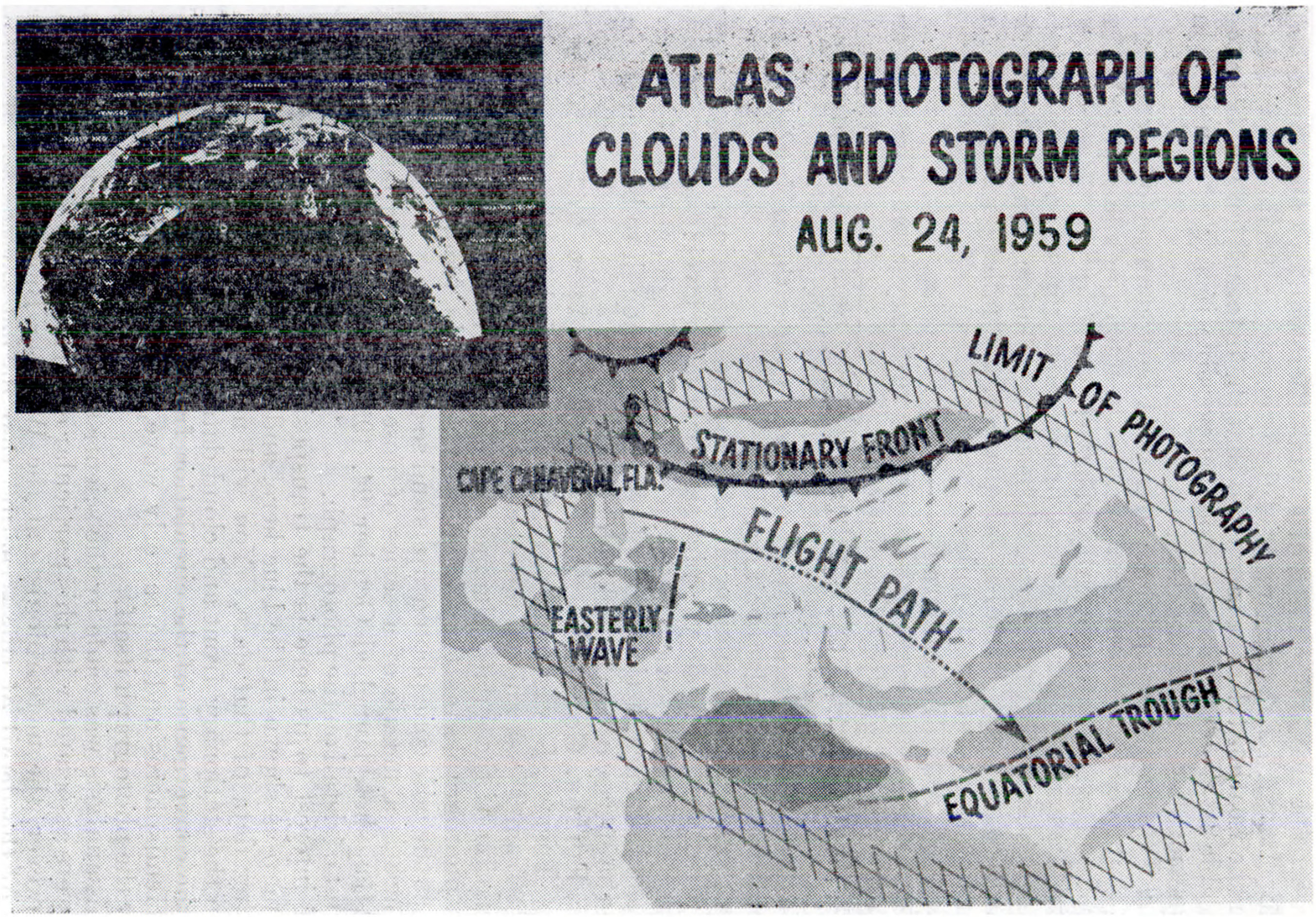
ATLAS PHOTOGRAPH OF
CLOUDS AND STORM REGIONS
AUG. 24, 1959
LIMIT OF PHOTOGRAPHY
STATIONARY FRONT
CAPE CANAVERAL, FLA.
FLIGHT PATH
EASTERLY WAVE
EQUATORIAL TROUGH

FIGURE 69

It is necessary before launching to develop techniques and procedures so that when the data becomes available it can be used on an operational basis, and perhaps I can refer to your previous question, Mr. Fulton, by stating that at each of the Tiros read out stations—there will be two in our Tiros program—there will be a meteorological team. It will be abstracting useful meteorological data and putting it on the weather teletype service so that the information will be made available to weather users as soon as possible if any is identified in the meteorological satellite data.

Mr. FULTON. How small an area will be your area of reception? For example, on a storm or a burst of a nuclear explosion? What height and what focal area will you have?

Dr. TEPPER. I think we are in privileged regions here. There are two cameras aboard the Tiros. The low resolution camera will view an area of roughly 700 miles—a square of 700 miles on a side with a line resolution of about 1½ miles.

The high resolution camera is——

Mr. FULTON. You could pick up the ordinary atomic or nuclear explosion with that type of resolution.

Dr. TEPPER. I am not familiar with the resolution required to identify such explosions, but I imagine it would be.

Mr. FULTON. Of what type would you expect the orbit to be? Is it going to be an annular orbit or elliptical?

Dr. TEPPER. A circular orbit of 380 miles elevation.

Mr. FULTON. Why do you pick that particular level?

Dr. TEPPER. This was chosen in order to be high enough to be outside the influence of the atmosphere and low enough to be compatible with the energy of the launch vehicle.

Mr. FULTON. Go ahead.

Dr. TEPPER. I was mentioning the type of data that we expect to get from Tiros, and its newness. And, in order to prepare for the utilization of these data, the meteorologists have been studying high-level photographs as they have been available from other sources, such as the nose cone photographs and so on.

There is a mosaic of a series of nose cone photographs taken by an Atlas shot, launched October 24, 1959. It shows a considerable amount of detail on the photograph.

Of interest to us here is the transposition of the cloud data onto this map as shown in the blue here, and its correspondence with the weather data of that date. You will notice the correspondence between the stationary front and cloud data here; the equatorial trough and the convergence of the circulation from the Northern and Southern Hemispheres and the easterly wave, and the cloud cover picked up by the photograph itself.

This analysis was made by the scientists at the General Electric Co. who were associated with this particular experiment.

However, the meteorologists at the Weather Bureau are studying some of the detail of this structure that do not correspond directly with the gross analysis made previously in order to see whether there is any additional information to be gleaned from data of this kind.

In addition to analysis of cloud photographs, they have studies of radiation and data transmission and dissemination, in order that when the data become available, a minimum amount of time would lapse between the getting of data and its usefulness.

Mr. FULTON. With respect to that photograph there, obviously, if you have an Atlas missile you have a ballistic trajectory at a certain point. How do you cure the distortion that would occur in order to get the picture that you have there, that is perfectly balanced?

Dr. TEPPER. I don't know how long the entire picture sequence took, but this particular picture was taken in the neighborhood of 300 miles. This is not the entire trajectory.

