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Proceedings of the Second National

CONFERENCE ON THE PEACEFUL USES OF SPACE

Seattle, Washington May 8-10, 1962

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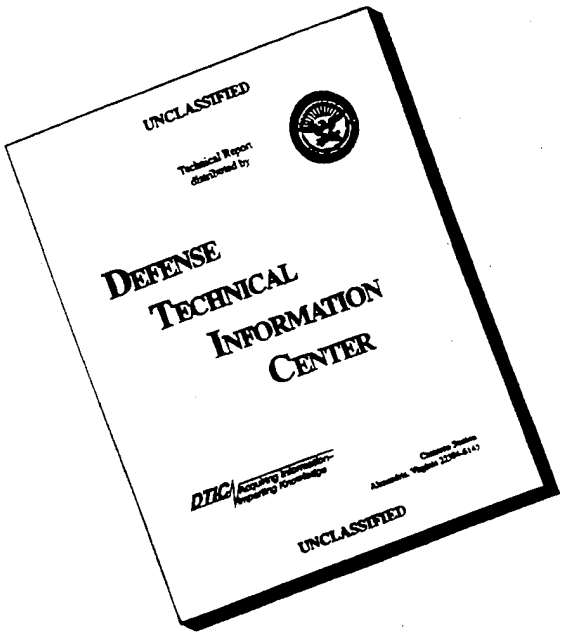

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Now comes the chance,
In one great leap,
To bridge the gap
To probe the deep,
To walk the moon
To touch a star—
Oh, man's dream,
For ages past,
To pierce the heavens' blue—
So deep, so vast.

MAX D. PAGLIN

Call to Order

Welcome

Keynote Address

Call to Order

By WILLIAM P. WOODS, *General Chairman of Conference*

Mr. Woods is president of the Washington Natural Gas Company. He was born in Selma, Alabama, and was graduated from the Alabama Polytechnic Institute in 1930. Shortly thereafter he entered the gas industry as an employee of an Alabama utility.

Mr. Woods became president of Conversions and Surveys, Inc., a wholly owned subsidiary of Stone & Webster Service Corporation in 1948. He was also a vice president of Stone & Webster Service Corporation from 1954 until 1960 when he assumed his present position.

Mr. Woods is a trustee of the Seattle Chamber of Commerce and a member of the Board of Directors of the Seattle Area Industrial Council. He is a member of the Board of Directors of the American Gas Association; the Board of Trustees of the Institute of Gas Technology of Chicago, Illinois; and the Board of Directors of the Association of Washington Industries. He is president of Century 21 Gas Exhibit, Inc., and president of the Association of Washington Gas Utilities.

On behalf of your host committee, the Seattle Chamber of Commerce, and our local Executive Committee, I would like to welcome you to the Second National Conference on the Peaceful Uses of Space and call this 3-day report to the Nation to order.

First, we have a telegram from President Kennedy which reads:

It gives me great pleasure to join Governor Rosellini and Senator Magnuson in opening this Second National Conference on the Peaceful Uses of Space.

Our pioneering effort to probe the mysteries of space and to apply this new knowledge for the benefit of all mankind presents many challenges. These go beyond our laboratories, the launching platforms, and industrial facilities. They reach the minds of all informed people, in this country and throughout the world, who need to understand better the new dimensions of the age of space.

The conference which you are attending in Seattle is an important contribution to better understanding of the problems we face and the opportunities now within our grasp.

Our nation is dedicated to the peaceful utilization of the knowledge acquired in this great effort. As we move forward on our own program, we will continue to press for cooperation with all nations in the exploration and the exploitation of space for peaceful purposes.

The United States is already working hand-in-hand with scientific groups of 50 nations. Ours is an open society and the benefits of our space program will continue to flow throughout the world. It is my hope that the Soviet Union will cooperate constructively in the proposals which we have made so that all peoples will gain in the improvement of weather observation, communications systems, and the manifold output of the peaceful application of space technology.

Though it was impossible for me to accept Senator Magnuson's kind invitation to participate in your meeting, I am pleased that Vice President Johnson, who heads our Space Council, will be present to share with you his great understanding of our national space program.

I am delighted that the people of Seattle have taken the initiative in calling this important meeting and that the Federal Government and many scientific and industry groups have cooperated in organizing the program. I hope that many other communities will take a similar active interest as we sail into the uncharted sea of space.

JOHN F. KENNEDY

As you can well appreciate, Seattle was quite pleased to receive the honor of hosting what has already been termed by the press the most timely and significant meeting planned for 1962. We are also pleased that the conference could be held during the running of our space-age-oriented World's Fair. The National Aeronautics and Space Administration is not alone in sponsoring this conference. The Seattle Chamber of Commerce is not alone as host. Realizing the broad recognition of the conference's value to the nation, several trade and scientific associations have joined with NASA as cosponsors. In addition, many local and national firms have stepped forth with financial assistance to share the cohost responsibilities. To these cosponsors and cohosts we extend our sincere thanks and appreciation.

Prior to the start of today's session, over 650 individuals have registered for the conference. The majority of these will be full-time conferees. Others will attend sessions by the day or by the session. Also in attendance will be approximately 170 members of the working press. The majority of these are from outside the Seattle area.

During the conference we will also play host to at least 6,000 high school and college science students and faculty members. We are also hoping students and faculty members will be able to sit in on the luncheon address Thursday. We also anticipate that another 6,000 World's Fair visitors will attend the conference as observers.

This Space Parley, as it is referred to in the newspapers, has funneled the entire eyes of the Nation in the direction of the Northwest. For the next 3 days Seatle will replace Cape Canaveral as the space capital of the Nation. It is obvious that people all over the United States are anxious to learn from this second report to the Nation; they are extremely interested to learn what has happened since the first report to the Nation which was held in Tulsa during May of 1961. I am sure nothing in this century has excited man's imagination as much as the exploration of space: what lies above the atmosphere and beyond, among the stars. One might say that we today, in our research of space, are much in the same position as man was in the fifteenth and sixteenth centuries when our great explorers were researching the world seas trying to learn what lay beyond man's knowledge.

Just what is happening in our efforts to conquer space? How will this research benefit mankind in everyday life? What lies ahead in this exciting frontier?

Reporting progress on these and similar questions will be the underlying theme of this conference, the most ambitious program of this type undertaken to date.

Welcome

By ALBERT D. ROSELLINI, *Governor of the State of Washington*

Governor Rosellini was formerly a state senator, Seattle lawyer, and deputy prosecutor. He earned B.A. and LL.B. degrees from the University of Washington.

In 1938 at the age of 28 Governor Rosellini was elected to the state senate to represent the 33d District. He served in this post for 18 consecutive years and during most of this time was Democratic floor leader. During this time he also left the prosecutor's office to enter private practice. He was elected governor in November 1956.

I am happy to have the opportunity to welcome all of you to Seattle and to the State of Washington.

We are especially pleased to have you here to attend the Second Annual Conference on the Peaceful Uses of Space. We feel privileged that you chose Seattle as the site for a conference to bring the public up to date on the civilian space program in these United States.

Your meeting here is most appropriate because of the Seattle World's Fair and its space-age theme. Science, as you know, dominates the fair. The theme is most evident in all of the fair's symbols—the space needle, the monorail—and certainly in its main attractions, which are the Federal Science Pavilion and the exhibit of the National Aeronautics and Space Administration. The pavilion portrays the advance of mankind since the dawn of civilization, and the NASA exhibit portrays the story of man's penetration of space.

One of the most delightful functions that a governor has the opportunity to perform is to extend welcome to visiting people, because at that time we have the opportunity to do what we like to do best, and that is to brag, so to speak, about our own state. I am not going to do that, however. I am just going to ask that you people, while you are here, in between your busy sessions, take the opportunity to see a little of Washington. I am sure that you will be convinced that it is a beautiful state, a desirable place in which to live, one with schools, the finest universities, and great livability.

I do want to take a moment, however, to comment on the relationship of science with government and politics. Science aims at understanding nature and enlarging the bonds of human knowledge. Technology seeks to increase man's control over nature and enlarge his capacity to fulfill his practical goals. One of these practical goals is the pursuit of common good, which is also the purpose of politics.

The politician is concerned with science, as he is with every aspect of society that is related to the public interest. Science and technology serve the common good. Thus, the politician currently is deeply involved with science, especially on the national level. It is imperative to the future welfare of this country that the scientist become equally involved with politics. The man of science no longer

can say that he has no responsibility for the use made of the knowledge that he provides. The direction of research and development is now a matter of important national policy, and I am sure you are more aware of this than I.

I take a moment to quote from a recent magazine article by Wallace Sayre, who said:

> As politicians in a democratic order, [scientists] are effective in the degree to which they understand the political process, accept its rules, and play their part in the process with more candor than piety, accepting gladly the fact that they are in the battle rather than above it. The spokesmen for science have occasionally lectured the nonscientists, sometimes sternly, upon their obligation to understand science. Perhaps the advice may be reversed: The scientist has an obligation to understand, and to play his significant role forthrightly in, the polity.

In other words, I am urging each of you to involve yourselves in the political processes of this country. Like it or not, you belong to politics. You cannot escape it and you have an obligation as scientists to enter into the political affairs of your communities. This will not be an easy thing for you to do. There are many problems which you must solve as an individual and as a member of a profession. That it is necessary for you to meet these problems is becoming more apparent each day to those of us now charged with the responsibility.

There is a great cultural lag between technological and sociological progress. This lag in recent years has been widening and has placed severe stress on communication and the ability of lay citizens to understand. Yet science in the final analysis depends upon the lay citizen.

I know that we all recognize that in our complex social organization the lay citizen provides the support for many of the things upon which science depends—for instance, the universities, government research funds, grants, and the market for goods. And unless leaders in science take part in politics, decisions vital to them will be preempted by selfinterest groups with perhaps greater skill in publicity.

We are experiencing a social revolution of major proportions. This revolution, which stems from science and technology, is accelerating. The revolution will create matters of great importance requiring wise public action.

The scientist is struggling with the problems of the relationship of science to politics. He is troubled. The politician is struggling with the problem of developing a national science policy. And he also is confused and troubled.

If solutions to these and other problems are ever to be found they must be sought by scientists in the area of public relations. I urge you, therefore, to enter into politics with the same enthusiasm, with the same humility, and certainly with the same intense desire to learn that you would apply to a problem in your particular branch of study.

I know that you will have a most successful conference here; I do hope you take this opportunity to see Washington State.

May I extend to you, on behalf of all of the people of the State of Washington, a most sincere welcome and our best wishes for the success that I know you will have.

Keynote Address

By **WARREN G. MAGNUSON,** *Senior U.S. Senator from the State of Washington*

Chairman, Senate Commerce Committee; member, Senate Appropriations Committee; member, Senate Committee on Aeronautical and Space Sciences.

I want to welcome you to our Seattle World's Fair for the Second National Conference on the Peaceful Uses of Space.

It is fitting that you meet here, because already we have reached out into space twice peacefully, getting this fair underway.

The first occasion was when my speech for the ground breaking of the U.S. Science Pavilion came to Seattle from Washington, D.C., by way of the moon.

One of the gentlemen in the audience, Bob Bright of the American Telephone and Telegraph Company, worked to make that feat possible. He worked to set another first when the fair was opened, because the President, pressing a historic golden key at Palm Beach, Florida, activated two of our radio telescopes. They in turn intercepted radio waves from Cassiopeia A. Those radio waves—already 10,000 years old—proceeded over the lines to the fair and started this exposition—with its man-in-space theme—on its 6-month run.

Having twice made peaceful use of space, our fair makes a fine setting for this meeting.

Most of the delegates must feel thoroughly at home. You are surrounded with the products of your ingenuity, your work, yes, your dreams, because you had much to do with designing and building the items which are making the hits in the National Aeronautics and Space Administration Exhibit and in the U.S. Science Pavilion.

We want you to take time, while in Seattle, to see all of the fair.

If your assignment happens to be Cape Caneveral, then I want you to watch the pride in the eyes of the lads when they inspect the boosters and capsules in the NASA exhibit. Their reaction will spur you on in your job. If you work in the laboratory, spend some time in the U.S. Science Exhibit. Look closely as the boys and girls watch the science experiments. You—in your work—have instilled the urge to learn and study in others. Soon, you will have reinforcements. If your field is planning for space flights, then our Spacearium in the Science Exhibit is for you. The lights may dim as you take the simulated flight through space. But you will still note the amazement around you. And when the lights go up, again I urge you to watch those faces. They tell of the interest and hope which is held in your work.

But my good friend, Administrator Jim Webb, said my assignment was to keynote this Conference, which has been a year in

the making, and one on which Seattle has worked nearly a year so that the greater number may learn more about their space program and the accomplishments to this moment. These will be hard to cover in 3 short days, because the accomplishments, already great, will be greater. But we have in this audience—and on the way to Seattle —those who best can tell the facts.

You will hear the full story told. Just as you heard and saw the flights of Alan Shepard, Vigil Grisson, and John Glenn from start to finish.

We Americans weren't told a day later that the flight had been made. We saw the boosters take off and climb. We heard the astronauts communicating with their bases. We knew how cabin pressure was being maintained inside the capsule. We knew the decisions—as they were made. Not a day or two later. We triumphed in the capsule recovery because we knew also the thrill of the launching. America tried no "sleight of hand" or frantic "rabbit pulling from the hat" while a magic scientific wand waved or hankerchief of secrecy hung carefully in place.

When we design a new booster with more power to carry a larger payload a greater distance, we make it public. Our people know while the mission is still on the launch pad the course which is to be followed, the speed to be attained, the length of time it will take for the mission to be judged a success or failure. And we do have our failures. But we learn from them. And the world learns with us.

Speaking of freedom, a classic example of the American approach to the peaceful use of space came a few days ago when the international satellite was launched. Here was a capsule and launch in which several nations took part. And each nation had observers at Cape Canaveral when the product of their thinking and planning went up—with the help of an American booster.

Before the Space Age is much older, there will be other international launchings from Cape Caneveral, because we seek to learn in peaceful concert with others of like mind and determination.

But there have been worthwhile products of our space effort other than international cooperation, products which we have almost instantly accepted and adapted to our daily living. Some of these have advanced medicine, prolonged life, certainly made it more enjoyable. I think immediately of the tiny electronic device which can be implanted surgically to restore hearing in deaf persons. Now the same company is working to perfect a sight aid for the blind. The General Data Corporation of Garden Grove, California, was building instruments for spacecraft when these by-products were developed. Now it is possible for an artificial larynx, powered by mercury batteries, similar to those used in satellites, to restore speech for many.

Think of the work being done with a maser, an intense pinpoint of light, a million times brighter than the sun. Already this has been used successfully in eye operations. Soon it may be used for coagulation in brain surgery as well as in removing eye tumors and retinal welding.

In consumer goods, we have the process, developed by The Boeing Company, Seattle, for making flour of high nutritive value from bleached seaweed. The company was seeking a food which could be used on space flight. Soon we may be using it on Earth as a low cost, easily produced life sustainer. Infrared food blanching in preparing foods for canning and freezing is another space-age development. Then, the teflon-coated cloth filter, developed for use in space research where extreme cleanliness is required, now has been put to use in the kitchen. Researchers tell us that when teflon cloth replaces ordinary paper or cloth filters in the percolator, the coffee tastes better.

By overcoming the reentry problem on nose cones, we saved a lot of breakage in the kitchen, too, because pyroceram is being used to make utensils as well as nose cones. The housewife can take them from the freezer to the oven without losing a step —or the container!

No longer do we wait for the merchant ship or ocean liner to report that a hurricane has been sighted. Our weather satellites tell us when these storms are forming, how they are growing, what direction they

are moving, how much time we have to take shore precautions. I'm sure that our research will develop much of value in the use of satellites and space-aids in understanding and eventually controlling weather.

During hearings before the Senate Commerce Committee, as well as authorization hearings before the Senate Committee on Aeronautic and Space Sciences, we learn that NASA's research in the global communication satellite field has been productive and promises to be still greater.

Already we have launched Echo and Courier. Soon Relay, Telstar, and Syncom will follow.

Then we may enjoy, I am told:

Almost instant mail without mailmen. A single satellite with modern facsimile equipment could transmit letters to any place on earth in a few minutes.

You may be able to watch the 1964 Olympics in Japan—"live," as it is happening—on your home TV set. Or tune in on an opera in Paris.

You may be reading an orbital newspaper originating in London, New York, or Tokyo —simply by pressing a button.

A business conference with associates halfway around the globe could be held by turning a knob.

Dialing Hong Kong would be as simple as calling a local number and the cost would be reduced substantially.

Better yet, children in our schools will have available to them important worldwide events as they occur, through space-based TV and radio. And the man in the Belgian Congo could get the same program which we would watch in Seattle, Chicago, or New York. In fact, he would be watching the same telecast.

Our nation expects this year to launch at least six new communication satellites. Four are being built with Government funds. Two are privately financed by the American Telephone and Telegraph Company.

The NASA satellites will test two-way telephone, telegraph, and television communications. Among these will be Echo II, larger than the one orbiting now. The new one will have a polar orbit.

Then an active repeater, Syncom, will be shot to an altitude of 22,300 miles. The 55-pound synchronous satellite will have a speed identical to our Earth's rotation.

The Telstar and Relay satellites, both "active" since they can retransmit signals received by them, are planned to orbit at an altitude of 3,000 miles. They are designed to demonstrate transoceanic television and multichannel voice and telegraph communication.

This decade may see the revolution in communications accomplished.

My hope is that we work fast and accurately so that those first transoceanic telecasts are in a friendly tongue and the programs devoted to sharing knowledge, not propaganda.

I'm informed that at least 9,000 industrial and business organizations worked together to help launch our astronauts into space. These firms are expanding. More are entering the field. Undoubtedly more will be needed. They will need manpower from our colleges and universities. NASA and other agencies have special facilities set up at this conference to discuss career possibilities with the students who have joined us for this meeting. I know those facilities will be used to advantage.

Also, there is a special facility maintained at this conference for business men to learn more about the possibilities for their industries as our space program develops. I feel sure that this facility will be highly successful, too.

Meantime, there is much to tell of the goals in space achieved already and of those for which we reach. Let us learn more about how we have reached the milestone of May 8, 1962, and how we plan for the year, the decade, and the thirty-eight years ahead which will bring us Century 21, the period which our Seattle World's Fair portrays.

Principal Addresses

The Role of Government in Scientific Exploration

By JAMES E. WEBB, *Administrator, NASA*

Born October 7, 1906, in Granville County, North Carolina, Mr. Webb graduated in 1928 from the University of North Carolina with a bachelor's degree in education. Later, he studied law at George Washington University, Washington, D.C., and was admitted to the District of Columbia bar in 1936.

Mr. Webb is a member of the Federal Council for Science and Technology, the President's Committee on Equal Opportunity, and the National Aeronautics and Space Council, and is chairman of the Distinguished Civilian Service Awards Board. He is a former director of the Bureau of the Budget and a former Under Secretary of State.

Mr. Webb has been awarded the following honorary degrees: LL.D., University of North Carolina, 1949; Syracuse University, 1950; Colorado College, 1957; and George Washington University, 1961. Sc.D., Notre Dame University, June 1961, and Washington University, St. Louis, February 1962.

It is a pleasure to be here, on the grounds of this great international exposition, to participate in the Second National Conference on the Peaceful Uses of Space. I am greatful to Governor Rosellini and Senator Magnuson for the warm welcome which they extended at the opening meeting. The participation of your great senior senator is particularly appreciated, for it has been my privilege to know and respect him in his vital role as Chairman of the Committee on Interstate and Foreign Commerce of the United States Senate.

Those of us who are devoting our time and our energy to the mastery of space can also be greatful to Century 21, the city of Seattle, and the State of Washington for creating an atmosphere here which certainly was designed to make us feel at home.

I might say that I have *felt* a few space needles in my time, when we have had to postpone flights to assure the best conditions for success, or when one of our launch vehicles failed to do what it was supposed to do, but this is the first time that I have *seen* one.

One cannot tour the grounds of this imposing exposition without being impressed with it as a demonstration of the pace at which we are moving in this age of space. When the idea of the Seattle World's Fair was first proposed in 1955, the first satellite had yet to be launched, and the National Aeronautics and Space Administration did not yet exist.

Century 21, as many of you may know, was not originally proposed as the showcase for space science and technology which it has become. Rather, those who conceived the idea of this event envisioned it as a 50th anniversary celebration of the Alaska-Yukon-Pacific Exposition. This event, held here in 1909, was conducted to highlight the progress made by Seattle and the Pacific Northwest following the Klondike gold strike in 1898—an event which touched off a population explosion in this area.

It is apparent, observing Century 21 as it stands here today, that its planners were

men of vision as well as imagination. They have kept abreast of the astonishing scientific and technological progress which has occurred in the short span of years since the idea of Century 21 was born. As a result, rather than commemorating the activities of those pioneers who first went to the Yukon to dig for gold, the exposition has as its symbol the towering space needle, acknowledging the efforts of a new group of pioneers who are soaring into space in search of new treasures to be found there.

To me, this rapid change in the emphasis of Century 21—and remember, the symbolic space needle was not even thought of until 3 years ago—is evidence of the readiness of this generation to accept and pursue new ideas which were considered visionary, if not actually ridiculous, only a few years ago.

Even more significant is the change in the attitude of citizens toward Federal participation in and support of the kind of scientific research, development, and exploration which our accelerated national space program represents.

Throughout this conference, the details of this national space program will be thoroughly examined by able speakers and participants who are interested in space, many of whom are associated with NASA and its industrial and educational contractors. I shall not, therefore, attempt to discuss the program of the National Aeronautics and Space Administration in detail. Rather, I would like to explore with you the thought which I have just mentioned—the developing role of Federal agencies in scientific research and exploration, and the relationships of the NASA organization with the President, the Congress, other agencies of our government, and with foreign governments.

In considering the remarks which I would make here, I could not help reflecting on the early role of the Pacific Northwest in Government-sponsored scientific exploration. This area—today the host of a conference on the problems of exploring what President Kennedy has so aptly called "a new ocean" —was actually the target of the United States' first major scientific expedition.

The role of government in science has been the subject of national debate since this nation was born. Thomas Jefferson, as early as 1783, talked to George Rogers Clark about conducting an expedition up the Missouri River, and, as President of the United States in 1803, sent a secret message to the Congress requesting $2,500 to finance what was to become known as the Lewis and Clark expedition. (Not, incidentally, the same Clark. This one's first name was William.)

The Congress of that day, and to a lesser degree throughout the first century and a half of our national existence, was reluctant to invest in scientific research. This attitude was largely responsible for the fact that on the eve of World War II, despite our great technological prowess, we were still almost totally reliant for basic knowledge on European research.

Jefferson got his appropriation, but not without resorting to some mild deception. While telling the envoys of France and Spain that the objectives of the expedition were to enlarge scientific knowledge, he sold it to the Congress "for the purpose of extending the external commerce of the United States."

His real objectives were evident, however, when he confronted that problem of recruiting personnel for the expedition—a problem with which we have great sympathy, for it is still with us today. He wrote: "We cannot in the United States find a person who to courage, prudence, habits and health adapted to the woods, and some familiarity with the Indian character, joins a perfect knowledge of botany, natural history, mineralogy and astronomy, all of which would be desirable."

Jefferson never did find this paragon, and in the end settled for his secretary, Captain Meriwether Lewis, who had "all the first qualifications." Captain Lewis' lack in scientific knowledge was overcome by sending him to Philadelphia for several weeks, where the learned gentlemen of the American Philosophical Society taught him to make celestial observations, to collect plants and animals, and to study the Indians.

I devote so much attention to the Lewis and Clark expedition not only because it was the first such national effort, but because its dramatic success established the precedent for future Federal participation in scientific exploration.

During almost a half-century which followed that expedition, men in science and government discussed and debated the Federal role in this form of activity. There was created, in 1807, a bureau that was to become the U. S. Coast and Geodetic Survey and, in 1846, Federal scientific activity was enhanced with the creation of the Smithsonian Institution. Subsequently, the Civil War gave the scientists a chance to establish an institution of which they had been dreaming for decades—the National Academy of Sciences, created in 1863.

Throughout the 19th century and the early years of our own century, Government participation in science and technology experienced a slow but steady growth, largely in agriculture research. Yet, science had not yet come into its own as an instrument of public policy. It took another military conflict—World War I—to provide a renewed impetus to Governmental scientific activity.

Our national civilian and military leaders, at the beginning of World War I, were forced to a heightened appreciation of the importance of aeronautical science. The early advantages which might have been gained from the pioneer work of Samuel P. Langley and the Wright brothers had largely been overlooked or ignored in this country. The development of aircraft design and technology had been left to the Europeans, and we entered World War I with neither design experience nor manufacturing capability of our own.

Recognition of this deficiency led to the creation by the Congress in 1915 of the National Advisory Committee for Aeronautics, the first war research agency of World War I.

There followed, after the successful conclusion of that great conflict, another period in which Federal participation in science lagged, and once again it was a threat to our national security which increased the momentum and broadened Federal participation in this activity.

If a line can be drawn across the continuous path of history, it must be said that the year 1940 separates the first century and a half of American experience in this field from the period of accelerated national interest in science which followed.

World War II produced a new awareness of the changing role of science in government. When the atom bombs fell on Hiroshima and Nagasaki—a result of highly secret Government scientific effort in the Manhattan Project—the entire Nation became fully aware, for the first time, of science as a political, economic, and social force with which it must reckon.

Consequently, after extensive national debate, the Congress recognized the expanding role of government in science by creating the Atomic Energy Commission in 1946 and the National Science Foundation in 1950. Professor Don. K. Price, an outstanding student of the relationships between government and science, described the new attitude well in 1953, when he wrote:

> The United States has come to see that it is in a new kind of rivalry with the Soviet Union—a rivalry that may well turn, not on territorial or diplomatic gains, or even (in the narrow sense of the word) on military advantage. The crucial advantage in the issue of power is likely to be with the nation whose scientific program can produce the next revolutionary advance in military tactics, following those already made by radar, jet propulsion, and nuclear fission.
>
> Partially obscured by this spectacular military aspect of the role of science, but closely related to it, is its long-range economic aspect. The same fields of technology that are crucial to military tactics—electronic communications, aeronautics, and power—are also those that may have great influence in economic competition. The massing of scientific research for attack on military problems has its industrial by-products. In these fields the tremendous military research program is probably pushing our country farther and farther ahead of its competitors.

Professor Price was right on every count but the last—a fact which became apparent on October 4, 1957, when the ominous beeps of Sputnik I awakened the world to the realization that the Soviet Union had scored an important triumph in a new and exciting area of science and technology.

Within months, the Congress acted to correct this deficiency, and our determination to move forward in space was expressed in the National Aeronautics and Space Act of 1958. In accordance with this Act, the Eisenhower Administration went forward with a long-range plan for space development which, in ordinary circumstances, would have been regarded as rapid and ambitious.

The circumstances, however, proved to be far from ordinary ones. This fact was quickly made apparent to President Kennedy during his first weeks in the Presidency by a series of Soviet achievements which finally included the manned orbiting of the earth by Cosmonaut Gagarin. New circumstances made a new policy imperative.

Recognizing that if a nation so great and powerful as ours has not the will to be first, it shall almost certainly be last, President Kennedy responded promptly to the Soviet challenge, and in his State of the Union Message told the Congress that it was "time to act" to restore American leadership in this vital new field of endeavor. He called for an accelerated space program which would place an American exploratory team on the moon "within this decade," something which otherwise could not be achieved before the mid-1970's.

Sensing the urgency of his request, and responding in a thoroughly nonpartisan manner, the Congress quickly approved. This country's most ambitious scientific undertaking was underway.

It is important to consider the significance of these actions as they reflect a further expansion of the role of government in science. A clear understanding of the accelerating growth of Federal participation in scientific research and development can be gained by examining the funding of these activities during the current century. In 1900, Federal research and development expenditures were under $10 million annually, with the greater portion of the research devoted to the agricultural sciences.

As recently as 1940, just prior to World War II, Federal research and development outlays were still under $100 million a year; that is, about one-fifth of what will have been spent, through Fiscal Year 1963, on the development of a single type of NASA launch vehicle—the mighty Saturn C–1, which is the most powerful rocket stage known to exist in the world.

With World War II, Government-sponsored science and technology really came of age. By 1945, Federal R&D expenditures had risen to $1 billion a year, and by 1953 to $2 billion annually.

During fiscal year 1961, the Nation's total expenditures for all research and development were $16 billion, about $10.4 billion of which was supplied by Federal appropriation. Of the total, $1.8 billion was for basic research and $3.2 billion, for applied research. The balance of $11 billion was spent for development. The Federal Government supported 60 percent of the Nation's total activity in basic research.

Final figures on the Government expenditures for the current fiscal year are not yet available. However, in fiscal year 1962, the Congress appropriated to some 38 agencies in the Executive Branch of the Government a total of $10.8 billion for research and development—this is about two-thirds of what will be spent this fiscal year in the Nation for this purpose from both public and private funds. About three-fourths of the total Federal expenditures were allocated to NASA and the Department of Defense—$1.4 billion to NASA, $6.2 billion to DOD.

We have noted the influence of military requirements in expanding and accelerating Government participation in scientific research. We should not overlook the fact that, while heavy emphasis is being placed within NASA on the peaceful uses of space science and technology, military requirements continue to dominate the research and development field.

Authorization by the Congress for fiscal year 1963, already approved by the President, provide a Department of Defense budget for new missiles, aircraft, and naval vessels of almost $13 billion. Of this total, slightly over $4 billion is allocated to the Army, Navy, Marine Corps, and Air Force, for research, development, and hardware in their missile programs.

A comparable figure in NASA would be the sum which the President has requested for research and development, not yet authorized by the Congress, an amount slightly under $3 billion. This is less than three-fourths of the Department of Defense authorization for new missiles, and less than one-fourth of the DOD authorizations for aircraft, missiles, and ships.

We should also remember that the NASA expenditures are devoted exclusively to research and development which will make a continuing contribution to our knowledge of space science and technology. NASA has no appropriations for expendable hardware, other than that constructed for developmental purposes. Thus, all of NASA's research and development expenditures make a lasting contribution to human knowledge.

I do not remind you of this to minimize the vital importance of the Department of Defense programs for our national defense, but merely to indicate that NASA expenditures are not duplicative of that effort. Instead, they exist for purposes which not only supplement, but transcend the national defense and security.

Another point which I should like to emphasize about this vastly increased Federal participation in scientific research is the extent to which it acknowledges—and rather belated—the necessity for this nation to produce its own basic research. As I have indicated, despite our great technological advances, the United States was for too many years content to rely on the scientists of other nations for the basic scientific research efforts on which this technology was based.

The great technological progress made during World War II exploited and developed much of that basic knowledge. The reservoir was beginning to run dry. Meanwhile, in the rehabilitation of the European nations, increasing emphasis was being placed on technolology, rather than basic science, and fewer advanced degrees were being granted. It became apparent that, if we were to satisfy our needs for basic knowledge—outside of the work going on in the Soviet Union—we would have to produce it ourselves.

If we are to survive in a scientifically oriented world and be, as President Kennedy has urged, "in a position second to none," a great deal remains to be done.

I have indicated that during fiscal year 1961, the total national expenditures for basic scientific research—by Government, educational institutions, private foundations, and industry—was $1.8 billion. The National Science Foundation estimates that by 1970, nearly $3 billion per year will be required for basic research alone—more than double the amount expended last year.

The professional staffing in universities and colleges will have to increase from the present 45,000 to 85,000 full-time positions to perform the universities' share. This means adding 4,000 full-time researchers in our universities every year. Actually, since many university researchers are on a part-time basis only, the number of new professional personnel will be much greater.

Such an upsurge in research and development also means, according to the Science Foundation, that professional teaching staffs for science and engineering in our universities and colleges must increase from 100,000 to 175,000 full-time positions by 1970; that is, 7,500 new teachers of science and engineering at the university level every year.

Remember, this is the impact on university staffs alone. It does not include the new scientists and engineers needed directly in Government and industry undertakings.

The fact that, as one historian has put it, "Government and science have joined in a national enterprise born of necessity and sustained by the challenges and complexities of the modern world," is readily justified by the circumstances which confront us.

Major scientific advances today require group efforts, expensive equipment, and massive technological support, often over many years of sustained effort. Only Government can marshal the resources to organize and finance such endeavors. Private enterprise stands ready to take up feasible and salable applications as they can be identified, but many of the pioneering opportunities now opening up on the frontiers of science require such large investments that they first

must be developed to meet Governmental requirements if they are to be made available for the benefit of mankind.

In a directed society, such as that of the Soviet Union, implementation of public policy in the field of science, or any other for that matter, is less complex. There, Government officials decide who will be trained and educated to perform needed tasks, and the extent to which the Russians regard science and engineering as essential is now readily apparent in the enormous increase in advanced degrees in these fields which have been granted in the Soviet Union during recent years.

In our own society, where individual interests and desires govern the choice of a career, our problems are more difficult; yet I am confident that they will be met and overcome, within the framework of our democratic principles, as they have been in the past.

But the question of science and public policy does not end with the recognition of Federal responsibility. Of equal importance is the determination of how the Government shall carry out its responsibilities; how it apportions the work among industry, Government laboratories, and educational institutions; how the views of the scientific community are taken into account; how the traditional independence of the university professor, researcher, and student are to be safeguarded; how national goals are to be established and achieved.

The establishment and implementation of our program of space research and technological development involves a coordination of national skills and facilities which touches every facet of our society and is unequalled in complexity by any previous undertaking. Involved are the President, the Congress, other Government agencies, foreign governments, educational institutions and public purpose foundations, and the private industries and commercial enterprises of the Nation.

The blending and welding together of this complex of individuals, groups, and organizations constitutes an almost superhuman challenge, but one to which our form of Government is proving itself equal.