I mentioned before following the Tiros experiment will come the Nimbus program. This is to correct two of the major difficulties, two of the major faults of the Tiros program (fig. 70).

Tiros, which is represented to the left, has these two features: An inclined orbit, roughly going to 50° north, 50° south, which does not

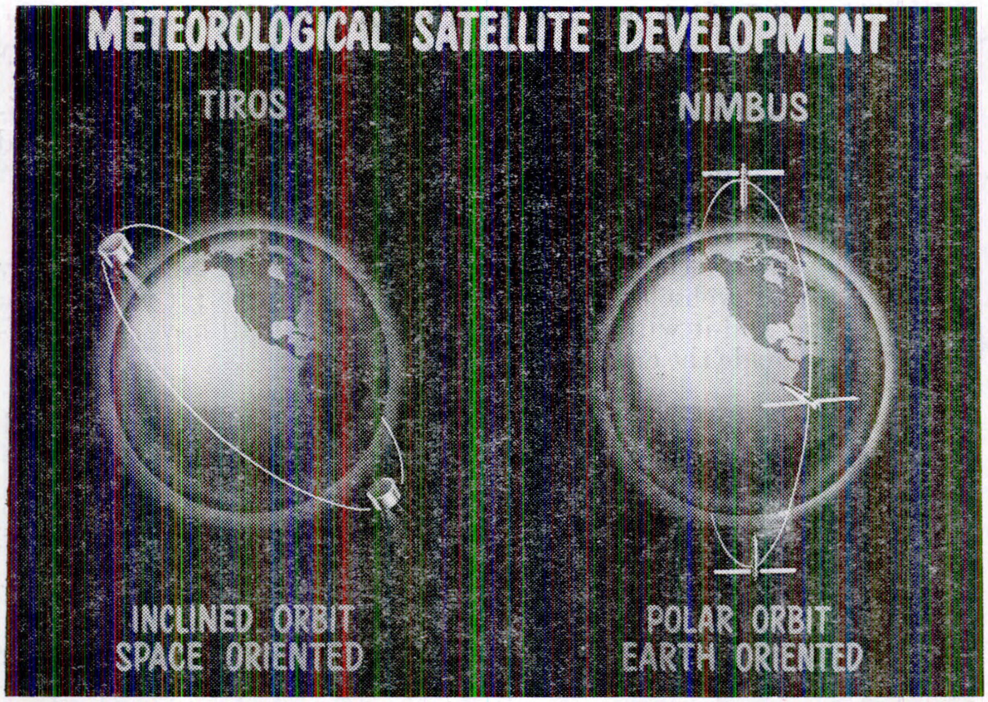

FIGURE 70

permit us to view the events poleward. Sometimes it looks at the Earth and sometimes it looks out into space.

In order to correct that, the Nimbus program represented here will be in polar orbit and will then be able to cover all latitudes and it will be Earth-oriented so it will be facing the Earth at all times and giving us maximum possible acquisition of data during its travel around the Earth.

Of course, it will still be dependent upon the illumination by the Sun, but this, too, we hope to be able to get around eventually by using other techniques.

Mr. FULTON. Why, if you are going to orient it, for example, on the Sun, why then can't you have it move in an orbit which will have it reflected toward the Earth's surface?

If you have a particular set point that you are able to have it revert to, why can't you have a mechanism that can move it on some sort of a pivot. You could have it set on the Sun at some fixed point. Then, as it goes around the Earth, have it revolve so that it aims toward the Earth's surface rather than out into space, sometimes. Why couldn't you do that?

Dr. TEPPER. Are you referring to Nimbus or to the Tiros?

Mr. FULTON. The Tiros.

Dr. TEPPER. In order to stabilize it on launch, it has to spin around and keeps this orientation throughout its history.

Mr. FULTON. Yes, but I think it would be fairly simple if you could have a point it would have a reference to when it is in orbit, that you could then have it aiming toward the earth's surface all the time.

What percentage of the orbital equipment will be facing right out into space and doing you no good?

Dr. TEPPER. I think you are referring to a stabilization technique, or an orientation technique. Well, this is what we are going to try to do in Nimbus: orient it so it is facing the earth at all times.

Our first experiment is—well, it is a first experiment and it is launched in the simplest manner, spin stabilizing it and keeping a fixed orientation.

Mr. FULTON. You are doing that with Nimbus?

Dr. TEPPER. Yes, Nimbus will always look at the earth.

This is an artist's conception of Nimbus and it will be launched by a Thor Agena–B vehicle. It will be about 650 pounds; it will be in a 600-mile orbit and it will have these wings which will have solar cells on them to provide the energy (fig. 71).

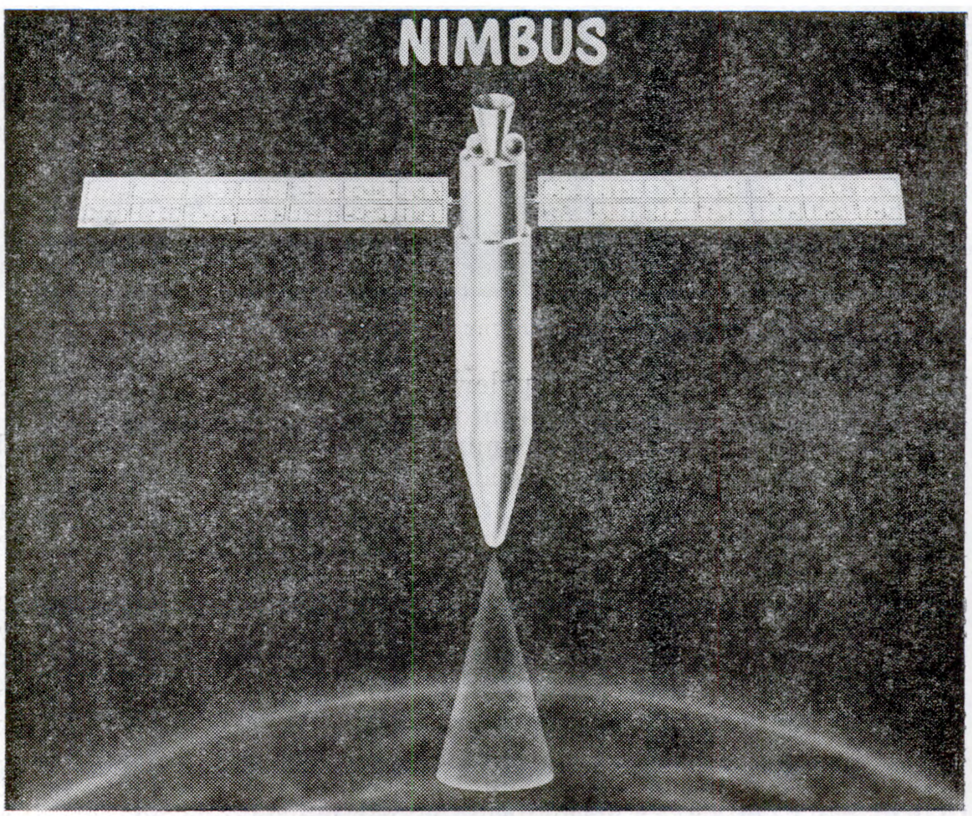

FIGURE 71

It will have advanced instrumentation, but similar to the kind on Tiros. Later versions of Nimbus might have the spectrometer, or the radar.

As I mentioned, the two major features that indicate improvement of Nimbus over Tiros, are its pole-to-pole transit and that it will be earth oriented, looking at the earth all the time.

This then briefly is the meteorological satellite program.

Now, in the communications satellite program, just to review the presentation of last year, there are two types of communications satellite. One is an active repeater, one that contains electronics aboard, receives information from the ground and retransmits it. The other is the passive satellite from which signals are merely reflected back toward the Earth.

The Department of Defense is engaged in the active satellite field and NASA is looking during these early stages to the Department of Defense for the first developments in this field; NASA is primarily concerned now with the passive communications satellite.

The project which I will discuss is Project Echo.

The reflector to be used in this experiment is a hundred-foot sphere which will be launched in about a 900-mile circular orbit around the Earth. It will consist of mylar about a half a thousandth of an inch thick with a weight of 136 pounds (fig. 72).

In order to test this sphere, as a communications satellite, there will be a signal transmitted from Goldstone, Calif., and reflected to the receiver at Holmdel, N.J. Experiments will also be done in the other direction from the transmitter on the east coast to the receiver on the west coast.

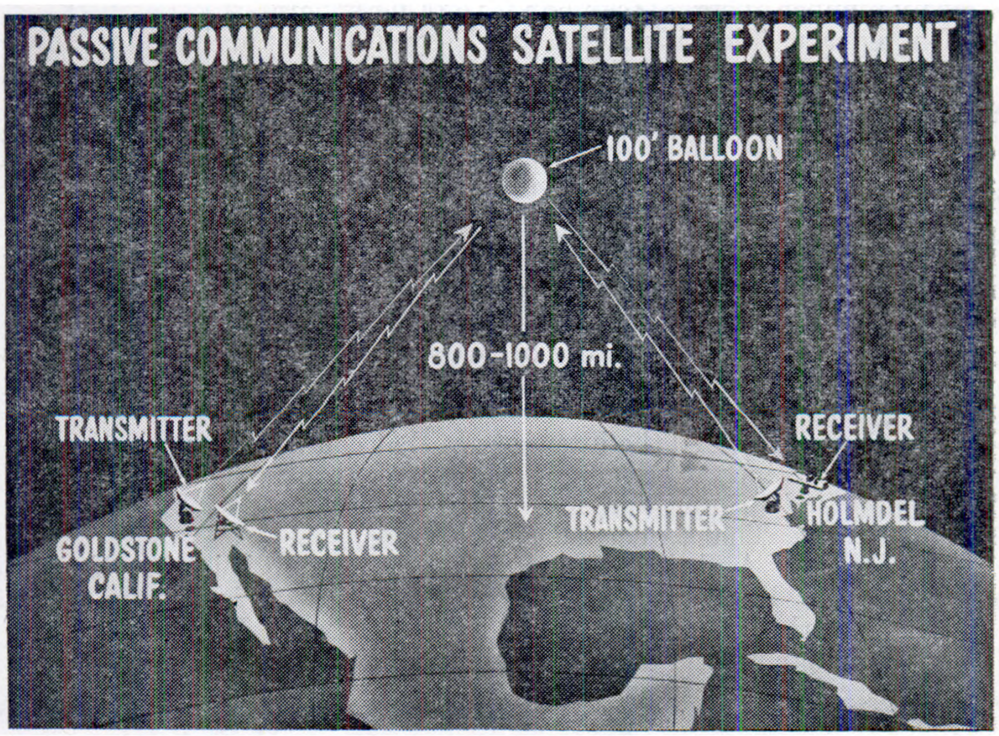

FIGURE 72

Mr. FULTON. Actually, any nation could use that then and there is no way we could prevent it?

Dr. TEPPER. That is right.

Mr. FULTON. Secondly, could another nation jam what you are doing?

Dr. TEPPER. This is a completely passive satellite, like the Moon. Anybody can use it.

Mr. FULTON. On your reflected signal, what could the other nation do to jam what you are doing? Do they have to interfere with line-of-sight communication?

Dr. TEPPER. There isn't anything that I can think of that they could do in order to interfere with any signal sent from one receiver to the other side.

Mr. FULTON. How many signals then could be received or transferred?

Dr. TEPPER. There is no limit to the use of this.

Mr. FULTON. The transmitters' radio wave bands would be the only limiting feature?

Dr. TEPPER. That is right. To clarify this point on intentional interference or jamming of communications via such spheres, this would be extremely difficult to do. To effectively interfere one would have to use an excessive amount of power spread out over the frequencies on which communications were taking place. The unlimited range of frequencies which is afforded the communicator using such spherical satellites makes it virtually impossible for anyone to muster up enough power to cause interference.

Mr. FULTON. Your transmitter is on a certain band. It is the number of bands that limit it and not the transfer to the sphere.

Any number of signals can bounce off that sphere.

Dr. TEPPER. That is right. But I say in this experiment what we are going to do is send it from one part of the country to the other, in order to test this type of a configuration.

The CHAIRMAN. Any interference would not affect the sphere, but it would affect the means of bringing the signal from the sphere back to the Earth, or taking the signal up to the sphere.

Mr. FULTON. That is what I said. There can't be interference. Only if you are on a narrow band, it can then only be through cutting that almost line-of-sight projection.

The CHAIRMAN. Is that right? Is it true nothing could be done there to interfere with the use of the sphere, because it is passive, as you say?

Dr. TEPPER. That is my understanding.

The CHAIRMAN. All the interference that could be set up in the case of communications would be on the wavelength being used to reach the sphere and then reflect back. That is correct, isn't it?

Dr. TEPPER. That is correct.

Mr. FULTON. And that, almost, has to be cutting it in line-of-sight, does it not? You are using a narrow band to go from your transmitter up to the reflector and down to the receiver. In order to cut off that particular message, as the chairman says, you would have to cut that particular message as it travels.

Dr. TEPPER. That is right.

Mr. FULTON. So it would be really a very narrow line-of-sight cutting and it would be very hard to do. Is that right?

Dr. TEPPER. Yes.

In all satellite experiments, we try to test out the satellite under space conditions, as much as possible.

Obviously it is not very feasible to try to test out a 100-foot sphere in space conditions, on Earth. We have arranged for a series of vertical launchings of this sphere in order to test the configuration of the payload passage and the inflation technique.

We have a short film——

Mr. FULTON. Before you leave that, you could really have any number of receivers and any number of transmitters within the United States that could send messages back and forth, or really make a zigzag pattern up and down and relay it?

Dr. TEPPER. The only limit would be in the amount of energy you could transmit and how much would come back eventually after going through all these transits.

The CHAIRMAN. There is nothing exclusive, though, in the use of that sphere. Anyone could use it, either friend or foe.

Dr. TEPPER. That is correct.

Mr. FULTON. Practically, we could use it for both military and civilian purposes and carry thousands of messages per second on a 100-foot sphere.

Dr. TEPPER. Hopefully, yes.