It might be well, to complete our understanding of how the Nation's space program is conceived and operated, to review briefly the roles of these varied groups and agencies. The National Aeronautics and Space Act of 1958 established four major objectives:

1. To conduct scientific exploration of space.
2. To conduct manned exporation of space.
3. To apply space science and technology to the development of Earth satellites for peaceful purposes, to promote human welfare.
4. To develop space science and technology in the interests of the national defense.

In practice, the first three of these broad objectives, those which are nonmilitary in character, have become the responsibility of the National Aeronautics and Space Administration. Military efforts in space are the responsibility of the Department of Defense.

In developing our space program, the agencies involved are required to submit to the Bureau of the Budget, prior to September 15 of each year, a detailed plan of activity and statement of the funds required to support it. During the ensuing weeks this program is reviewed by the Budget Bureau with the participation of agency representatives, and a budget recommendation made to the President about December 1. The President then reviews the request, and by the end of December a final budget is prepared for submission to the Congress, to cover the fiscal year beginning the next July 1st.

In addition to the preparation of the budget itself, NASA also contributes space material to the preparation of the President's State of the Union message, his Budget message, and, where desirable, to his Economic message, and any special messages which he may elect to submit to the Congress.

Following the submission of the budget by the President, the various committees of the two houses begin hearings. A civics book review of the procedure would indicate that the policy aspects of the budget—the authorizations—are the initial responsibility of the House Committee on Science and Astronautics and the Senate Committee on Aeronautical and Space Sciences. The actual appropriations would subsequently be

determined initially by the Appropriations Committees of the two houses, and then be given final approval by the Congress and the President.

In practice, it is not quite that simple. Over the years, the necessity for supporting their proposed authorizations has led the first named committees to become more detailed in dollar authorizations than are the Appropriations Committees which actually approve the funds. Thus, although a considerable amount of flexibility is retained, we must account annually to the Congress, on a dollar-by-dollar basis, for each program which we propose to undertake.

This, when you consider that we are already at work on our appropriation request for the fiscal year beginning a year from next July, is no simple task. It is made particularly difficult by the fact that ours is such a fast-paced, rapidly evolving program, in which needs constantly arise which the fertile brains of our scientists have not previously conceived, and which, consequently, cannot be anticipated 18 months in advance.

The Congress has proved to be remarkably understanding and tolerant of these difficulties, however. Where space progress is concerned, I think the attitude of most members is akin to that once expressed by Teddy Roosevelt, speaking of the Panama Canal:

"Instead of debating for half a century before building the canal," Roosevelt said, "better to build the canal first and debate me for a half-century afterward. What this Nation will insist upon is that results be achieved. The utmost practicable speed. Push the work rapidly and at the same time with safety and thoroughness."

We like to feel that these words would be applied as well to the program in which we are now engaged.

In addition to these committees with a major interest in space—and I should note that Washington's distinguished Senator, Warren Magnuson, in addition to being chairman of the Commerce Committee, also serves on both the Aeronautical and Space Sciences and the Appropriations Committees of the Senate—we are also guided by other committees with a more limited interest in specific NASA activities.

To cite my own experience, during the period from February 27, 1961, to April 17, 1962, I made 31 separate appearances before 12 different committees and subcommittees of the two houses of Congress. Dozens of other NASA officials were also called upon to testify and, in fact, scarcely a day passes during which some congressional committee is not involved in considering some phase of the space program, either publicly, or in executive session.

These committees include two on which another great citizen of the State of Washington, Senator Henry M. Jackson, is serving with great distinction. I refer to the Joint Committee on Atomic Energy, which shares with us a concern over the development of nuclear rocket engines, and the Senate Committee on Government Operations, which includes among its interests the long-range Federal budgeting for research and development. Other committees before which I appeared were the House Committee on Post Office and Civil Service, which is concerned with the difficulty which salary limitations have imposed on the recruiting of scientific, engineering, and managerial talent, and the Commerce Committees of the two houses, which are concerned with the communications satellite program, which is moving rapidly from the developmental to the operational stage.

While a great deal of time is consumed in these congressional hearings, I would like to express the conviction that it is time well spent, offering as it does a mutual opportunity for the exchange of ideas about the course which the Nation must pursue in its space program. Our relationships with the Congress have been excellent, and while the various committees and the Congress itself have painstakingly examined our requests to assure themselves of their necessity and desirability, there has been no lack of support for programs which are clearly in the national interest.

Because the Space Act divided responsibility for the peaceful and military aspects of space research and development, a high degree of cooperation has been necessary

among the various Government agencies in order to insure maximum progress with a minimum of duplication. This is achieved, in part, through the participation of the White House in budget preparation. It is strengthened further by the existence of an unusual agency, the National Aeronautics and Space Council, presided over by Vice President Lyndon Johnson, and including in its membership the Secretaries of State and Defense, the Chariman of the Atomic Energy Commission, and myself.

The Nation is particularly fortunate in having the Vice President as Chairman of this important council. His enthusiasm for progress in space science and technology and his broad knowledge of the problems involved, both strengthened by his years of service as Chairman of the Senate Committee on Aeronautical and Space Sciences, have enabled him to make an enormous contribution to the advancement of United States efforts in space.

In addition, there is a very close working relationship, on a day-to-day basis, among the Government agencies concerned with the program. In our launch-vehicle development, we presently are utilizing 10 vehicles of various sizes for numerous scientific and military purposes. In some instances, responsibility for development is in the hands of the Department of Defense. In others, it lies with NASA. Thus, administration becomes highly complex, but has proved to be remarkably successful.

As an example of this complexity, I might give you the example of the Scout rocket booster. At Point Arguello, California, a situation such as this can occur. The Air Force may, on a given day, launch a Scout rocket built by NASA, with an Air Force ground crew trained by NASA, from a launch pad designed and funded by NASA, controlled from a blockhouse funded by the Air Force. And, perched atop the rocket is an experiment designed and conducted by the Navy. This is an excellent example of the quality of teamwork which has evolved in our space program. In other situations, such as the Dyna-Soar program, the primary responsibility lies with the Air Force, with NASA technical support.

But the Department of Defense is only one of many Federal agencies with which we cooperate. To name a few others, we work with the Weather Bureau on meteorological satellites, which are rapidly introducing a new era of weather forecasting. We cooperate with the Federal Aviation Agency and DOD in research on supersonic transport aircraft. We cooperate with the Atomic Energy Commission, as noted, on development of nuclear rocket engines. We work with the Smithsonian Astrophysical Observatory. The Navy provides extensive and generous assistance in our Mercury recovery operations, and our development of the X-15 research airplane is closely coordinated with both the Air Force and the Navy. This is only a partial list of the agencies with whom we enjoy a close working relationship.

Outside the Government, NASA has developed a very good liaison with the Nation's educational institutions. We look to the universities to produce the scientific and engineering personnel required to accomplish the space programs and we depend upon them to conduct advanced research and development. The extent and growth of our program of grants and research contracts with educational institutions is illustrated by the fact that NASA awards totaled $11.7 million in FY 1961, and estimated $30 million during the current fiscal year, and are expected to total $65 to $70 million in FY 1963. Participating institutions of higher learning totaled 65 in 1961, and are estimated at 70 to 75 for 1962, and 90 to 100 for 1963.

In addition, NASA depends upon qualified scientists and engineers in our colleges and universities for professional consultation and advice, and direct participation in our programs as consultants or directors of research projects. Our concern for encouraging greater participation by young people in scientific and engineering fields recently led us to establish fellowship programs with several institutions, and more are contemplated.

American industry, of course, is a major contributor to the space effort. The NASA budget, which will approach the $4 billion mark in fiscal year 1963, is largely expended

under contract with non-Governmental organizations. We estimate that this amount will total more than 90 percent of our budget in FY 1963.

Although our larger contracts must, of necessity, go to firms with the facilities and management capability to undertake them, subcontractor activity accounts for a major portion of the expenditures. One NASA prime contractor recently released figures showing that during the calendar year 1961, it had used in excess of 9,000 subcontractors and suppliers, located in virtually all the 50 states.

Another excellent example is the contract for the first stage of the advanced Saturn launch vehicle, known as the S–IB. This contract, which will run through 1966 and will involve in excess of $300 million, was awarded to The Boeing Company here in Seattle. This does not mean, however, that the contract will be of economic benefit only to the Seattle area.

While it calls for a peak employment of some 5,000 people, the S–IB contract will involve production here in Seattle and at Wichita, Kansas; assembly of the vehicle at the NASA Michoud Operations plant at New Orleans; static testing at the NASA Mississippi Test Facility in southwestern Mississippi, and launching at Cape Caneveral, Florida. Literally thousands of subcontractors and suppliers from all over the United States will be involved in the project.

Finally, in welding together all the phases of our national space program, it must be remembered that we are under a Congressional directive to cooperate in the development of space for peaceful purposes with the other nations of the world. You have seen a recent example of this cooperation with launching from Cape Canaveral of the first international satellite, a cooperative project with Great Britain which Prime Minister MacMillan named the "Ariel" on his recent visit here. Last month, in addition, two space probes were launched from the NASA facility at Wallops Island, Virginia, in cooperation with Japan.

Other similar ventures are in developmental stages, including sounding-rocket launches in cooperation with France, New Zealand, Norway-Denmark, Pakistan, and Sweden, and satellite launches with the United Kingdom and Canada. It should also be noted that our successes in Project Mercury relied heavily on the cooperation extended by other nations around the world in developing and operating our tracking and data acquisition network.

Cooperative ground activities have been undertaken with other nations in connection with both communication and meteorological satellite activities. Agreements for the provision of major ground facilities to permit intercontinental testing of communication satellites to be launched later this year by NASA have been concluded with England, France, Germany, Italy, and Brazil, and others are being negotiated at this time. In the meteorological satellite program we have concluded agreements with 28 nations around the world.

In its report to the recent meeting of the Committee on Space Research in Washington, the Space Science Board also cited our extensive cooperation in conforming with COSPAR resolutions. The United States has issued launching announcements, distributed current orbital elements for the U.S. satellites and descriptive experimental information, exchanged scientific data and results, and published numerous publications and catalogues detailing its space activities. Training arrangements and graduate fellowships in space science are also made available to representatives of other nations.

As the United States delegate to the COSPAR meeting, Richard W. Porter, of the National Academy of Sciences, said in his report:

> These programs . . . are regarded as vitally important in our country because we look forward to a day when scientists of all nationalities can join in some truly cooperative project to study and explore the universe in the name of all mankind.
>
> Within the limits of our capability we stand ready to cooperate with scientists of any nation on any space research projects, large or small, which will increase man's knowledge and bring him closer to the stars.

We also are engaged in negotiations with the Soviet Union to determine whether our two nations may find the means to cooperate in the development of space science for

peaceful purposes. This is a proposal which the United States has advanced repeatedly and which the Soviet Union has now indicated some willingness to pursue. Initial discussions have been held, and more are planned. What the result will be remains to be seen.

It must be remembered that in addition to achieving the objectives which have been outlined by the Congress, the Nation's space agency must also perform in accordance with certain guidelines established by that body. Among the most important of these are three which deserve special attention.

First of all, recognizing the opportunity, through our space program, to demonstrate the differences between our space objectives and those of other nations, we are directed not only to cooperate with other nations in space research, but to share our information with the world.

Secondly, and for the same purpose, we are required to conduct our activities in the full light of publicity. We may not choose, as may be the case elsewhere, to publicize our successes and conceal our failures.

Finally, and this is of particular interest to this conference, we are directed to encourage the application of the results of space research to practical uses which will be of immediate or ultimate indirect benefit to mankind.

The hazards in the first two of these mandates are obvious and, frankly, were the object of a great deal of concern during the many and protracted delays which preceded the successful orbital flight of Colonel Glenn. The wisdom of our open approach, however, was fully demonstrated in the international reaction to that mission.

I have read excerpts from literally scores of newspapers published throughout the world following the Glenn mission. Permit me to quote two of them, which are representative of the worldwide reaction to this achievement of the United States:

From Amsterdam:

> Now that the experiment has been crowned with success, those who weigh the advantages and disadvantages of American frankness realize that the advantages outweigh the disadvantages. All the world watched the achievement of the American Astronaut and all the disappointments about earlier setbacks seemed to vanish. The Americans have taken and accepted the risk of failure before the entire world. Isn't this more refreshing, and above all, more human?

And from Brazil:

> . . . the United States ran a great risk: Announced and postponed so many times with the attention of the whole world focused on her, failure of Glenn's flight would have appeared to the less informed as a North American defeat. This makes the feat even more outstanding and it must be credited not only to the United States but to the democratic way of life—to the free world.

And now a word about the final directive —that the fruits of space research be applied for the benefit of mankind.

Attending, as you are, a conference on the peaceful uses of space, you are, I know, familiar with much of the work which we are doing in this field. Our activities in the development of communications satellites, meteorological satellites, and navigation satellites have been, or will be, described to you in great detail. All of them offer great promise.

In addition, however, we are undertaking a program for the practical application of space science and technology which is unique.

Each of the great scientific and technological revolutions of the past has produced countless new methods, ideas, and materials which have altered the course of our existence. In some instances these were totally new ideas and concepts discovered in the course of research devoted toward other goals. In other instances, ideas and methods long known suddenly became applicable to practical, everyday purposes because further developmental work, designed for other purposes, rendered them suitable for mass production at costs within the public reach.

Many of the great scientific discoveries of the past occurred by accident. We even have a word—serendipity—to describe this process.

Accidental observations led Priestly to discover oxygen, Willson to discover calcium carbide, Goodyear to develop the vulcanization process, Roentgen to discover the X-ray which led, ultimately, to photography, and Becquerel to discover radioactivity. Other

accidental discoveries, whose number is almost limitless, include the discovery of specific gravity by Archimedes, dynamite by Nobel, aniline dye by Perkin, and, if you will, the discovery of America by Christopher Columbus.

Space research is already producing spin-off benefits in the form of new products, new methods, and new materials which can be employed in the manufacture of countless articles for human use. Yet we have scarcely scratched the surface as far as these benefits are concerned.

We have as a goal the exploration of the Moon, but that is not an end in itself, nor do we propose to overlook the opportunities which present themselves along the way. We are determined that the huge sums which are required to fulfill our objectives in space research and exploration will also provide the maximum amount of auxiliary benefit which can be obtained. To this end, we will not be content to have these benefits come only as the result of fortunate accidents. Rather, we hope to seek out and identify results of space research which can have practical applications, and to make this knowledge available now to those with the capability to develop and utilize it for the benefit of every citizen.

Recently, we have undertaken an initial pilot program in this field, which is being conducted in six Midwestern states. An NASA contractor is seeking practical applications of space science and technology and working with private industries to make certain that their benefits will become available to the public. If this program proves as effective as we hope, and we have reason to believe that it will, it will be expanded to include other sections of the Nation as well.

The other day I came across a novel, written in 1894 by a man whose grandfather, only a few years after the expedition of Lewis and Clark, opened a fur trading post not far from here, at the mouth of the Columbia River.

The grandson, John Jacob Astor, shared his ancestor's vision and curiosity. In addition to building the Waldorf-Astoria hotel, he invented things ranging from turbine engines to bicycle brakes. Everything about the man was dramatic, even death, for he went down on the Titanic.

Mr. Astor's novel, "Journey to Other Worlds," was an early form of science fiction, involving space travel to the planets. It was startling, considereing the fact that the book was written almost three-quarters of a century ago, to find in it an artist's sketch of a spacecraft hurtling through the universe. Even more startling was the fact that, in design, it was so much like our present concept of the Apollo spacecraft it could almost have been drawn by one of our engineers.

In the preface, Mr. Astor sounded a note which, had it been heeded in his day, would have vastly advanced scientific and technological progress, and which has real application and meaning even today. He wrote:

> There can be no question that there are many forces and influences in nature whose existence we as yet little more than suspect. How . . . interesting it would be if, instead of reciting (our) past achievements . . . (we would devote our) consideration to what we do *not* know.
>
> It is only through investigation and research that inventions come; we may not find what we are in search of, but may discover something of perhaps greater moment. It is probable that the principal glories of the future will be found in as yet untrodden paths.

As we assess our position one year after the First Conference on the Peaceful Uses of Space, some of the visions to be found on those untrodden paths have already opened to us. Those which remain offer a challenge unequaled in the history of mankind.

Sailing in New and Old Oceans

By ROGER REVELLE, *Science Advisor to the Secretary of the Interior*

Born in Seattle, Washington, on March 7, 1909, Dr. Revelle received his A.B. degree in geology from Pomona College in 1929 and his Ph.D. degree in oceanography from the University of California in 1936. He has been professor of oceanography at the University's Scripps Institution of Oceanography since 1948 and its director since 1950. For the past several years, he has also been director of the La Jolla campus and dean of the University's School of Science and Engineering at La Jolla. He is at present on leave from these posts.

One of the country's leading geophysicists, Dr. Revelle has led several oceanographic exploring expeditions into the south and west Pacific and is one of the authors of modern theories of the structure of the Earth underneath the oceans.