Mr. FULTON. So if you put up various hundred-foot spheres in orbit and have them all so they were within a line of sight to a certain tangent, air to surface, three of them would pretty well cover the Earth.

Dr. TEPPER. I will show you a slide a little bit later, and indicate that it will require 25 to 26 at 3,000 miles altitude, if they were distributed in a random manner, and we would have to consider that they would be. It would require that many in order to have a 99-percent probability of having a satellite available for communication at any given time.

The CHAIRMAN. Would that sphere stay in the same relative position?

Dr. TEPPER. Oh, no.

The CHAIRMAN. It would vary?

Dr. TEPPER. It would be in orbit. This is a 900-mile orbit. You have to get it up to about 23,000 miles or so, in order to keep it in stationary position over the Earth.

The CHAIRMAN. If you send a signal based on reflection from that sphere you would have to catch the sphere in the right position?

Dr. TEPPER. Relative to the station, yes.

Mr. FULTON. Actually, what you are doing then on the orbit that you are proposing, with some variation, is putting one of these hundred-foot spheres about every 1,000 to 1,200 miles.

Dr. TEPPER. That is roughly correct.

Mr. FULTON. Every thousand miles you get one of these, right around the Earth.

Dr. TEPPER. Yes, sir.

I would like to show you now the preparation for and the launch of the vertical test shot for Project Echo.

[Whereupon, a moving picture was shown.]

Dr. TEPPER. This is the inflated sphere. The hangar is somewhere in North Carolina.

Here we see the satellite folding table, some 150 feet long and the sphere being folded into about 400 pleats. This is the 26-inch-diameter container that contains the sphere. Here the sphere is being folded into the container. The top part of the container is now being put over it.

This is the telemetry that will be included in order to report back the events of the experiment.

Next you will see the second stage which will launch the sphere. It is the same rocket that will be used in the final shot.

The sphere is now placed on top of the second stage.

Here we have the launch site at Wallops Island, with the first stage in place and the second stage being placed on top of it.

The sphere is protected by fairing during flight.

The first launch was in October of last year and the second in January of this year. They were launched in the evening so that the sun's light could be reflected off the sphere for visual observation.

Here we see the first stage ignition. The vehicle is spinning for stabilization.

In a minute you will see the balloon being ejected.

Here it is being ejected.

[End of film.]

Dr. TEPPER. Here we have some models of the sphere. This is the container into which it will be placed and this is a transparent plastic container showing you how the sphere is folded. You will note it is folded inside this container. This is the satellite that will be launched and then it will be inflated.

The CHAIRMAN. That is the original that is going to be launched?

Dr. TEPPER. Oh, no.

The CHAIRMAN. That is just a sample?

Dr. TEPPER. It is one of several which were fabricated for the development of this payload. Of course, the plastic container is for display so that we can look inside.

This is being built by the Bell Telephone Laboratory at the east coast (figs. 73 and 74).

NASA provides direction, payload, development, tracking, and orbit calculation (fig. 75, p. 376).

We have the Jet Propulsion Laboratory for the west coast site.

The Bell Telephone Laboratories for the east coast site.

The Lincoln Laboratory provides the Millstone radar for tracking.

Industry provides the mylar spheres, radio beacons and so forth.

The military services' research and development organizations are participating in individual experiments of their own with this sphere, and the radio industry at large is also setting up experiments so that when the sphere is launched, they can utilize the sphere for their independent experiments.

This slide illustrates the very thing Mr. Fulton was talking about before. At any time the sphere can be seen only in a certain radius, a region on Earth. As it moves, this area where it can be seen by any