He is a member of the National Academy of Sciences, the American Philosophical Society, and the International Council of Scientific Unions. He has served the Government as a member of the U.S. National Commission for UNESCO, the Naval Research Advisory Committee, the Advisory Council of the Peace Corps, and panels of the President's Science Advisory Committee, and as a U.S. delegate to various international conferences.

I take my text today from something President Kennedy said when he heard that Colonel Glenn had come home successfully after his wild ride.

The President's words were, "This is the new ocean, and we must sail on it."

Naturally, as a professional sailor, I am glad that the President chose to compare space to the ocean. I like to think that the words came naturally to him, because he, himself, is a famous and brave sailor. But, for the moment, I would like to emphasize something else about the President's words. He didn't say why we must sail on this new ocean of space, he simply said, "we must." He didn't say that space exploration is intellectually stimulating, morally sound, or practically useful.

By the very simplicity of his words, the President implied something quite profound: What men can do, they must do. Unbelievably, inconceivably, we are beginning to be able to leave the surface of the Earth, on which our ancestors have crawled for countless generations, and to reach for the stars. In using our new-found ability, we are simply being human; we are rising to the challenge that lies deep within us as human beings.

At this early stage of the greatest of all human adventures, people who talk about the uses of space are like Queen Victoria. She asked Michael Faraday what was the use of his experiments in electricity and magnetism—experiments which are the basis of our electric power industry and of nearly everything else in our electronic world. Faraday replied, "Why Madam, what is the use of a new-born baby?" He didn't say it, but he might have added, "It's a miracle, it's a wonder, it's human. That is its usefulness."

Our new baby, our space adventure, faces many difficulties. We are all worried about the impact on our economy of the enormous amounts of money and effort that must be spent. We are worried because other things that need to be done may be delayed by the space effort. We are worried about what will happen to our universities, our science, and our humanities, as our new baby grows

to giant size. But it must grow—we are committed to its growth. We are committed, not because it will help us in our competition with the Russians, or because of the economic benefits it will bring, but simply because we are human beings, and the challenge of space is the greatest challenge human beings have ever had.

When we Americans talk about the use of something, we usually have the word "practical" in our minds. I am always puzzled by this word "practical." What does it mean? I would like to think it means more than faster transportation, greater comfort, more food, or increased longevity. Anything is useful, and thus practical, if it fills the needs of human beings.

One of the greatest needs of human beings is the need for understanding. You will remember that the unknown poet who wrote the Book of Job imagined that God appeared to Job out of the whirlwind, and said: "Gird up now thy loins like a man. Declare if thou hast understanding." The voice out of the whirlwind speaks to each one of us. We are that one among God's creatures who has the possibility of understanding and the need to understand.

To me, this is the greatest practical use of space. By venturing out from our own planet, we will gain immeasurably, and in ways which we cannot now even imagine, in our understanding of the world and the universe. Let me illustrate my thesis by an example. From the beginning of human life on Earth, men have imagined that there might somewhere be other beings like themselves. Every child and every man who has looked upward to the heavens has wondered if men or angels lived on the stars.

There are three questions about the possibility of life on other planets. The first and most easily answered one is: Are there other planets on which life is possible at all? We are reasonably sure that within our own solar system primitive forms of life can exist on Mars, and the same may well be true of Venus. But the conditions on these other planets of our own corner of the universe are probably too difficult for intelligent, highly developed life such as we know it on the Earth.

The second question is, therefore: Are there other stars among the myriads of stars in the Milky Way around which planets revolve with conditions somewhat like those on our own Earth—conditions that have permitted the development of thinking, conscious forms of life with whom we would be able to communicate? Many astronomers now believe it is as natural for a star to have planets as for a cat to have kittens.

If modern theories about the formation of stars are correct, probably the great majority of stars have planets around them. The number of planets must then be enormous—billions upon billions. There is a chance that on at least some of these, life began as it did on the Earth, perhaps 2 billion years ago. If so, it may have evolved in a beneficent realm of light and liquid water, and in an atmosphere of oxygen and nitrogen, to a level perhaps as high, perhaps much higher, than the highest life we know on Earth.

But no one knows how good the chances are that life could arise independently in many different places in the universe. This third question is a statistical one. We know that such an event took place once, for we are alive, and we can trace the evolution of life on Earth back to very simple beginnings. But the great question still remains, perhaps the most meaningful of all questions to human beings: Are we alone in the universe?

We might thoughtlessly answer by asking another question: If we are not alone, where is everybody else? Yet a moment's thought will show us that, even if other intelligent beings exist on the planets of other stars, communication is almost impossible because of the distance involved. A radio message to one of the planets of Betelgeuse or Rigel, which are among our nearest stellar neighbors, would take several hundred years to get there, and the reply an equal time. In the present state of civilization, by the time a reply was received, everybody on Earth would have forgotten what was said in the first place. A radio message from one side of our own galaxy to the other would take 200 thousand years before a reply could be heard. This is almost as long as human

beings have lived on the Earth and 40 times longer than the entire history of our human civilization. This difficulty of communication with whatever other beings exist has been called by the British novelist C. S. Lewis, "God's quarantine regulations."

Right now, we are caught up by the adventure and the possibility of great accomplishment in space exploration. But the space sailors of the future will want better reasons for leaving the cozy certainties of Earth to venture into the bitter night of space. I believe there is one overwhelming question which will dominate their thinking and that of those who are left behind. That question is whether man is alone in the universe.

Unfortunately, even when we can travel among the planets of our own solar system as freely as we now travel over this Earth, we will be no nearer to solving this problem of man's comrades in other worlds than ours. That secret will still lie hidden in the stars, for, as I have said, all the evidence indicates that we are the only thinking inhabitants of the solar system. We are the only conscious castaways upon this tiny raft of the Sun and its family of planets as it drifts forever along the Gulf Streams of the galaxy.

The nearest of the stars is a million times farther away than the closest of the planets. The space ships which we may expect to see within the next two or three generations will use nuclear power, and they may be able to get up to speeds of 1,000 miles a second—50 times faster than the Russian and American satellites that are now circling the Earth. Even so, it will take a thousand years to get to Alpha Centauri, our nearest stellar neighbor, and higher speeds would be necessary to reach any of the other nearby stars within a thousand years.

To plan and carry out a research project involving the sending out of a space ship which could not return for 2,000 years is beyond the capacity of our present society. Men who can plan effectively even 20 years ahead are quite rare; few of us have the imagination even to be able to visualize doing something today which would only come to fruition 2,000 years from now. It would be as if Archimedes had started a research project which could produce no results until the time of Einstein.

But we might conceivably send out a space ship manned with human beings. With the present life span of human beings, the original crew would not be able to survive for even a small fraction of the time required. Children would have to be conceived and born on the space ship, and they in turn would reproduce and die through many generations, so that finally one day the remote descendents of the original crew would return to Earth with a record of their celestial odyssey.

The engineering, biological and sociological problems involved in such an enterprise would be remarkably difficult and complex. Such a space ship would have to be completely self-contained and self-supporting, and no material of any kind could be wasted. Would the 50th generation, after a thousand years, still share the aspirations of their pilgrim fathers who set out from Earth so long ago? Would the crew be able to tolerate each other, generation after generation? It makes us shudder to think of generations of travelers doomed to spend their entire lives in empty space.

I have raised these seemingly fantastic questions because it seems to me that, by the very asking, we can gain insight into man's condition here on Earth. Our hypothetical space ship would, in fact, be a miniature planet. What is our Earth, then, but a 2-billion-man space ship hurtling through the void? We face exactly the problems that our hypothetical travelers would face.

This round ball, the Earth, on which mankind dwells, is a sphere unsupported in space, isolated and complete in itself. We who are condemned to live on it must be self-supporting and self-contained. We must not, and indeed we cannot, waste anything. We must somehow learn to live together, to tolerate one another, or else we cannot survive.

Perhaps fortunately for ourselves, we can't steer our terrestrial space ship, for if we could we might foolishly drive it farther away from the sun and lose the warmth and

light that makes life possible. Just like the children on our hypothetical space ship, we did not choose of our own volition to be passengers on this particular wanderer through space. We are here simply because our ancestors were here, and their remote ancestors arose blind and struggling in the primeval sea, mindless as the molecules that gave them birth, and completely unconscious that their remote descendants would be able to comprehend something of the world in which they live and be able to hope for a better life for their children. But just because they were our ancestors, we are inevitably and irrevocably children of Earth; all our instincts, our genes, and our heredity make us so. To the everlasting glory of our race, we may soon hope to reach the stars, to fulfill the old proud motto, *per aspera ad astra*. But wherever we go in the universe, Earth will always be our home.

The passengers on our hypothetical space ship, on their return journey after many generations, would gasp in wonder when they first saw this wonderful planet under the bright Sun—when they first saw the beautiful pattern of sea and land, with the brown and green continents rising like great islands from the world-girdling blue of the ocean; and they would be filled with delight when they first landed on the sweet green fields of home.

I have led you by what I hope are imperceptible stages to my second thesis: The exploration of space and of the Earth must go hand in hand if we are to achieve our goal of understanding. When we drill our Mohole through the ocean floor, we will learn a great deal that will help us to understand the inside of the moon. When the first scientist collects a piece of rock from the moon's surface, he will be holding in his hand a sample of what our own Earth may have been like four and a half billion years ago. When we can study at first hand the clouds of Venus and the winds of Mars, we will have a priceless laboratory to help us to understand the weather and the climate of our own Earth.

The scientists of space and the scientists who study the Earth are engaged in a common enterprise. Their joint objective is the highest that science can have. It is nothing less than to understand the origin and the history of the universe, and that greatest of wonders is a world of wonder, the history of life. This is not an objective that can be reached by physicists or chemists or mathematicians working in a laboratory. The physicist is concerned with the nature of matter and energy, with all the possible ways in which matter can exist—if you will, with all possible worlds. In contrast, the astronomer, the geophysicist, and the biologist are concerned with the world as it is, with this one existing world among all possible worlds. These different scientists work in different ways. The astronomer deals with the vast reaches of space; the scientist who studies the Earth, with the inconceivable depths of time. But the objectives of the Earth scientist and the astronomer are the same, and there must be a constant interplay of questions and answers between them if our understanding of the history of the universe is to increase. We must explore together the new ocean of space and the old oceans of Earth.

Not only intellectually, but emotionally and normally, our new thinking about space has affected our attitudes toward the Earth. In a deeper way than ever before, we know now in our bones that the Earth is a planet, a single object that cannot be subdivided, and must be thought of as a whole, as the planetary home of all men. We realize as never before that our Earth depends on us for its well-being, just as we depend upon the Earth.

The new awareness we have gained within a few short generations of the fathomless reaches of space and the almost inconceivable depths of time brings us a variety of emotions. Two of these are certainly humility and awe: Humility, because of our small size and fleeting life span in the presence of the starry universe and its majestic history; awe that we are privileged to exist and be part of such a world of wonders.

Two other emotions should certainly be pride and hope: Pride that the minds of men are able to comprehend, at least to

some degree, the laws and the forces, awful in their complexity, which govern the universe; pride that within a few centuries men have been able to go so far in understanding after the tens and hundreds of thousands of years in which they lived in ignorance; hope that our knowledge will continue to increase, and with it our understanding and our ability to improve our human condition. But it seems to me that the most important emotion we should feel is one of responsibility and obligation. Whether or not we are alone in the universe, we are the crew of our space ship.

The New World of Space

By LYNDON BAINES JOHNSON, *Vice President of the United States*

Chairman of the National Aeronautics and Space Council.

After a lapse of so many years, it is indeed a stimulating and inspiring experience to have a World's Fair on American soil again. In these times of vitality and progress, it is appropriate to have it here in the great Pacific Northwest.

At a World's Fair, the nations of the Earth portray their histories and their proudest accomplishments in industry and agriculture; in the arts and sciences, and in the improvement of their people's welfare. But like all World's Fairs, Century 21 also reveals something of man's hopes and dreams for the generations yet to come.

First of all, our hopes for the future are based on peace.

Second, they are based on a world in which our children will be healthier and possessed of a greater amount of material goods than ourselves.

In the third place, we dream of a world where our children can enjoy this peace and this material well-being in freedom.

All these make a worthy goal, but one that will be difficult to obtain. Powerful forces today deny freedom's meaning, or give it strange definitions that exclude liberty of conscience, of free associations, of the individual's right to make certain basic and personal decisions of his own.

To the leaders of nations who think they have a historic mission to conquer the world, I say this: In the long run, it is these great ideals that prevail—and nothing else. What small comfort it must be for a ruler to realize that his predecessor can use slave labor and the wealth of a great part of the globe to erect monuments to himself, and that a few years later these monuments can be torn down and that man's name erased from the history of his nation.

SPACE — THE THEME

Our ideals are all embodied in this latest World's Fair—dominated by the theme of Outer Space, that greater world around the planet Earth.

Since the time when earliest man looked cautiously beyond his immediate surroundings, he has had vastly different visions of the worlds around and above him. The world nearby was evil, dark, and dangerous. The world above was somehow purer, freer, closer to God than the earthbound existence that imprisoned our ancestors.

The shackles of Earth are being broken and the resulting freedom will affect us all.

As this fair promises, Century 21 will be an outer space era. But so, ladies and gentlemen, is our own century.

We in the United States find the dawn of the Space Age a particularly exciting time. Moreover, we are the first nation to realize the power of space to affect every aspect of our daily lives.

SPACE BENEFITS

Our probings into space have taken many forms and will return a host of benefits. Space science and technology are already working vast changes in our dynamic, free society. Revolutions are occurring in our industries, in our systems of education, in our hiring policies, in the realms of science, law, medicine, and journalism.

Because the Space Age is here, we are recruiting the best talent regardless of race or religion, and, importantly, senseless patterns of discrimination in employment are being broken up.

Because the Space Age is here, a U.S. weather satellite was able to track a hurricane and help save thousands of lives and millions of dollars of property along our Gulf coast. Vital weather information so obtained is being relayed by us to the other nations of the Earth.

And because the Space Age is here, we will be able to develop new products, improve old ones, and discover answers to yet unsolved problems. For example:

Research in the medical problems of men in space will lead to cures for man's most serious illnesses.

The development of miniature electronic parts for spacecraft will give us pocket-sized television sets and radios the size of a pearl.

New batteries developed for space will lead to automobiles being powered by plants no larger than a coffee can and to the bringing of the Sun's power to desert areas. These new sources of power will be used to operate new machines that will drill deep to recover water and scarce metals from places now inaccessible.

Someday, we will be able to bring an asteroid containing billions of dollars worth of critically needed metals close to Earth to provide a vast new source of mineral wealth for our factories.

These are only a few of the endless number of new treasures that we can already foresee. Many others cannot even be guessed at today.

COMMUNICATIONS SYSTEM

I want to make special mention of one such beneficial project in which our efforts are nearing final success: I refer to a communications satellite system that will instantly bring together and transmit the words and pictures that pour forth daily from every corner of the globe.

Congress is currently considering a bill proposed by the President and developed through the mechanism of the National Aeronautics and Space Council.

It proposes a corporation with widespread private ownership to be regulated by the Government in the public interest.

This will assure the program's speedy development; will prevent control of the corporation by any single, special interest; will utilize the genius of private competitive enterprise; and will provide the world with greatly expanded communications service at low cost to our Government.

Such a system will do more than improve all-weather message capacity.

It will reshape our lives in ways difficult to predict today. Worldwide patterns of radio, television, and telephone services; face-to-face meetings of world leaders a great distance apart; worldwide systems of industrial and scientific computers; the ability to transmit quickly the entire contents of a great library to an underdeveloped country—these are merely some of the probable gifts this communications satellite system will bring to the world.

COST OF THE SPACE PROGRAM

I mention all these things to show what we have already gained from this new era and to indicate what is to come. To achieve all this, we have spent about $6 billion so far. This is a large amount of money, but it is only slightly more than the $5.3 billion we took in last year alone from the Federal taxes on alcohol and tobacco.

Our entire space program now costs each American 30 cents a week. During the next few years, we plan to spend about 50 cents a week per person on space. This will amount to no more than 1 percent of our gross national product.

Furthermore, our space program and its by-products will stimulate a sharp increase in the Nation's productive output, which in turn will increase our gross national product, our income, and the Federal Government's tax intake.

The space program is a profitable investment—not a waste of the Nation's resources.

SPACE AND NATIONAL SECURITY

This program is not viewed in military versus nonmilitary terms. Our capacity in space will contribute to keeping the peace; and it will help us to live better in peace.

A number of space programs contribute directly to the Nation's security as well as to the well-being of mankind. Among these are: mapping, surveillance, identification, navigation, communications, and weather projects.

Progress in manned flights, spaceship propulsion, in rocketry, medicine, and metallurgy—all of these support our national objectives.

It is, therefore, a unified program that emphasizes peaceful purposes and is ready to meet peace-keeping needs.

COOPERATION IN OUTER SPACE

It would be arrogant of me to come to a meeting at a World's Fair merely to boast of our nation's accomplishments. I am proud of what the United States has done in the Age of Space, but I am not satisfied. It is necessary that we continue to talk and to explain the importance of our space efforts. But it is even more important that we turn words into acts; we must see to it that the United States carries out its national space program with a feeling of urgency based not on any political conflict, but on the benefits to be gained by this country, as well as other nations of the world.

Furthermore, the United States does not intend to act alone. We are encouraging other nations to cooperate in space and to use the new Age as a catalyst to release long-dormant energy.

Our efforts have already yielded the first fruits of success. U.S. launching rockets have sent forth exploratory instruments designed by Canadian, British, and Japanese scientists. We have cooperated with many other nations in sending up sounding rockets; in constructing tracking stations to follow space flights; and in observing weather phenomena in conjunction with our Tiros weather satellites. NASA has established a fellowship program to train foreign scientists in space research in American institutions.

But the responsibility to cooperate also lies heavily on another great space power—the Soviet Union.

At this time, I am able to tell you in a spirit of cautious optimism that the Soviet Union appears to realize that—in outer space, at least—there may be something to be gained by cooperating with the rest of humanity.

The United States introduced and the USSR supported a resolution that was unanimously passed last December by the Political Committee of the United Nations General Assembly. This resolution urged the member nations to extend the rules of international law to outer space, to refrain from claiming territory there, and to cooperate in its exploration.

This action was followed by an exchange of letters between the President and Premier Khrushchev, and meetings between American and Soviet space scientists to explore some technical aspects of cooperation. So far, no specific agreement has been reached, but the atmosphere is encouraging.

I say this even though the United States was recently forced to resume nuclear testing, following the failure to reach agreement with the Soviet Union on nuclear disarmament with adequate safeguards.

The breakdown on one front will not affect our efforts to achieve cooperation on the other.

Without ignoring the admitted differences that still exist, and without revealing anything vital to our nation's security, we are hopeful of achieving fruitful cooperation

with the Soviet Union in such fields as communications, weather forecasting, mapping the Earth's magnetic fields, and space medicine.

We feel that cooperation in outer space may establish a firm basis for greater mutual understanding—which in turn will help in our efforts to obtain disarmament.

We are hopeful because we are going through a new Age, and on into outer space. I know that the American people are thrilled by this, and I hope that the other peoples of this planet will come along into outer space with us.

A great new outlet for human energy has been discovered. I pray we will be exalted by this so that nations will want to abandon their dreams of earthly conquest and so that the people of the Earth, by exploring the stars, will discover in themselves the means of finding peace and happiness in a world of decency and prosperity.

Session I

Chairman: L. Eugene Root

L. EUGENE ROOT, *President, Lockheed Missiles & Space Company, Group Vice President, Lockheed Aircraft Corporation*

Dr. Root has held various major posts in aerospace industry and the Department of Defense, and is currently president of the Institute of the Aerospace Sciences. He holds or has held numerous special government assignments, including executive committee, Defense Science Board; steering group, Advisory Panel for Mutual Weapons Development Program; and USAF Scientific Advisory Board.

He is a member of many technical societies, has a wide range of awards, and has published numerous technical articles. He holds master's degrees from California Institute of Technology, and an honorary doctorate from the University of the Pacific. He is a member of the Board of Regents of the University of the Pacific.

There are three fundamental problems that have occupied and are continously occupying the mind of man: the origin and the development of light, and whether it is unique to the earth; the origin and development of the solar system; and the origin and development of the universe as a whole.

With the recent developments in space technology, with which our speakers had much to do, we can now begin to see our way clear toward getting some of these answers. As you know, we can fly instruments outside the Earth's atmosphere, and this is good because our atmosphere actually acts as a very large-scale factor in removing, either by reflection or absorption or both, much of the extraterrestrial information obtained. We can also land instruments, and finally man, to explore other planets for answers to these problems.

The first three papers in this session cover the basic space science topics: the Earth-Sun relationship; the lunar and planetary missions that are being implemented to provide some of the answers to the questions raised; and the various engineering and bioastronautic problems that must be solved to insure the success of these missions.

The fourth paper covers the propulsion techniques which must be developed and perfected as a part of the implementation of these space missions.

1. Space Science — Earth, Sun, and Stars

By **HOMER E. NEWELL**, *Director of Office of Space Sciences, NASA*

Dr. Newell was formerly Deputy Directory of Space Flight Programs. Before joining the NASA on October 20, 1958, Dr. Newell was Acting Superintendent of the Atmosphere Astrophysics Division of the U. S. Naval Research Laboratory. He was also Science Program Coordinator for Project Vanguard, the U.S. scientific Earth satellite program for the International Geophysical Year.

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

His scientific committee memberships have included the Special Subcommittee on the Upper Atmosphere of the National Advisory Committee for Aeronautics (1947–1951), and the Rocket and Satellite Research Panel (formerly Upper Atmosphere Rocket Research Panel) since 1947. He was Chairman of the Rocket and Satellite Research Panel in 1959 and 1960.

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

INTRODUCTION

Space science is science carried out in space. There is much that is exciting, but nothing mysterious about it. Space science calls upon physics, chemistry, astronomy, biosciences, and other scientific disciplines to attack some of the most important and challenging scientific problems of today. Among these problems are the investigation of the Earth and Sun, Moon and planets, stars and galaxies, and life in space from the vantage point provided by the orbiting satellite or the deep space probe.

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

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

Because of this great breadth and scope of space science, and because of the many basic scientific problems that it encompasses, our country must have a sound and vigorous space science program if we intend to maintain our position of leadership in world science. Such leadership is of great practical importance in today's world in which the

value of those ideals and principles for which we stand is measured in the minds of men in terms of achievement and accomplishment.

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

The space science program supports other activities. The distribution of harmful radiations in space, the times of their occurrence, whether their presence is predictable, and the influence of magnetic fields in space upon the radiation hazard are all important problems that space science investigations must solve before we can safely proceed to send men out into space. Similarly, unmanned investigation and exploration of the surface of the Moon will give data needed in the engineering of lunar landing craft and for planning the landing operation. In return, putting man into space will further the scientific exploration of the solar system.

Continued investigation of the atmosphere is essential to realizing the maximum benefits from weather satellites. Likewise, the influence of radiation belt particles on communications equipment and components must be known in order to design communications satellites properly. Similarly, the knowledge obtained in the space science program supports the development of military applications of space for communications, reconnaissance and surveillance, and other uses.

EARTH AND SUN

The Sun might well have been grouped together with the stars in this discussion, since the Sun is a star, our nearest star, and scientists do, indeed, study it from that point of view. However, because of its closeness to us, the Sun exerts a profound influence on the Earth. Its energy is the primary source of support for life on Earth. We find, therefore, that the study of the Earth necessarily involves a simultaneous study of the Sun and its activities. (See fig. 1–1.)

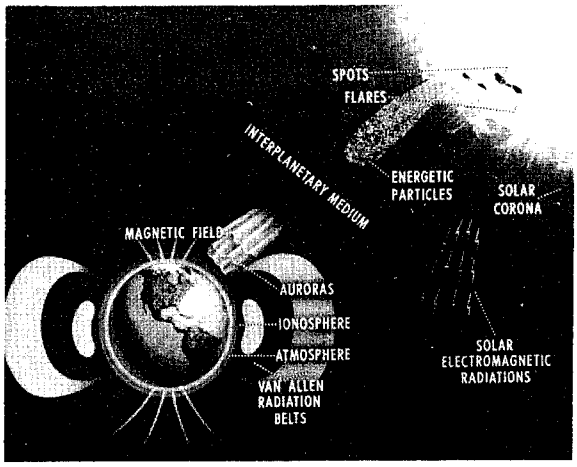


FIGURE 1–1. Earth and Sun.

Satellites and sounding rockets afford the scientist a very powerful means of investigating the Earth on which we live. Equipment can be sent aloft to investigate the atmosphere at all heights and to study the ionosphere, which lies in the upper reaches of the atmosphere and consists of large numbers of electrons and ions. The atmosphere is important because it comprises the source and substance of our everyday weather. The ionosphere is important practically because it furnishes the means by which radio waves may be reflected beyond the horizon, thereby making it possible to communicate around the world. Since the ionosphere is highly variable, we would much rather not be dependent upon it, and hence look forward to the day when communication satellites will furnish us with a much better means of sending messages around the world.

Satellite-borne instruments plot out the Earth's magnetic field and measure the radiations to be found in the Van Allen belts. They, likewise, provide a new line of attack on the auroras which hitherto have had to be studied from observatories on the ground. One can also use satellites to study the interior of the Earth. Observations on the influence of the Earth's shape and mass distribution on the orbit of the satellite enable one to determine the strength of the Earth's interior and measure the distribution of matter within the Earth.

Observatories above the Earth's atmosphere make it possible to investigate the Sun and its activity in a thoroughness not possible from the ground. The ultraviolet, X-ray, radio, and infrared radiations that do not reach the ground can be observed and measured from space platforms. Sunspots, solar flares and solar storms, electromagnetic radiations from the Sun, the solar corona, and clouds of energetic particles expelled from the solar surface are all amenable to investigation by means of satellite-borne and space-probe-borne instruments.

The interplanetary medium consists of about 30 to 100 particles per cubic inch at our distance from the Sun. At this density, it would take 200,000 cubic miles of the interplanetary medium to equal in amount the material in 1 cubic inch of the Earth's atmosphere at sea level. One might well ask, then, if there is so little matter in interplanetary space, why should there be a great interest in it. The first answer, perhaps, is that the question, as phrased, implies a misconception. Actually, there is more than just a little matter in space. Indeed, the total amount of matter in the space between the stars of our galaxy adds up to at least the amount contained in the stars. It is just that the space throughout which this matter is dispersed is so vast that the matter exists at a very low density. Thus, we are not talking about a small amount of matter, but rather a lot of matter under conditions of low density. This interplanetary material, existing at such very low densities, and imbedded in the weak magnetic fields that pervade the regions of the solar system, exists under conditions that are unattainable in the laboratory. We have, therefore, an opportunity to study matter and physical processes under conditions that reveal much about the fundamental nature of the universe.

Actually, much of the study of the interplanetary medium will be associated with the investigation of the Moon and planets, which will be discussed at greater length in paper 2. However, since it is through interplanetary space that the Sun exerts its influence on the Earth, giving rise to our weather, creating the ionosphere and the auroras, stirring up radiation belts, and causing magnetic storms, and at times completely disrupting radio communications on the surface of the Earth, it is clear that the interplanetary medium is important in the study of solar-terrestrial relationships.

STARS AND GALAXIES

Satellite-borne instruments open a new era in astronomy. With them, not only the Sun and the solar system, but also the stars, interstellar gases, and external galaxies may be studied in wavelengths not observable from the surface of the Earth. The importance of being able to make observations in all parts of the spectrum is illustrated in some measure in the inset at the lower right corner of figure 1–2. Here the same object is shown photographed in blue, yellow, red, and infrared wavelengths. The differences are quite striking. Even greater are the differences when observations are made, for example, in the ultraviolet and X-ray wavelengths. Much information about the most fundamental processes of stellar birth and evolution are to be found only in the ultraviolet region of the spectrum, for example.

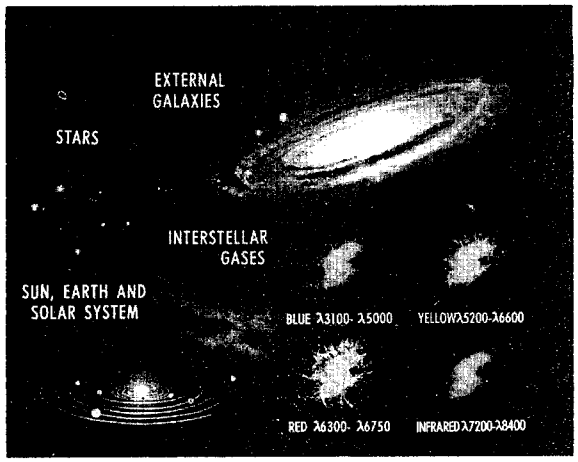


FIGURE 1–2. Stars and galaxies.

SOUNDING ROCKETS, SATELLITES, SPACE PROBES

The basic tool that makes all these investigations possible is the rocket (fig. 1-3). With the rocket one may sound the immediate environs of the Earth in the same sense that the meteorologist sounds the lower atmosphere with his weather ballons and the mariner sounds the ocean depths with his

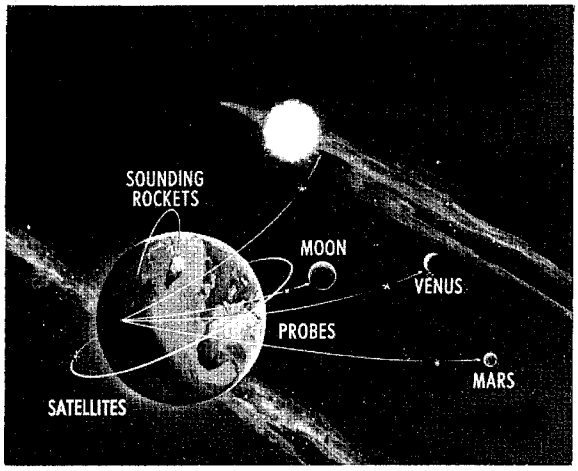
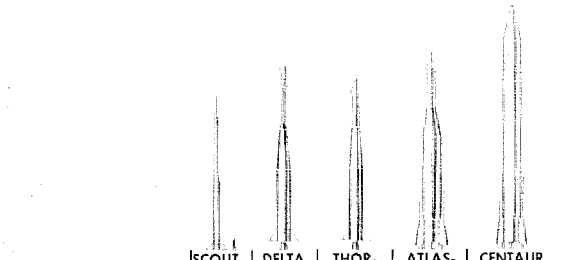


FIGURE 1–3. Sounding rockets, satellites, space probes.

lead line. In general, we reserve the term "sounding rocket" for the vertical or near vertical probe that rises no higher than 1 Earth's radius. Rockets that go beyond this altitude, but still do not approach lunar or planetary distances, have come to be known as geoprobes.

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

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



	SCOUT	DELTA	THOR-AGENA	ATLAS-AGENA	CENTAUR
PAYLOAD: 300 MILE ORBIT	150	500	1,600	5,000	8,500
ESCAPE	–	60	–	750	2,300
LAUNCHES THRU 1963	23	28	6	16	11

FIGURE 1–4. Light and medium launch vehicles.

LIGHT AND MEDIUM LAUNCH VEHICLES

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

In the case of satellite vehicles and space probes, however, the rocket is so large, so complex, and so expensive that one can afford to have only a limited number of different vehicles. For this reason, NASA and the Department of Defense have agreed on a common national vehicle program. The light and medium launch vehicles shown in figure 1-4 constitute the mainstay of the present NASA space sciences program. Scout, Delta, and Centaur are NASA sponsored vehicles. The Earth-escape perfomance of Centaur is required for the Surveyor and Mariner programs, to be discussed in subsequent papers. Thor-Agena and Atlas-Agena have been developed by the Air Force. For later, more difficult missions to the Moon and planets, the NASA space science program will require the Saturn launch vehicle, now under development by NASA.

NASA PROBES AND SATELLITES

The space science program has made considerable progress since NASA began business in October 1958. The satellites and space probes launched under NASA's aegis and the research area of each are listed in the following table:

Pioneer I	Magnetic field, radiation belts
Pioneer II	Magnetic field, radiation belts, cosmic rays
Pioneer III	Radiation belts, cosmic rays
Vanguard II	Cloud cover
Pioneer IV	Radiation belts, cosmic rays
Explorer VI	Magnetic field, radiation belts
Vanguard III	Magnetic field
Explorer VII	Radiation belts, cosmic rays, thermal radiation, micrometeors
Pioneer V	Magnetic field, cosmic rays
Tiros I	Cloud cover
Echo I	Air density
Explorer VIII	Ionosphere, micrometeors
Tiros II	Cloud cover, thermal radiation
Explorer IX	Air density

Explorer X	Magnetic field, plasma
Explorer XI	Gamma radiation
Tiros III	Cloud cover, thermal radiation
Explorer XII	Magnetic field, radiation belts, cosmic rays
Ranger I	Fields, particles, cosmic rays, plasma
Explorer XIII	Micrometeors
P-21	Electron density
Ranger II	Fields, particles, cosmic rays, plasma
Ranger III	Lunar seismology, gamma ray, radar reflectivity, TV photographs
Tiros IV	Cloud cover, thermal radiation
OSO I	Electromagnetic radiation from the Sun
P-21a	Electron density

Although the meteorological satellites fall in the Applications area and will be discussed in a subsequent paper, they are included here because their observations contribute to the advancement of geophysics and, conversely, the basic geophysical research enhances the usefulness of the weather satellites. Likewise, the Echo communications satellite, in addition to accomplishing its task in communications research, contributed considerable information about the Earth's atmosphere.