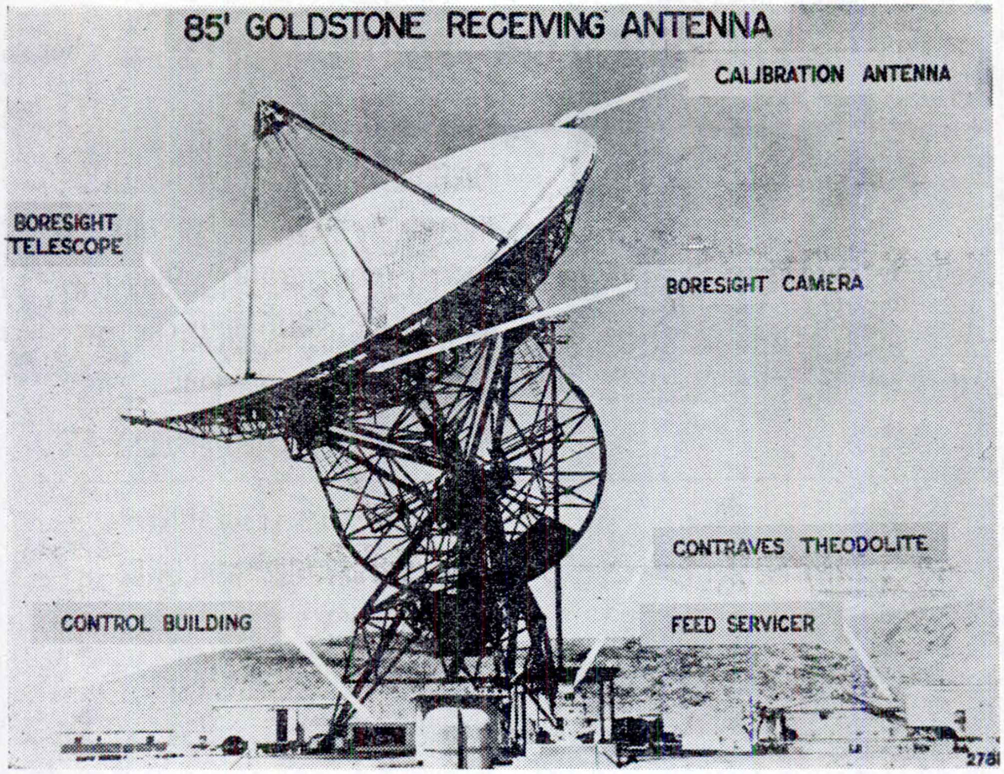

FIGURE 73

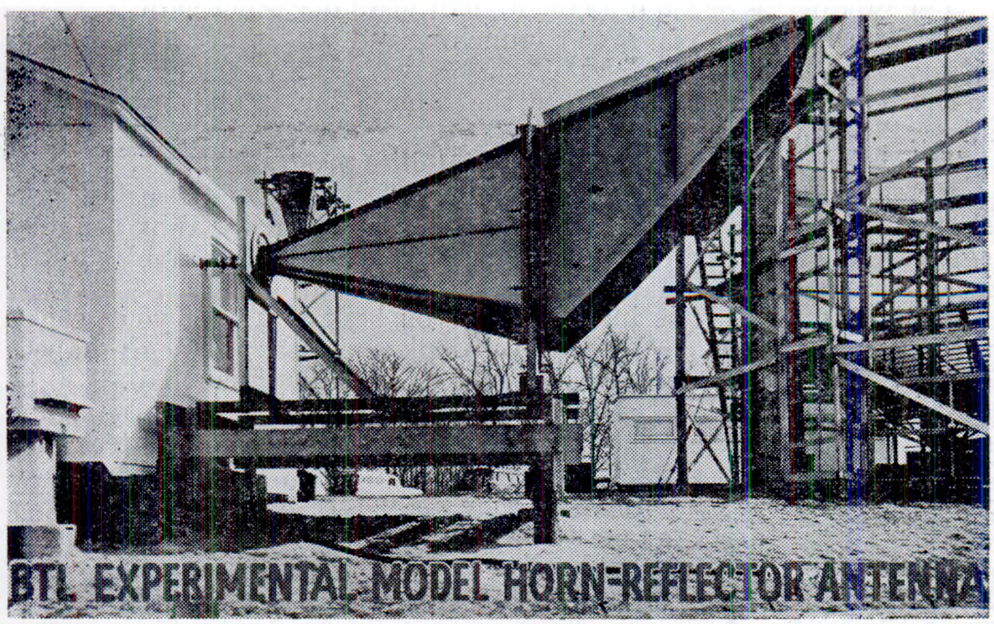

FIGURE 74

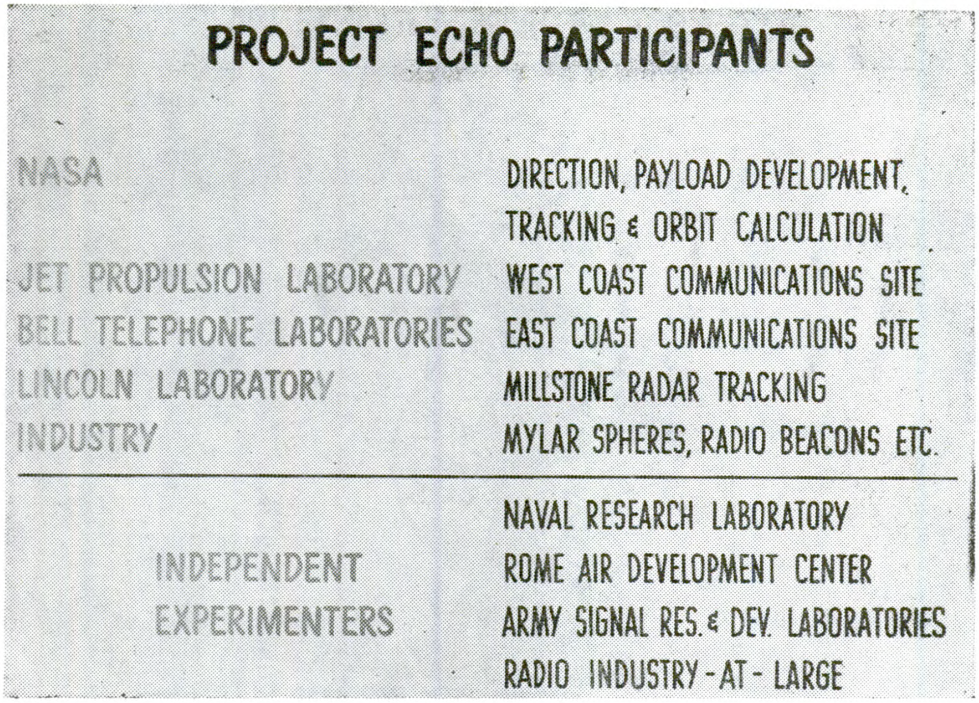

FIGURE 75

two stations also moves, so that in an operational system you have to have a number of such satellites in space. This brings us to the problem of the possibility of launching multiple satellites from one launch vehicle and having them separate in space once they get up there (fig. 76).

Mr. FULTON. Why are all the spheres silver and one is red.

Dr. TEPPER. This is to have a place to point to, to talk to.

You talk to this one and its red area of visibility is out here.

Mr. FULTON. But you aren't launching red ones, you are launching silver.

Dr. TEPPER. They will all be the same color. They will all be silver.

This is briefly the communications satellite program.

Mr. FULTON. Let me ask you this. It looks like those are egg-shaped at the outer reaches of where they will reach. Why are they egg-shaped rather than circular? The pattern on the Earth's surface is a——

The CHAIRMAN. It is just the way you look at it. If you project that right, they are circles. If you look at it flat, it is egg-shaped.

Mr. HORNER. That is because of the projection of the map.

The CHAIRMAN. Well, Doctor, you have certainly given us a fine statement. I wish that the whole membership of the committee could have heard you, but they will have an opportunity to read your statement. It will be printed, so if they are interested, they will really have full opportunity to take advantage of that.

Mr. FULTON. Why do you have to have so many?

Dr. TEPPER. Why do you have to have so many of these?

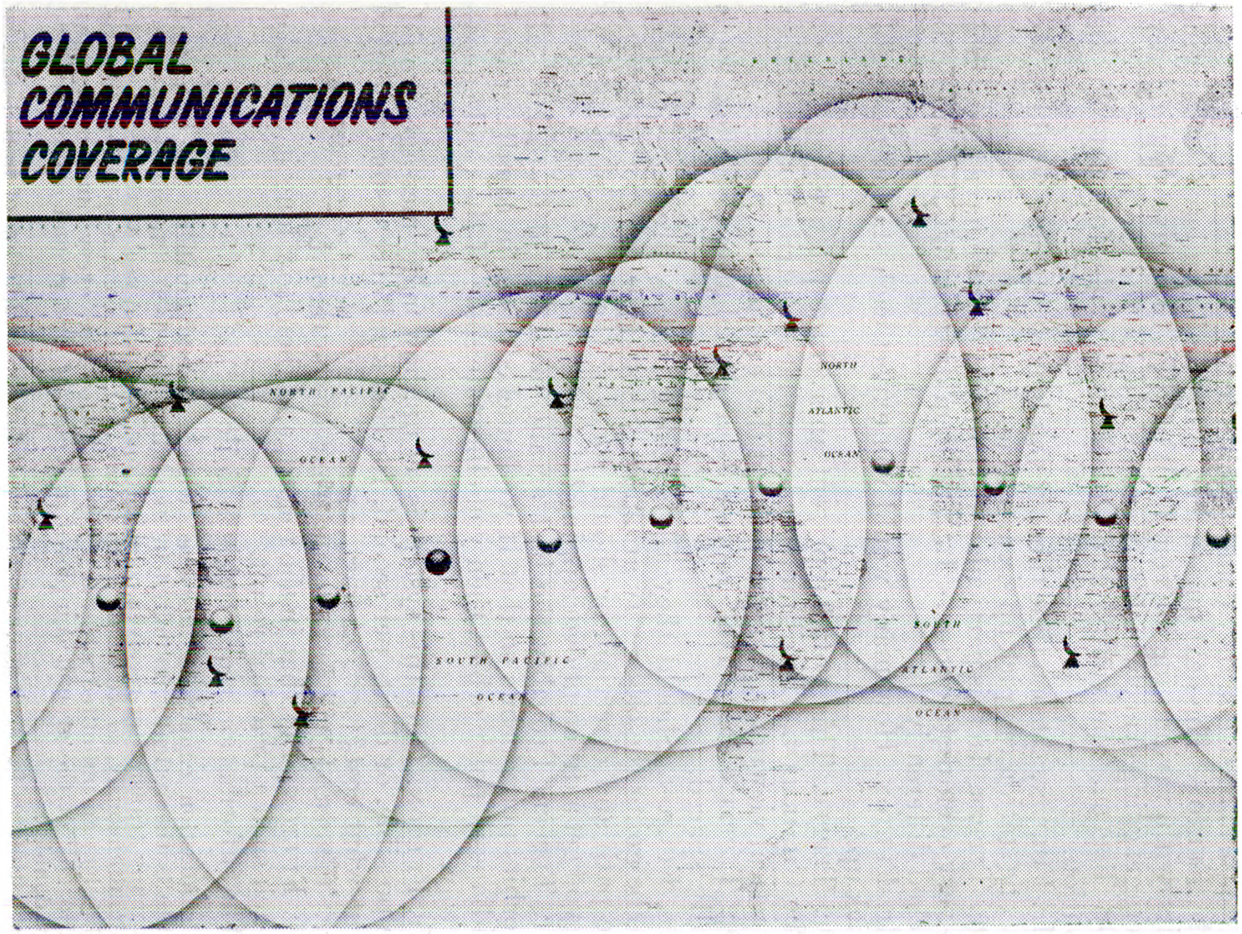
GLOBAL COMMUNICATIONS COVERAGE
NORTH PACIFIC
OCEAN
SOUTH PACIFIC
NORTH
ATLANTIC
OCEAN