The individual results, in various papers reporting on the NASA space science experiments, have achieved a considerable volume. It would be impossible to review, even briefly, all the accomplishments. Instead, let us consider two areas in some detail.

Radiation Belt Studies

At the end of 1961, the following picture had evolved concerning the sequence of events occurring during and after a solar flare. Under normal conditions the interplanetary medium appears to consist of a low concentration of relatively slow-moving electrons and protons, perhaps 100 per cubic inch, plus a still smaller number of the very energetic cosmic rays. Normally, there is less than one such energetic cosmic ray per cubic yard. There is also a small interplanetary magnetic field of about 2 gamma in magnitude, which is about one ten-thousandth the strength of the Earth's magnetic field at the equator. When a solar flare occurs, it appears that a tongue of plasma, that is, relatively slow moving charged particles, erupts from the surface of the Sun at the site of the flare, as shown in figure 1-5. This tongue of plasma moves out across interplanetary space at a speed of roughly 1,000 miles per second. Moving at this speed, the plasma cloud takes about 1 day to reach the Earth. As it moves, the cloud drags with it lines of solar magnetic force, which are frozen into the cloud and forced to move with it by the laws of electromagnetism. These lines of magnetic force have their roots on the surface of the Sun in the vicinity of the flare, but as the tongue of plasma moves across space, the lines are drawn out with it like loops of taffy.

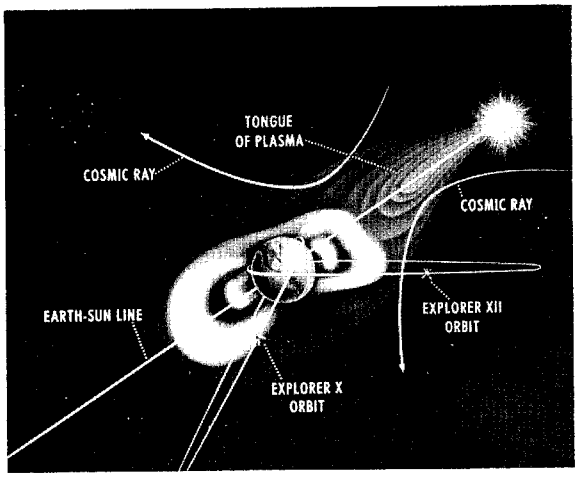


FIGURE 1–5. Radiation-belt studies.

When magnetic lines of force becomes distended in this fashion, they weaken, and by the time such lines reach the Earth, they are perhaps as much as 500 times weaker than they were at the surface of the Sun. Nevertheless, the magnetic field within the plasma tongue is still sufficiently strong to screen the Earth partially from the cosmic rays which are normally observed. This screening effect is referred to as the Forbush decrease, after Forbush of the Carnegie Institution, who discovered the effect about 20 years ago.

This plasma cloud impinging upon the Earth's magnetic field distorts the Earth's field, markedly affects the intensity of the Van Allen radiation, and is associated in some way with magnetic storms and auroral displays. When the Earth is enveloped in such a tongue of plasma, the imbedded solar magnetic field lines form a sort of channel to the Sun along which solar particles emitted in subsequent flares may be guided with very little delay. Such periods of time are very

likely to be of especial hazard to manned space flight within the Earth-Moon system.

Explorer XII, a satellite instrumented to measure energetic particles and magnetic fields, was launched on August 15, 1961. The satellite had an apogee of 48,000 miles and a perige of 182 miles. It operated continuously for 112 days, passing through the radiation belts twice per orbit, for a total of 204 transits. This satellite revealed a large flux of medium-energy protons trapped in the outer zone of the radiation belt. No protons had been seen in the outer belt before this measurement. The number of protons observed was probably about as many as the magnetic field in that region of space could hold.

Measurements with the Explorer XII instruments, which were considerably more refined than those of previous satellites, failed to reveal the expected great increase in flux of lower energy electrons. Indeed, the total flux was observed by Van Allen to be about 100 million electrons per square centimeter every second, which is 1,000 times lower than had been estimated from earlier experiments. Some scientists believe that the earlier experiments were actually misleading and that the new results would also have been obtained in the earlier experiments had better instrumentation been used. It is, however, also possible that the decline in solar activity as we approach the minimum in the solar sunspot cycle may account for the new measurement. There is a need to obtain more accurate and broader measurements throughout an entire sunspot cycle before the true facts can be regarded as fully known.

These values of electron intensity in the outer belt represent a far lesser radiation problem, for example, to solar cells and electronic components, than the earlier measurements had indicated. Continued examination of earlier satellite and sounding rocket data has yielded a more accurate estimate of the radiation hazard due to streams of protons from the Sun. Some of Van Allen's results indicate that the total radiation dose that would have been caused by solar protons from one of the flares during the November 1960 solar events would have exceeded 700 roentgens. Under very little shielding, this radiation dose would have been lethal, and indeed this new estimate of the hazard emphasizes the great importance to the manned flight program of continued careful observation and study of the radiations in space.

The satellite, Explorer X, launched on March 25, 1961, carried several highly sensitive magnetometers and a plasma probe for the measurement of the flux of low-energy protons. The satellite was powered by batteries designed to operate for about 55 hours; actual reliable operation was obtained for 53 hours. Whereas magnetic field measurements on Explorer XII indicated an abrupt end to the trapped particles and a merging of the Earth's magnetic field with the interplanetary magnetic field at about 10 Earth radii, the Explorer X observations seemed to show that the probe passed through the edge of the Earth's magnetic field at about 20 Earth radii. In figure 1-5 it can be seen that the orbit of Explorer XII was oriented in more or less the direction of the Sun, whereas Explorer X moved backward from the Sun at about 140° to the solar direction. This would seem to suggest that a solar wind may be compressing the Earth's magnetic field on the side toward the Sun and blowing it out on the other side. Such a solar wind, if it does exist, was not observable all the time. The magnetic field during the more distant part of the flight of Explorer X changed in both direction and character. When the magnetic field intensity dropped to low values, the plasma probe observed a flux from the general direction of the Sun; but when the field intensity was high, no plasma flux was observed.

The Explorer X magnetic-field observations appeared to indicate a ring of electric current about the Earth at a distance of about 2 or 3 Earth radii. This observation must now be added to those of the Soviets and Explorer VI, the latter indicating the possible existence of a ring current centered, perhaps, at 10 Earth radii. At the same time, continued analysis of the magnetic-field measurements taken with the Vanguard III International Geophysical Year satellite reveals a great deal of structure in the magnetic field over the equator. Sometimes a ring

current appears to be quite high, sometimes quite low.

Gamma-Ray Astronomy

Rocket astronomy was begun by a Naval Research Laboratory group a number of years ago. During the past year, the NASA program not only made exciting advances in rocket astronomy, but also inaugurated gamma-ray astronomy. (See fig. 1-6.)

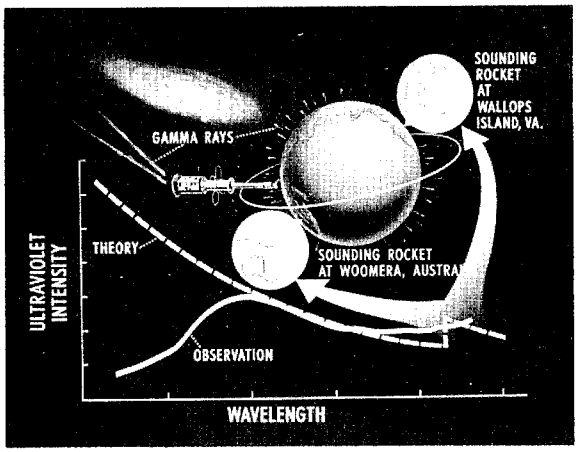


FIGURE 1–6. Gamma-ray astronomy.

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

The gamma-ray detector gathered data until last September. Most of the gamma-ray counts that were received came from the Earth. This Earth count rate was consistent with previous gamma-ray measurements made in the upper atmosphere. About 20 percent of the observed counts came from space and not from the Earth. These counts did not come primarily from any one direction. They seemed to be well distributed in space with some preference for the plane of our galaxy. The count rate of the detector is quite low, but it is about what one might expect from gamma rays arising from neutral pi mesons produced by collisions between cosmic rays and the gas existing throughout the galaxy. The observed counts are a thousandfold fewer than would arise from the interaction between positive protons and negative protons if one certain theory of the universe were true, namely, the theory that holds that matter and antimatter are being created continously at equal rates. Thus, the first gamma-ray satellite has succeeded in paring down by one the number of possible theories of the universe.

No "gamma-ray stars" have been seen, but this may be because the amount of data available is small. This experiment has for the first time detected gamma rays from space and has opened a new field in astronomy. Inasmuch as the gamma rays arise from some of the most fundamental processes in nature, their investigation is of great importance.

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

The results of these rocket experiments were most startling. For example, of the 10 stars observed on one of the flights, only one star, one of the cooler ones, at about 12,000°, appeared in the ultraviolet as one might expect it to from a knowledge of the Sun. The other stars showed great disagreement with current theory, and the hotter the star, the greater the disagreement. To explain the observations, the Goddard scientists have suggested that quasi-molecules such as helium hydride ($HeH++$ and $HeH+$) might be responsible for the observed output of ultraviolet radiation from the stars. Those who have been through an elementary course in chemistry will recall learning that helium under conditions met with on the Earth does not form compounds. It is more interesting to be probing into conditions where the rules of the game admit many things that do not happen under the conditions existing on Earth.

SPACE SCIENCE PROGRAM

The following table summarizes the total proposed schedule for the space science program during the next several years:

Field of study	Spacecraft	Launch vehicle	Launches per calendar year				
			1961	1962	1963	1964	1965
Lunar	Ranger	Atlas-Agena B	2	3	4		
	Surveyor	Centaur				4	5
	Prospector	Saturn					3
Planetary	Mariner R	Atlas-Agena B		2		2	
	Mariner B	Centaur			1	4	3
	Voyager	Saturn					1
Geophysics		Sounding Rockets	60	70	100		
Earth	Explorers	Scout	[a]6	4	2	3	6
		Delta	1	3	1	2	3
		Thor-Agena B		2			
	OGO	Atlas-Agena B			2	2	2
		Thor-Agena B				2	2
Sun	OSO	Sounding Rockets	3	6	10		
	Mod. A	Delta		2	2	2	2
	Mod. B	Atlas-Agena B				1	2
Astronomy	OAO	Sounding Rockets	4	8	10		
		Atlas-Agena B				2	2
Biosciences		Argo D-8	2				

[a] Includes Juno II.

Under each major heading may be noted an advance in sophistication with the passage of time due to the growing launch-vehicle capability. Details of these on-going programs will be given in the remainder of this paper and in paper 2.

Geophysics and Solar Physics

The magnitude of the program in Geophysics and Solar Physics is indicated by the chart of planned number of launch attempts in figure 1-7. The numbers shown through 1961 are actual launches, whereas those after 1961 are planned programs and extensions of these programs. The program shown involves sounding rockets, small satellites (Explorer type), and large observatory satellites. As indicated by the number of launches prior to 1962, this is an "on-going" program firmly based on previous flight experience.

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

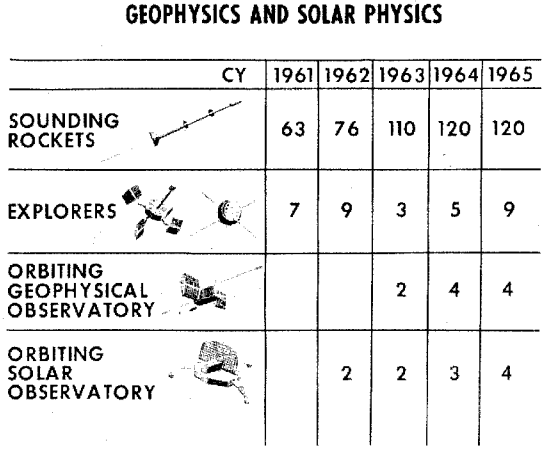


FIGURE 1–7.

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

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

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

The first orbiting solar observatory was launched by a Delta rocket. Delta will also be used to launch the next solar observatory. Later versions of this observatory, however, as well as the geophysical observatories, will require the larger capabilities of the Thor-Agena and Atlas-Agena launch vehicles. In order to mount an adequate attack on the scientific problems of Sun-Earth relationships, several basic types of observatories should be in orbit at all times. Hence, several launch attempts per year are anticipated for the immediate future. Moreover, an effort will be made to achieve a 1-year lifetime for each observatory.

Scientific Satellites

Figure 1-8 shows six special-purpose satellites that at the beginning of 1961 were scheduled for launching in the years indicated. Of these, the gamma-ray telescope and the energetic particles satellites were launched successfully, becoming Explorer XI and Explorer XII, respectively. The very gratifying success of these satellites was discussed previously. Two attempts were made to launch the Ionosphere Beacon satellite, both resulting in failure because of malperformance of the Juno II rocket. The launching of the atmospheric structure satellite was postponed to 1962 and present plans are to launch it in the near future. The international ionosphere satellite, which was instrumented by scientists of the United Kingdom, was recently put in orbit by a Delta vehicle. Its successful launching marks a good beginning to our international cooperation in satellite research. The ionospheric topside sounder satellites are both still under preparation for launching late in 1962.

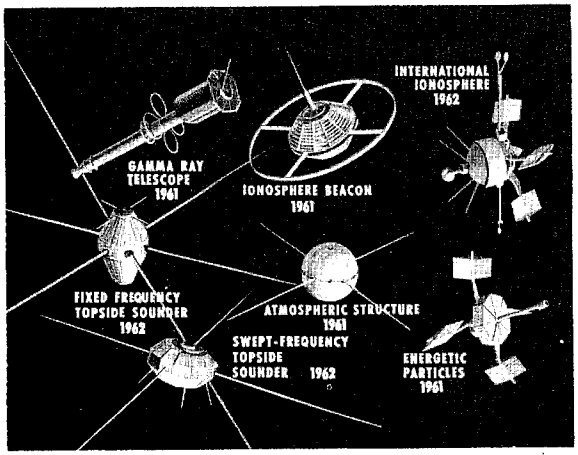


FIGURE 1–8. Scientific satellites.

Polar Orbiting Geophysical Satellite, Topside Sounder

Many experiments on the properties of the atmosphere and the ionosphere call for low-altitude polar orbits. Such is the case for the topside sounder satellite being prepared by Canadian scientists (fig. 1-9). This cooperative Canadian-U.S. satellite project has been given the name Alouette. During the past year, two types of sounding-rocket flights were made in support of this project. One successfully tested the antenna elements

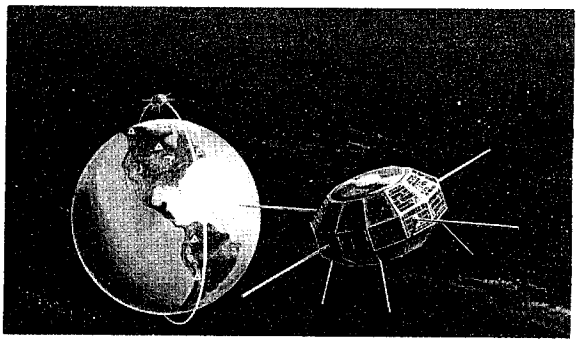


FIGURE 1–9. Polar orbiting geophysical satellite, topside sounder; electron density measurements between 200 and 600 miles.

which unfold to a length of about 75 feet after the satellite is placed in orbit. The other demonstrated for the first time the use of the topside-sounding experimental technique to obtain ionospheric data. This technique is similar to the ground-based ionosonde technique long used to study the ionosphere from below. From a satellite, one is able to apply the technique to a study of the ionosphere from above, hence the name topside sounder. Alouette has passed its initial design test and flight hardware is now being fabricated for a launch attempt in 1962 using a Thor-Agena vehicle from the Pacific Missile Range.

Orbiting Solar Observatory

The first of the observatories designed to point instruments at the Sun for long periods of time is shown in figure 1–10. This spacecraft, now called Orbiting Solar Observatory I, was built by the Ball Brothers Research Laboratory in Boulder, Colorado, and was launched into orbit about the Earth on March 7, 1962. One of the instruments aboard the satellite is an X-ray spectrometer, provided

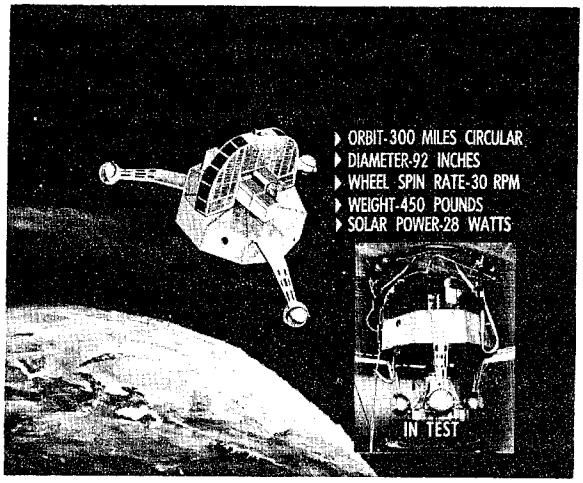


FIGURE 1–10. Orbiting solar observatory.

by the Goddard Space Flight Center. It is known primarily from previous sounding-rocket experiments that the Sun is a generator of X-rays. These X-rays cannot be measured from the ground because they are absorbed in the atmosphere. However, knowledge of the intensity and "hardness" of X-ray radiation is important to an understanding of the exact nature of the physical processes which take place in the Sun. The X-ray spectrometer is now giving us a detailed picture of this radiation. Although the instrument was successfully checked out on an Aerobee sounding rocket last year, the longer times of observation available from the satellite are needed to give the variation of solar X-radiation over long periods of time and during solar storms. Fortunately, a number of solar flares have already occurred during the period of operation of OSO I, and a considerable advance in our knowledge of the Sun is anticipated.

Eccentric Orbiting Geophysical Observatories

For a little over a year now, the Space Technology Laboratories (STL), under the technical guidance of Goddard Space Flight Center (GFSC), have been working on the design and development of an orbiting geophysical observatory (OGO). (See fig. 1-11.) This is part of a program to develop and operate a standard spacecraft capable of orienting experiments in a desired direction

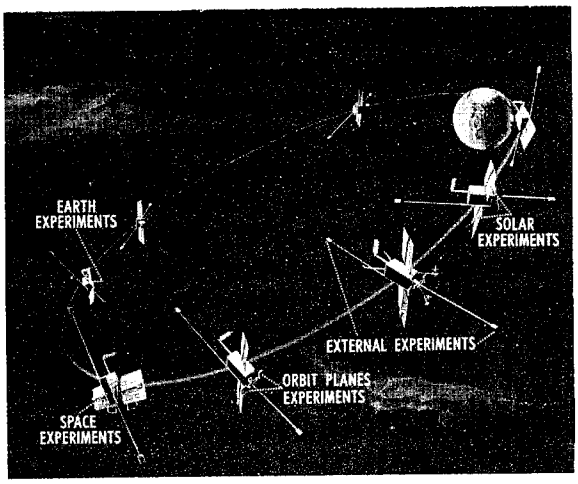


FIGURE 1–11. Eccentric orbiting geophysical observatories.

relative to the Earth and the Sun simultaneously, and to carry out a large number of easily integrated scientific experiments in a wide variety of orbits. The first observatory will be placed in an eccentric orbit with perigee about 160 miles and apogee about 70,000 miles. For this reason it is referred to as EGO for Eccentric (Orbiting) Geophysical Observatory. The experiments (a total of 20) and experimenters (from universities, NASA, DOD, and other government agencies) were selected for EGO in November 1961, and work is proceeding on the development of flight-qualified hardware. It is expected that the construction, test, and calibration of the EGO spacecraft and experiments will be completed in about a year, so that the first launching of EGO will take place in 1963. The experiments selected for EGO emphasize the study of Sun-Earth relationships. EGO will allow us for the first time to make continous simultaneous observations of both solar and geophysical phenomena.

Astronomy

Astronomy, the oldest of the sciences, sometimes called the "Mother of Science", has the broadest objectives of all: to understand the origin, present state, and evolution of the universe by observation of the stars, nebulas, and other celestial bodies. The NASA astronomy program is directed toward the utilization of space technology to make these observations of the stars and other celestial bodies from above the obscuring and distorting influence of the Earth's atmosphere. (See fig. 1-12.)

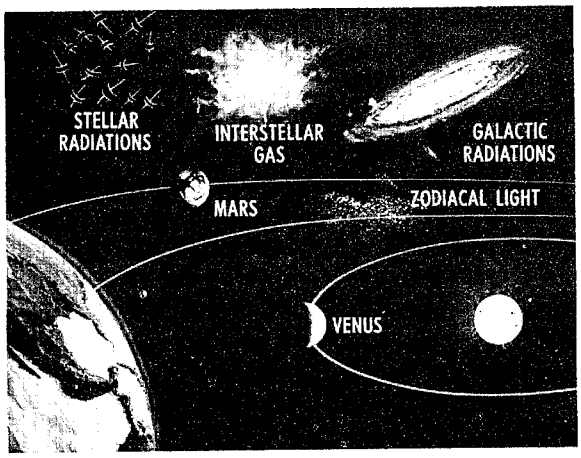


FIGURE 1–12. Objective of research.

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

Figure 1-13 shows the presently planned launchings in the astronomy program. It was

ASTRONOMY

CY	1961	1962	1963	1964	1965
SOUNDING ROCKETS	4	8	10	10	10
ORBITING ASTRONOMICAL OBSERVATORY				2	2

FIGURE 1–13.

pointed out earlier that the study of the Sun as a star is an important part of astronomy and could well have been included here. However, the Sun was discussed previously in connection with geophysics, because of the tremendous importance of solar-terrestrial relationships.

At the present time, the astronomy flight program is predominantly carried out with sounding rockets. The Aerobee has been particularly useful for these measurements. Eventually, the orbiting astronomical observatories will be the mainstay of the astronomy effort.

During 1961 several sounding-rocket experiments carried out in this program were of particular significance. Four Skylark (a British sounding-rocket vehicle developed during the IGY) vehicles were launched from Woomera, Australia, with instrumentation designed to explore in ultraviolet light the sky as seen from the Southern Hemisphere. Prior to these flights, the small amount of data available covered only that portion of the sky seen from the Northern Hemisphere. Thus, these four flights, a total of about 15 minutes of observation, just about double our knowledge of the ultraviolet sky.

Orbiting Astronomical Observatory

For more than a year, the Grumman Aircraft Engineering Corporation, under the technical direction of GSFC, has been working on the design and development of the Orbiting Astronomical Observatory, OAO. The basic design was firmly established during 1961 and is shown in figure 1-14. This will be the largest of the scientific satellite observatories. As shown in this photograph of the engineering prototype, it is about 10 feet in length and will weigh about a ton and a half. Experiments for the first observatories are being developed by astronomers from the Smithsonian Astrophysical Observatory (SAO), the University of Wisconsin, GSFC, and Princeton University; contracts for the detailed design and construction of the first three of these experiments were let during 1961 with Electro-Mechanical Research Corporation, Cook Electric Company, and the Kollsman Instrument Company. The experiments for this program have been designed in an effort to anticipate the long range needs of astronomy, but keeping in mind the basic discovery nature of the program.

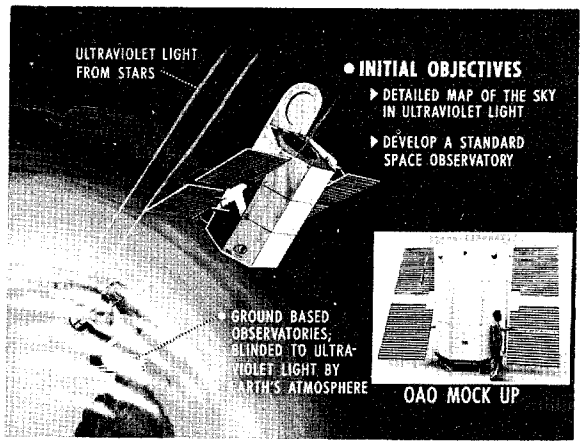


FIGURE 1–14. Orbiting Astronomical Observatory.

The first observatory is being equipped to carry both the Smithsonian and Wisconsin experiments, one in each end of the spacecraft. The major objectives of both of these experiments are aimed at survey type of observations. The Smithsonian experiment is designed to make a map of the sky as it looks in ultraviolet light; that is, to map the brightest stars in ultraviolet light. An Aerobee sounding rocket is expected to flight test this experiment very shortly. The Wisconsin experiment is designed to give more details about ultraviolet stars; that is, something about the amount and distribution of ultraviolet light in selected stars.

The GSFC experiment will be designed to obtain more detailed data on selected stars by means of a large telescope with a 36-inch primary mirror and a spectrometer which can select very narrow portions of the ultraviolet light for detailed study. The Princeton experiment will be designed for even more detailed ultraviolet studies involving observations to determine some of the characteristics of the gas between stars.

The specifications for the OAO were set on the basis of the requirements of all the experiments which could be reasonably foreseen. A fundamental objective of the program is to develop a basic spacecraft which will have the precise pointing capability, power, data handling equipment, and other

requirements necessary to carry a wide variety of future astronomical experiments.

The ultimate guiding accuracy of the OAO is expected to approach 0.1 second of arc. This is about equivalent to the accuracy required to use a telescope located in Baltimore to pick out either the right or left eye of an individual in Washington for detailed study as to its color and brightness. This requirement alone will call for a major engineering effort over the next few years. The previous history of astronomy assures us that this effort will be rewarded by a significant increase in our knowledge of the universe.

The orbiting astronomical observatory is our most ambitious undertaking among the space-science satellites. Nevertheless, it very likely does not represent the end of the line. To conduct all the observations that the astronomers will need to make will one day require even larger telescopes than those that can be caried in OAO. Whether these larger telescopes should be placed in larger satellites or planted on the Moon is something that must still be determined. Even though the first orbiting astronomical observatory is still to be launched, now is not too soon to begin thinking about such problems.

2. Space Science — Moon and Planets

By EDGAR M. CORTRIGHT, *Deputy Director of Office of Space Sciences, NASA*

Mr. Cortright was formerly Assistant Director for Lunar and Planetary Programs and Chief, Advanced Technology Programs in the Office of Advanced Technology. Mr. Cortright joined the National Advisory Committee for Aeronautics, the predecessor of the NASA, as an aeronautical research scientist on the staff of the Lewis Laboratory in 1948.

A native of Hastings, Pennsylvania, he earned a bachelor of aeronautical engineering degree in 1947 and a master of science degree in aeronautical engineering in 1949, both from Rensselaer Polytechnic Institute.

During his research career, Mr. Cortright has specialized in high-speed aerodynamics, particularly problems related to air induction system design, jet nozzle design, and interactions of a jet with external airflow. He is the author of numerous technical reports and articles. He is an Associate Fellow of the Institute of the Aerospace Sciences.

By some fortunate and unknown act of nature, you and I are privileged to occupy a very special place in the universe. We are gathered at a fine fair, in a fine city, in a fine country, on a fine planet, circling a fine young star. We meet to celebrate the accomplishments of modern civilization and to rejoice in our wisdom.

But our star is but one of the billion trillion stars within the more than 10 billion trillion mile range of our largest telescopes. We know relatively little about these stars, and what lies between and beyond. Our Earth is one of nine planets and their 30 moons which circle our Sun and which comprise the solar system. We know relatively little about the solar system; what we do know is largely derived from observations on our planet Earth during the last few hundred years of its brief few-billion-year history. Viewed in the eternity of time and the infinity of space, our "wisdom" shrinks to its proper perspective.

It is man's nature, however, that he apply his intellect to expanding his knowledge about all things. Thus, we find ourselves busily engaged in a number of fascinating projects to explore the solar system by means of unmanned instrumented spacecraft. These experiments will unlock secrets of the universe once thought to lie beyond man's grasp. One day, man himself will accompany his instruments to these distant worlds.

Exploration of the solar system during the next decade will concentrate on the Earth, Sun, Moon, and the near planets, Mars and Venus. In the previous paper, the exploration of the Earth and Sun by means of sounding rockets and satellites was discussed. In this paper, our most active projects to explore the Moon, Mars, and Venus will be reviewed briefly.

Figure 2-1 highlights those areas of exploration receiving active current attention. Our heaviest program is directed toward exploration of the Moon. The Moon, which orbits the Earth at only 239,000 miles distance, is the most convenient celestial body to explore, except for the Earth itself. Its relative proximity means that it is easier to get to then the near planets, Mars and Venus. Less energy is required and the opportunities to launch are far more frequent, being nearly continous compared with every 1½ years for Venus and 2 years for Mars. Trip times are measured in days rather than months. In

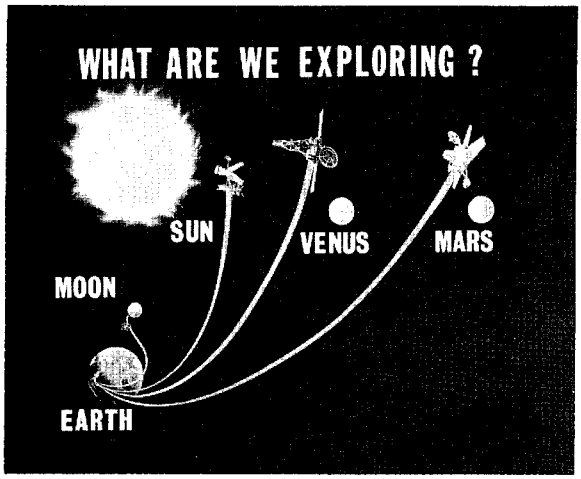


FIGURE 2–1.

addition, communicating to and from the Moon is far simpler than in the case of the planets. To radio information back from Mars takes over 40,000 times the energy required to send the same information from the Moon.

Where landings are desired, the airless Moon loses much of its energy advantage since rockets must replace the atmosphere as a braking device. However, where return flights are required, the small gravity field of the Moon, its lack of atmosphere, and its nearness are of great advantage. For these and other reasons, the Moon will continue to be the center of attention for some time.

The greater difficulty in exploring the planets is more than compensated for by their tremendous interest to us. Whereas the Moon may offer more clues to the formation of the solar system, since it is preserved in a near-original state, the planets more nearly approximate the Earth and are most likely to have indigenous life forms. This particularly applies to Mars and Venus since their orbits about the Sun are most like our own. Their relatively near orbits also make them easier to reach than Mercury, Jupiter, and the outer planets. Thus, we are concentrating our planetary exploration on Mars and Venus. Beyond the Moon, Mars, and Venus, our far-ranging spacecraft will most likely plunge close to the Sun itself.

It is easy for most people to see why we engage in satellite meteorology and communications since the return from these programs will soon exceed the investment. It is also relatively easy to accept the desirability of investigating space in the vicinity of the Earth, and its interactions with the Sun; this is, after all, our own planet. That man should begin to learn to fly in this new environment of space carries the same weight of logic as the Wright brothers' first flights.

Many people, however, have questioned the need for exploring the Moon and beyond. There are many valid ways of answering this question; some good reasons are as follows: From a scientific viewpoint, we want to unlock the secrets of nature—to search for extraterrestrial life, to determine the nature and origin of the solar system, to understand our Sun, and to probe the mysteries of the universe. From a sociological viewpoint, we want to excel in science and technology as a nation. We do this by tackling the toughest problems of our day and, in so doing, our society receives a tremendous stimulus.

This program to explore the solar system costs about one-quarter of 1 cent out of every tax dollar in fiscal year 1962. Thus, each wage or salary earner worked about 1 hour to put the program across. More effort will be required as we advance, but with it we will be building a priceless heritage for the future, one of which we can be quite proud. Those who do not take the time to enjoy this rare experience are foolish indeed.

Every program should have a timetable, whether it is fixing the garage roof or flying to Mars. In past years, we have spelled out our plans through the decade of the sixties. In this paper I am going to limit myself to projects in which we are heavily engaged and in which we hope to complete successful missions by 1965.

The milestones of our program are shown in figure 2–2. One is successfully past. In 1960, Pioneer V was placed into orbit about the Sun and remained in contact with the Earth to a distance of 22.5 million miles. By the end of 1962, we hope to have placed our first instrument on the Moon with Project Ranger and to have sent a Mariner spacecraft to Venus. During 1963, we plan to obtain some very high resolution pictures of the lunar surface with Project Ranger. In 1964, we hope to accomplish our first soft

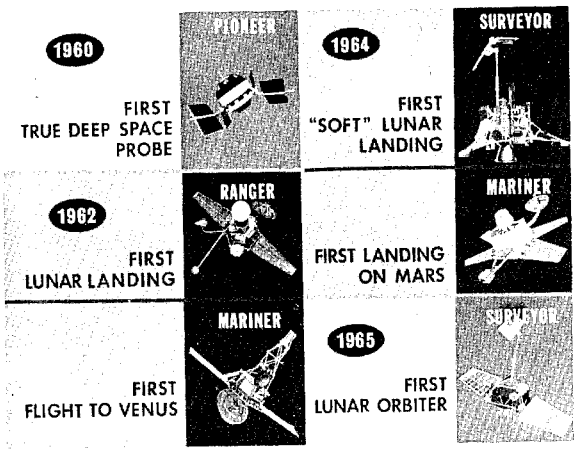


FIGURE 2–2. Space exploration time table.