FIGURE 76

Mr. FULTON. Yes. You will have 25 or 30 going around the earth in orbit.

The CHAIRMAN. There are only 12 there.

Dr. TEPPER. This is in order that any two stations can communicate with each other 99 percent of the time. If you didn't have this many, then at some time, these two stations would not have a satellite available to them by which they could communicate.

Mr. FULTON. The next question is, Why don't you have intersecting orbits with various inclinations? Wouldn't that give you a better coverage, going every which way around the Earth?

Dr. TEPPER. The computation of 26 was made for random distribution.

Mr. FULTON. At one time then, if you look at it, there would be six. Any one station can pick up six at a time.

Dr. TEPPER. In this particular distribution that we have here. This is a very even distribution. In a random distribution, they might be bunched differently.

Mr. FULTON. How many would you expect each station to be able to pick up?

Dr. TEPPER. This would represent an average picture.

The CHAIRMAN. This is more or less an ideal distribution, but from a practical viewpoint, you wouldn't get that evenness.

Dr. TEPPER. Yes. This represents a distribution, if they were equally spaced.

Mr. FULTON. Should they all be going in one direction or could some be going the other way around? Should the orbits all have the same path and direction, or should some of the orbits be shifted so that you get a different overlapping?

Dr. TEPPER. Probably the best arrangement would be to have all the orbits polar orbits so that if we launched them in equally spaced meridians in polar orbits, then you eliminate some of the randomness this way.

Mr. FULTON. Once this system is set up, how many messages would it be possible, or digits per second, for this kind of a system to carry and at what cost?

Dr. TEPPER. I will have to put that in the record.

Mr. FULTON. Put that in the record, and then how long it will take to reach such a practical result.

(The information requested is as follows:)

This question cannot be answered with a simple number. The spherical satellite is theoretically unlimited in its ability to reflect different frequencies. Thus many transmitter-receiver combinations can make use of the same satellite simultaneously, so we would have to say that, in theory, a spherical passive satellite has an unlimited message capacity. However, every time one doubles the capacity of the ground equipment, the cost of this ground equipment virtually doubles.

Cost estimates for such systems must wait for the completion of initial phases of the research and development. We must first determine just what is required to place such a structure in orbit and to keep it there for long periods of time.

The CHAIRMAN. Why do you work on this type system that requires so many spheres? Why would it not be better to work on a system where you would have stationary satellites at 18,000, 20,000, or 22,000 miles and have much fewer, too, and more dependable ones? Wouldn't that be a better arrangement?

Dr. TEPPER. I think we ought to consider that at this stage it is only an experiment as yet. In experiments you try to keep at a minimum the number of difficulties you have to contend with. This type of a launch at this altitude is much more simple to accomplish than the one that is a stationary orbit at 22,000 miles.

The CHAIRMAN. The altitude is really the governing factor then?

Dr. TEPPER. Partially. The altitude. The equatorial launch itself presents a difficulty. Another reason is that the power required to communicate via a 24-hour satellite is 100 times that required if the satellites were placed in a 2,000-mile-high orbit.

The CHAIRMAN. Is that going to be equatorially launched or is that a polar launching?

Mr. FULTON. That is 50° up from the Equator.

Dr. TEPPER. It will be an inclined orbit.

The CHAIRMAN. 50° above and 50° below?

Dr. TEPPER. Yes.

The CHAIRMAN. Rather than what you suggested which would be around the pole?

Dr. TEPPER. Again, this is a first experiment of this kind, and subsequent experiments will be pole to pole.

Mr. FULTON. If the polar orbit is better, why don't you try it first?

Dr. TEPPER. The pole to pole launch facility was not available to us.

Mr. FULTON. Vandenburg Air Force Base was not——

Dr. TEPPER. At the time these programs originated, you planned them and developed them, with what was available and what you had. In other words, there is a leadtime concept involved here.

The CHAIRMAN. You couldn't adapt it now to use at Vandenberg?

Dr. TEPPER. It is problematical whether the amount of complication you are introducing here would compensate for what you are gaining just for this particular item, this one thing.

In other words, this can be a very useful experiment and very helpful the way it is.

The CHAIRMAN. You know this is a preliminary experiment and what you want to do is launch the experiment and then provide for the future, on the basis of the findings from the experiment.

Dr. TEPPER. Yes. Subsequent Echo shots will be pole to pole.

I think the third one—there are three in this series, the third one will be a polar launching.

The CHAIRMAN. Are there any further questions?

Mr. FULTON. One more. Do you see any need for Christmas Island, that we should purchase Christmas Island as a satellite and sphere launching area? Have you heard of that?

Dr. TEPPER. Yes.

Mr. FULTON. Put that in the record.

The CHAIRMAN. Yes, I think so.

(The information requested is as follows:)

We can only say that ultimately it will be desirable to put some communications satellites in equatorial orbits. An equatorial launching site would for this mission minimize the requirements on the vehicle performance. As vehicles become more reliable and their controls more sophisticated it will certainly be possible to launch satellites into an equatorial orbit from a nonequatorial launch site at some cost in vehicle performance.

The CHAIRMAN. The reporter is worn out. He has been working all day.

Mr. FULTON. Look at the money he is making.

The CHAIRMAN. For the benefit of all the members of the committee who are present, we will meet tomorrow in our regular committee room.

Mr. FULTON. I want to say from the Republican side that we unanimously thank you for your good chairmanship today.

The CHAIRMAN. Thank you very much.

The committee will adjourn until 10 o'clock tomorrow morning.

(Whereupon, at 5:10 p.m., the committee adjourned to reconvene at 10 a.m., Tuesday, February 2, 1960.)

THE NASA SATELLITE APPLICATIONS PROGRAM

Gentlemen, after having heard the presentations so far, you may be wondering somewhat whether the exploration of space does not have a more practical side—something closer to our activities as individuals. This is indeed the case, as I expect to show during the next half hour, as I present the NASA satellite applications program—a program involving satellites that will have an impact on the day-to-day living of all of us.

Last year, we presented the general aspects of the program on which we had embarked.

Today, I would like to acquaint you with our progress during the past year, our activity of the present, and our plans for the immediate future.

The three primary fields of satellite applications to which I shall refer are the meteorological, the communications, and the navigation satellites (fig. 64, p. 361).

The first chart states very briefly our objectives in these fields. They are:

Meteorological: To develop a satellite capability for providing worldwide meteorological information.

Communications: To develop a satellite capability for making worldwide communications.

Navigation: To develop a satellite capability for making possible all-weather navigation at low cost.

I shall now discuss each of these programs in turn.

METEOROLOGICAL SATELLITE

Our meteorological satellite program has been designed to acquire certain information needed by meteorologists in order to adequately describe and understand atmospheric processes and to predict the weather. This information includes:

(*a*) Cloud observations, both day and night, on a global basis.

(*b*) The heat budget of the earth and atmosphere.

(*c*) Indirect measurements of the temperature structure and composition of the atmosphere.

(*d*) Radar coverage, giving worldwide precipitation information.

The next chart (fig. 65, p. 362) shows the kinds of instruments being considered for inclusion on board satellites which will provide this information:

(*a*) Photocells and television—storm location, cloud cover, cloud type, and cloud motion.

(*b*) Scanning infrared radiation detectors—average temperature of the earth's surface and lower atmosphere, temperature of cloud tops.

(*c*) Nonscanning infrared radiation detectors—gross heat budget measurements; i.e., reflected solar radiation and radiation from earth and atmosphere.

(*d*) Spectrometer: Composition of atmosphere, water vapor, ozone, carbon dioxide, and stratospheric temperatures.

(*e*) Radar: Rain and snow areas, heights and intensity of their layers.

The next chart (fig. 66, p. 363) shows the rate with which we are accomplishing our program.

During the past year, we had two successful launches of satellites containing major meteorological instrumentation.

Vanguard II contained a scanning photocell for mapping areas of high reflectivity (essentially cloud cover). As has already been explained, a wobble developed upon launch and we are experiencing some difficulty in reducing the data.

Explorer VII, which is still providing useful data, contains, among its other scientific instrumentation, a nonscanning IR radiation detector system for heat budget measurements.

Currently, we are actively preparing for the launch this calendar year of Tiros I and II. Tiros I contains two television camera systems for cloud cover photography and Tiros II, the later version, will have in addition both scanning and nonscanning infrared radiation detector systems.

Our future program, the series of satellites designated Nimbus, will contain improved instrumentation growing out of our experience with previous satellites. Hopefully, later versions of Nimbus will carry new instrumentation such as a spectrometer or a radar on board.

On the next chart (fig. 67, p. 364), we have an artist's drawing of the Tiros satellite. The following are its characteristics:

1. Launch vehicle: Thor-Able II (Tiros I), Thor-Delta (Tiros II);
2. Stabilization: Spin stabilized;
3. Weight: 270 pounds;
4. Size: 42-inch diameter, 19 inches high;
5. Orbit: 380 nautical miles, circular;
6. Inclination: About 50° to Equator;
7. Lifetime: 90 days;
8. Instrumentation: Two television systems, scanning and nonscanning IR and associated electronics;
9. Power: Solar cells and storage batteries;
10. Launch: From AMR;
11. Tracking: Minitrack and Millstone radar; and
12. Data acquisition: U.S. Army Signal Corps Station at Fort Monmouth, USAF station at Kaena Point, Hawaii.

Participation in Tiros has been extensive (fig. 68, p. 365). Tiros was initially begun in the Department of Defense. On April 13, 1959, overall project direction and coordination was transferred to NASA.

U.S. Army (USASDRL and contractors from industry—primarily RCA): Development of payload and selected ground equipment, data acquisition, and data transmission.

U.S. Air Force (BMD and contractors from industry—STL, Douglas, and Lockheed): Development of launch vehicle, mating of vehicle and payload, launch, data acquisition. AFCRC will assist with data analysis and interpretation.

U.S. Navy (NPIC): Will assist in the photoanalysis.

U.S. Weather Bureau: Data analysis and interpretation, data dissemination, and historical storage.

In addition, NASA has organized the Joint Meteorological Satellite Advisory Committee (JMSAC) with membership from ARPA, Army, Navy, Air Force, Weather Bureau, and NASA with the following objectives:

(*a*) To consider the requirements of the DOD and NASA in the meteorological satellite program;

(*b*) To serve as a medium of interchange of information among NASA and DOD members; and

(*c*) To assist wherever possible and appropriate in operating programs.

It is our intent that through the coordination of requirements in this committee, we shall be able to develop a true national meteorological satellite program, responsive to the needs of both the military and civilian users.

Meteorological satellite data, particularly the photographs of cloud cover, will present a new kind of data previously unavailable, to the meteorologists. In order to develop techniques of analysis and photointerpretation by means of which it will be possible to extract significant meteorological information from such photographs, meterologists are carefully studying all available photographs taken from high altitudes.

For example, during the past year, there have been several instances where a camera containing film was placed in a recoverable nose cone of an Atlas or Thor launch vehicles. Although the initial and primary purpose for the camera was nonmeteorological, it turned out that some very good pictures of the Earth's cloud cover emerged as a byproduct. On the next chart (fig. 69, p. 367) in the upper left-hand corner is a mosaic of several photographs taken at about 300 nautical miles elevation during the flight. The clouds were transcribed onto a map and are shown in tinted blue on the accompanying map.

50976—60——25

Superimposed on the chart is the weather situation for the day. We see how remarkable is the correspondence between the major cloud areas and the major weather storm regions—as shown by the stationary front, the equatorial trough and the easterly wave.

This very preliminary analysis was performed by the scientists of the General Electric Co.—the company directly concerned with the nose cone experiments. However, as you can see, there is a considerable amount of additional detail on this photograph. The Weather Bureau is studying these details in terms of meteorological significance.

The Weather Bureau is also conducting similar kinds of studies, though necessarily more theoretical in nature, in the field of radiation, data handling, data processing, and operational utilization of satellite data in order to be better prepared to interpret and use the data when they are available.

So much for Tiros and preparing for its data. What is beyond Tiros?

In order to understand better the direction which we are following in the follow-on to Tiros—it is important to understand two of the basic limitations of Tiros. The next chart (fig. 70, p. 369) illustrates these weaknesses. Tiros will be launched in an inclined orbit and will be space oriented. The former means that Tiros will reach a maximum northern and southern latitude (about 50°). It will view events primarily between these latitudes so that poleward from these latitudes we shall have little or no data from this satellite. Secondly, by being space oriented, Tiros views the earth only part of the time during its orbit. The rest of the time it looks glancingly at the earth or out into space. Our follow-on satellite, Nimbus, will correct this. It will be in a polar orbit and so will cover all latitudes from pole to pole; it will always face the earth.

The other characteristics of Nimbus are (fig. 71, p. 370)—

1. Launch vehicle: Thor Agena B;
2. Stabilization: Earth oriented, pneumatic and inertia wheel technique;
3. Weight: 650 pounds;
4. Orbit: 600 nautical miles, circular;
5. Inclination: Polar orbit;
6. Lifetime: 6 months;
7. Instrumentation: Advanced TV, scanning and nonscanning IR; spectrometer and radar on later versions;
8. Power: Solar cell and storage batteries; and
9. Launch: From PMR.

Maximum data acquisition from a satellite in a polar orbit would be from a station located at the pole or as close to it as feasible. Thus, we are looking into the possibility of establishing a station in high latitudes at which the Nimbus data might be acquired.

COMMUNICATIONS SATELLITES

To refresh your memory: Satellites which can be used to provide communications over large areas of the Earth can be placed into two broad categories—the active repeater satellites and the passive satellites. The active repeater satellites contain electronics and an appropriate power source which permit a radio signal, sent from one point on the Earth, to be received on board the satellite, amplified, and then to be retransmitted to a distant receiver. The other category, the passive satellite, is comprised of satellites which merely reflect back toward the Earth radio signals originating on the Earth (fig. 72, p. 371).

Because of some rather immediate tactical needs, the DOD has embarked on a program to develop certain forms of the active repeater communications satellite. NASA, as was implied earlier in the introduction, is interested in establishing the technology necessary to the design of the more general communications satellites for civilian and commercial use.

In the area of active repeater communications satellites, NASA is watching with interest and relying on the DOD programs to provide the early stages of development. NASA has established a research and development program in the area of passive communications satellites.

Our initial effort calls for the development of large spherical satellites and the investigation of this form of satellite as a communications medium. This program has been named Project Echo.

A 100-foot diameter inflatable spherical satellite, developed by our Langley Research Center will be placed in a circular orbit about the Earth at an altitude of approximately 900 nautical miles. The satellite is made of mylar, one-half thousandth of an inch thick, with a vapor-deposited coating of aluminum to provide reflectivity. It weighs approximately 136 pounds and has 31,416 square feet of surface area.

The satellite is evacuated and folded into a 26-inch diameter container such as this [model]. Here, we see a folded sphere in a transparent container as it appears prior to launching [model]. These mylar spheres were fabricated under contract by General Mills Co. and Schjeldahl Co. This entire package will be placed in orbit using a Delta vehicle, and then the container will be opened to release the sphere. Approximately 20 pounds of a sublimating powder, placed inside the sphere, will cause the satellite to inflate in the vacuum of space.

To investigate the characteristics of this satellite as a communications medium and to determine the condition of the sphere in orbit. Project Echo calls for a series of communications experiments between JPL, Goldstone, Calif., and BTL, Holmdel, N.J. Signals originating at Goldstone will be reflected by the satellite and received at Holmdel. Signals from Holmdel to Goldstone via the satellite will make use of a different frequency. These communications facilities are now under construction.

The satellite has undergone considerable ground testing; but the real test is to inflate the payload in space, for we do not have vacuum facilities large enough to inflate this structure on the ground as part of this development. The Langley Research Center has programed several ballistic launches of the 100-foot diameter sphere from Wallops Island. Two such tests have been performed: the first on October 28, 1959, and the second on January 16 of this year. We have prepared a short film showing the preparation for and the launching of the first of the two tests mentioned. I should like to show this film now.

[Film.]

This first scene shows the 100-foot diameter sphere inflated in a large hangar at Weeksville, N.C., to determine the quality of construction.

Here, we see the folding table. The sphere is first folded into a long thin shape, 153 feet long with over 400 accordian-type pleats.

Here, we see the payload container.

The sphere is then carefully folded into one-half of the container.

The other half of the container is put in place.

Here, we see being assembled the telemetry equipment which will radio back events during the flight.

Next, we shall see the second stage rocket. This, incidentally, is the same rocket we shall use to finally eject the payload into orbit on the Delta vehicle; thus, we are testing as nearly as possible the final configuration for the orbital experiment.

The payload is now being fitted onto the second stage rocket of the launching vehicle.

Here, the ballistic launching vehicle is being assembled at Wallops Island. The first stage is a Sergeant rocket.

The second stage and the payload are now being added. A protective nose cone has been added which will be jettisoned after the vehicle leaves most of the atmosphere.

The test was made just after sunset so that the sphere would be visible by reflected sunlight against a dark sky.

The rocket is fired. The vehicle is spinning to provide stability.

The sphere is ejected and inflated at an altitude of approximately 80 miles.

[End of film.]

This first test showed a fault in the payload, for the sphere ruptured on inflation. The second test suffered from a vehicle fault. However, the sphere was ejected and the data (which is still being analyzed) indicate that the payload fault observed in the first test may have been successfully corrected.

(Fig. 73, p. 375). Rather large ground facilities are required for the communications experiment and here we see one of two 85-foot diameter antennas which will be employed in Project Echo.

(Fig. 74, p. 375). A specially designed antenna is under construction for the experiment at Bell Telephone Laboratories in Holmdel. This antenna is designed to eliminate noises which are a result of the surroundings. The use of such techniques will permit the detection of extremely small signals.

(Fig. 75, p. 376). The participants in Project Echo are shown here. NASA is providing the management and the payload development, tracking, etc. Jet Propulsion Laboratory, west coast communications site and Bell Telephone Laboratories, the east coast communications site. Industry is providing many of the components; the mylar spheres, radiobeacons, antennas, transmitters, etc.

Last, but by no means least, are the independent experimenters. We have indicated that the military services will perform their own experiments but many other organizations will take advantage of the existence of this satellite and will perform additional radio propagation experiments. NASA is cooperating with these experimenters and their efforts, in turn, will augment the sum total of extremely valuable information to be gained from Project Echo.

NASA plans three launches of the 100-foot diameter sphere (the first, an inclined orbit and the last two, polar orbits) to determine the usefulness of such spheres as communications satellites and to determine the technology required to place and sustain such large structures in the space environment.

A single satellite of this type cannot comprise a satellite communications system, for as shown here (fig. 76, p. 377).

Even though with a single satellite, communications can be established between any two stations within a rather large area, as the satellite moves relative to the Earth its area of coverage moves with it. If continuous communication is to be maintained, a number of satellites will have to be in orbit so that at least one is always in sight of the two stations desiring to communicate. It would take on the order of 26 spheres in a 3,000- to 4,000-mile orbit to provide 99 percent availability, if the spheres were randomly spaced. Because of this requirement and the advent of larger boosters in the coming years, the follow-on program to Project Echo calls for the development of the ability to place a number of spherical satellites in orbit with a single booster vehicle.

Feasibility studies of larger structures and other, perhaps more efficient, reflectors will continue but the experience and technology to be gained in Project Echo will provide an invaluable foundation on which to build the required technology.

NAVIGATION SATELLITE

At the present, NASA does not have an active development program in navigation satellites. As you know, a navigation satellite system is being developed by DOD. We are keeping in close touch with these developments so as to be in a position to evaluate the usefulness of the system for civilian application.

The total funds required to carry out the satellite applications program, as I have presented it, are $26,300,000; of this, $20,700,000 is for the meteorological satellite program and $5,600,000 for the communications satellite program.