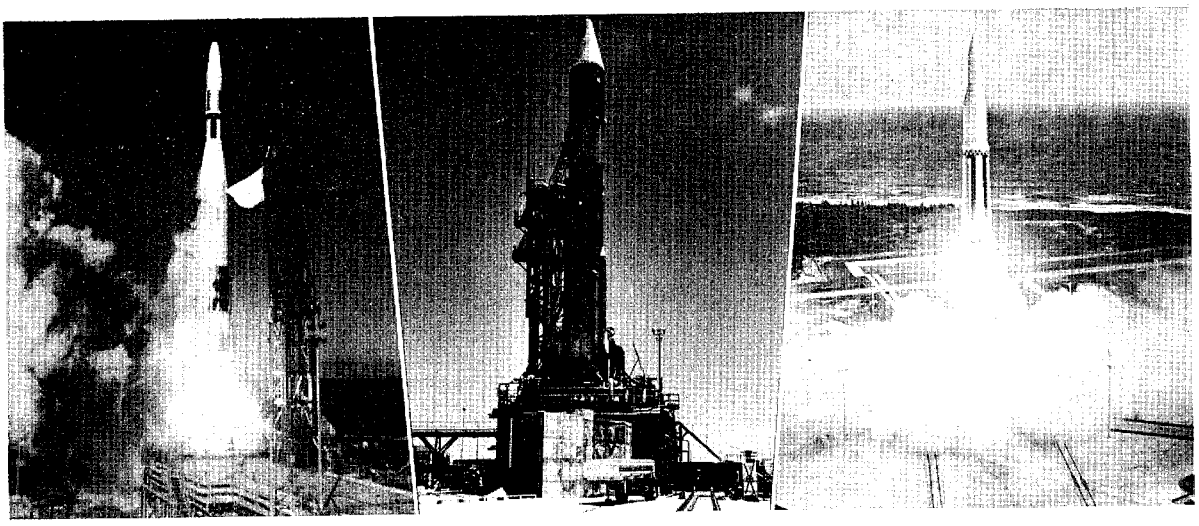
landing of an array of delicate instruments on the Moon as part of the Surveyor project. Also in 1964, we plan to launch our first missions to Mars, and, hopefully, to land an instrumented capsule on this planet. By 1965, we plan to have a version of Surveyor orbiting the Moon and taking comprehensive "aerial" photographs of the lunar surface.

To accomplish these missions, we are dependent on the success of a few launch-vehicle systems. These are shown in figure 2-3. It should be recognized that lunar and planetary missions require the very best performance that can be squeezed out of our launch vehicles. It requires a velocity of about 25,000 miles per hour to escape the Earth's gravity field and only 18,000 miles per hour to go into low Earth orbit; the escape mission thus requires about twice the energy. To get adequate payloads for our lunar and planetary missions it has been necessary to add complex upper stages to our basic booster rockets, with attendant reductions in reliability.

The Atlas-Agena, which is used for early Ranger and Mariner missions will launch about 750 pounds to the Moon and 450 to the near planets. We have scheduled heavy usage of this vehicle through 1964.

The Atlas-Centaur launch vehicle represents a great step forward in both performance and technology. This vehicle is the first to use the very high energy propellant combination of liquid hydrogen and liquid oxygen. These propellants are over 30 percent more efficient than the combination of hydrocarbon fuels and liquid oxygen. The Atlas-Centaur will launch about 2,300 pounds to the Moon and 1,300 pounds to the near planets. It is expected to be operational in 1964.

Although the Saturn rocket series is not required for the projects detailed herein, it is scheduled for use in Project Prospector and Project Voyager in the latter part of this decade. Prospector is planned as a large automated lunar landing craft to be used in direct logistic support of manned operations and for selected unmanned scientific missions. Voyager is the unmanned planetary explorer of the future, dwarfing the Mariner



Atlas-Agena Centaur Saturn

FIGURE 2–3. The rockets we will use.

series now under development. The Saturn shown in figure 2-3 is the first of the new multiengine series. Designed as a two-stage vehicle, it will place 20,000 pounds into an Earth orbit.

The spacecraft which will carry our first instruments to the Moon are illustrated in figure 2-4. Rangers A, B, and C are not three

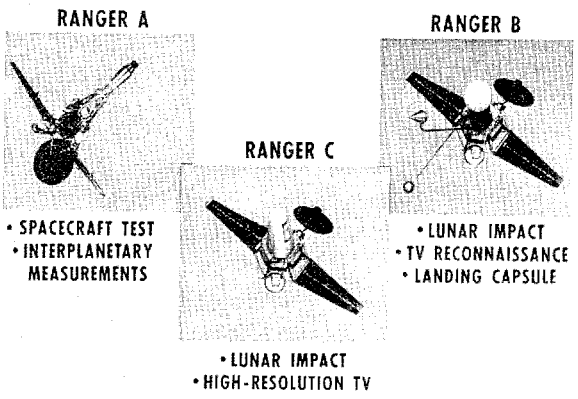


FIGURE 2–4. Ranger spacecraft.

different spacecraft but rather three variations of a single spacecraft designed to accomplish different missions. Ranger A was launched on two partially successful spacecraft test flights in 1961. Ranger B has been launched twice this year in attempts to accomplish several prime scientific objectives. First, it is designed to obtain television pictures of the lunar surface of sufficient definition to detect objects the size of automobiles. Such pictures would have over 200 times the resolution of our best telescopic photography from Earth. Second, Ranger B is designed to land an instrumented capsule on the lunar surface. This capsule will contain a sensitive seismometer to detect lunar vibrations which would provide clues to the structure of the Moon and the origin of the solar system. Our third launch of this payload, which is scheduled late in 1962 will carry two small bombs to insure local lunar tremors.

On Ranger C, the capsule and retrorocket have been replaced with a television package containing six TV telescopes. This spacecraft will be flown into the Moon with no attempt to slow it down. Before impact, however, the system is designed to radio back to Earth pictures containing enough detail to permit detection of objects the size of a basketball. Aside from the great intrinsic scientific value of the Ranger photography, we will obtain the first visual information of sufficient quality to guide the designers of the Apollo manned landing system.

With Project Surveyor, figure 2-5, we will take a giant stride beyond the Ranger. Surveyor will be utilized in a two-pronged as-

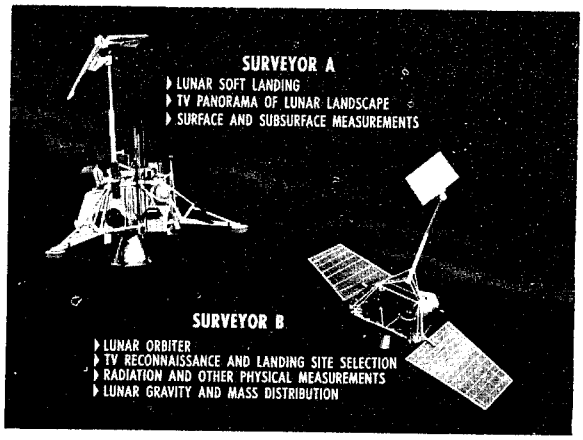


FIGURE 2–5. Surveyor spacecraft.

sault on the mysteries of the lunar surface. As our first spacecraft capable of true soft landings on the Moon, Surveyor A will land a multiplicity of sensitive equipment, including TV cameras and sensitive instruments for the physical and chemical analysis of the surface and subsurface.

The Surveyor B is a modification of the lander which will be designed for injection into an orbit about the Moon. Virtually complete lunar photoreconnaissance coverage will be obtainable. Combining the broad area photocoverage with highly detailed spot sampling should give us an excellent understanding of the lunar terrain and make it possible to select tentative landing sites for the unmanned and manned missions to follow. The Surveyor orbiter will also monitor solar radiation and other aspects of the lunar environment throughout its lifetime.

The manner in which the various phases of the unmanned lunar program blend together is highlighted in figure 2-6. The first

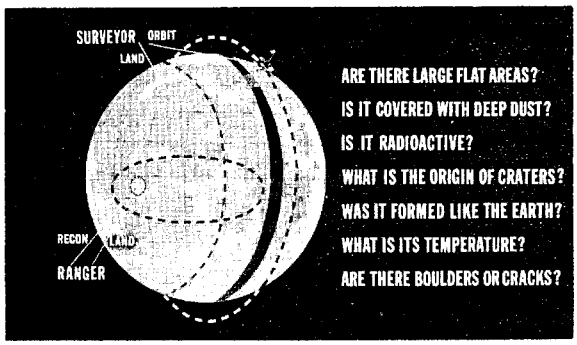


FIGURE 2–6. Target Moon.

three Rangers will all be aimed at the relatively small circle indicated. This landing area coincides with a vertical descent which is advantageous for both landing the capsule and surface photography. The high-resolution TV Ranger series will be programed to stray from this optimum aiming point in order to obtain greater coverage, as illustrated by the ellipse labeled 'recon'. The Surveyor is designed to land within the quarter of the lunar surface indicated in the figure. This flexibility does not require approach angles shallower than 45°. The Surveyor orbiter, however, can provide complete lunar photographic coverage in the indicated polar orbit.

Th narrative of a filmed progress report entitled "Exploration of the Moon and Planets" on our three major projects to explore the solar system—Ranger, Surveyor, and Mariner—is presented as follows. The discussion of Mariner will introduce the last portion of this paper, the planetary program.

In the coming age, man will go to the Moon, and beyond. But before he does, he will wish to know many things about his destination. It is therefore necessary that instrumented craft be sent out first to measure, sense, and describe what is encountered.

Today we are actively developing the craft, the communications, and the propulsion capability to fly missions of discovery into near and far space. Scientists and engineers, working closely together, are designing instruments to make the measurements needed to answer the questions: What is the nature of space and the bodies moving in it, the Moon, and the planets? How did our solar system come to be? Is there other life in our solar system? How can man survive in these hostile places? The instruments to give us the answers will be carried by spacecraft designed to meet complex new requirements. The first spacecraft developed in the NASA lunar program was the Ranger.

The primary purpose of the first two Ranger spacecraft was to test basic engineering concepts and design, which would affect space flight programs for years to come. A variety of instruments can be mounted upon the basic structure. Rangers I and II carried a family of instruments designed to measure the intensity of the complete spectrum of energized particles encountered in space—from slow-moving low-energy electrons to the more powerful cosmic rays. The base structure, called the "bus" because it can carry such a variety of experiments, contains the highly complex spacecraft electronics. The central computer and sequencer controls the S/C performance of events. The attitude control system, acting on signals from the Sun sensors, orients the craft toward the Sun by activating small nitrogen gas jets, providing thrust to pitch, roll, and yaw the craft around each of the three axes. The spacecraft was tested during exposure to environments simulating launch and space flight. Vibrations exceeding those expected at launch shook the craft to discover any weaknesses in the structure or in the cabling. Near-perfect vacuums were accomplished in this test chamber, and the spacecraft was operated for hours in this void, proving the design fit for space operations. The surface treatment of each part of the spacecraft is designed to absorb, reflect, or radiate heat in order to stabilize the internal temperature of the equipment. The shiny silvered surfaces reflect sunlight, thereby reducing heat absorbed. Dark surfaces absorb and radiate heat energy readily. At the bottom of the spacecraft is located the high-gain directional antenna. The dish concentrates the power of the radio transmissions into a narrow beam, making wide-band telemetry possible.

As Ranger I completed preparations for space flight, construction and checkout of the worldwide deep-space instrumentation facility was completed; 85-foot-diameter antennas were constructed in Australia, South Africa, and in the Southern California desert. These three permanent stations are spaced about equally around the world so that spacecraft in deep space will always be in communication with at least one of the stations. So powerful that they have bounced radar signals off of Venus, these stations are capable of receiving and recording the volumes of information measured by the spacecraft.

Late in August 1961, the spacecraft, the flight operations team, the communications networks, and the new launch vehicle, the Atlas-Agena B, were ready. The first Ranger launch occured at 4 minutes after 5 a.m., August 24. Both Rangers I and II were placed in the nominal parking orbits, but launch-vehicle difficulties occurred which prevented their gaining additional velocity to reach the highly elliptical deep-space orbits desired. Yet, during their brief stay in orbit, a hundred miles above the Earth, telemetered data indicated the craft operated as well as they could under the nonstandard conditions, and confidence in the design of craft and instruments was high.

Proof of the Ranger's capabality in space came with the flight of Ranger III in January 1962. Rangers III, IV, and V are identical spacecraft. Their mission is to impact the Moon, performing experiments during the flight and taking television pictures during the final approach. The precision necessary to accomplish this mission is such that small errors or failure of equipment during the flight can lead to overall mission failure or, at best, partial success, by supplying valuable engineering and scientific data. The Ranger "bus" is essentially the same for these missions, but the "passenger" is noticeably different. Mounted upon the bus is the spherical lunar capsule, and the solid-propellant retromotor. The capsule and motor will separate from the Ranger as it approaches and crashes on the Moon at 6,000 miles per hour. The retromotor will fire, slowing the capsule so that it hits the surface with a velocity of about 100 miles per hour.

High-speed photography showed the lunar capsule striking a steel plate at a velocity greater than 120 miles per hours. An outer covering of balsa wood absorbs most of the shock of impact protecting the precision equipment within. In a simulated lunar landing test, the capsule was dropped onto a cement runway and impacted with a velocity of 150 miles per hour. As expected, the balsa wood was crushed and shattered as it absorbed the force of impact, but the inner survival sphere was intact, and operated. Near the center of the capsule is a sensitive seismometer which will measure movements of the lunar surface due to moonquakes or meteor impacts. The seismometer is tightly fit into a flat-topped aluminum sphere. This inner sphere contains batteries, a radio transmitter, and a cooling system. Surrounding the metal ball is an insulating blanket, which helps to maintain the inner ball at the operating temperature of 32° to 80°. An antenna is placed on the flat top of the ball outside the insulating blanket, giving the inner assembly its spherical shape. A fiber-glass coating covers the sphere, completely sealing it from its surroundings. The ball is sealed within a larger shell and the 8-inch-thick balsa wood. The space between is filled with a fluid making the inner sphere neutrally bouyant. Fifteen minutes after landing on the Moon the bouyant inner sphere will have come to rest with the antenna pointing upward. A caging foot extends and locks the inner sphere to the capsule. After caging, two penetrators located in the inner sphere fire projectiles through the two fiber-glass shells and the balsa wood. The flotation fluid drains out and evaporates in the lunar vacuum. The penetrations permit a fluid which has restricted seismometer movements to escape. The seismometer is adjusted to move freely and begins transmitting data to Earth. The batteries are designed to supply power to the transmitter for a month of continuous operation, giving a long-term record of lunar crust movements through the lunar day and lunar night.

The lunar capsule is assembled in a sterile environment to prevent biological contamination of the surface of the Moon with living organisms from Earth. Difficult assembly procedures must be performed through airtight gloved sleeves. All the tools and supplies needed to do the job must be placed into the glove box before the assembly operations can begin. Surface sterility of the Ranger is accomplished just before launch by exposing the craft to sterilant gasses.

The television experiment to be performed by Ranger will give man his first close look at the surface of the Moon. The camera will shoot more than 100 pictures during the last 40 minutes before impact. The series of pictures taken from 2,500 to 15 miles above the Moon's surface will provide definition fine enough to distinguish features the size of a compact automobile.

This radiation detector measures the average gamma-ray intensity in space and from the Moon's surface during the spacecraft final approach. This information will help determine the origin of the lunar material—whether it is volcanic or meteoritic. The instrument is mounted on a telescoping boom which is extended by pressurized gas. This places the experiment 6 feet away from the spacecraft, reducing the count of secondary gamma rays produced when cosmic rays bombard the craft.

The Ranger spacecraft on flights to the Moon will use a small 50-pound-thrust midcourse correction motor. To gain the precision necessary to impact a target at distances as far as the Moon, all small variations remaining at the time of spacecraft separation from the booster stages must be removed. The liquid monopropellant motor is so precise that it can impart velocity corrections from one-tenth of a foot per second to 144 feet per second.

Ranger III was launched on January 26 this year. Early in the flight, ground guidance of the booster was lost, so the flight was controlled by the automatic program in the Atlas. Fine adjustments to the flight direction and the times of booster-stage cutoff were not controlled. The parking orbit was achieved and the Agena-B successfully restarted, boosting the spacecraft onto a deep-space trajectory. Thirty-one minutes after launch the solar panels opened and 3 minutes later the Sun-seeking maneuver began. Telemetry indicated that the spacecraft took 9 minutes to orient itself to the Sun so that the solar panels received maximum solar power. Two and a half hours later the command for Earth acquisition occurred, and within 3 minutes the craft had pointed the high-gain antenna toward the Earth. Now in the cruise mode, the craft would continue on trajectory with the attitude control system keeping the solar panels facing the Sun and the high-gain antenna facing the Earth. Continued refinements of the trajectory from tracking data indicated that the spacecraft had excess velocity, beyond the correction capability of the midcourse motor. A midcourse correction was calculated, transmitted to the craft, and executed,

placing the craft closer to the Moon. When the craft came closest to the Moon, a terminal maneuver was executed to attempt to point the TV camera at the Moon. A spacecraft component failure at this time prohibited the craft from stabilizing its attitude, which keeps the high-gain antenna oriented to the Earth. From this time on the craft continued tumbling, and effective communication with Earth was lost as the craft went into its own orbit about the Sun.

A combination of difficulties kept ranger III from completing its overall mission, yet this flight gave us the first deep-space test of the capabilities of Ranger in Sun and Earth seeking, command reception and execution, stabilization in the cruise mode oriented to the Sun and Earth, midcourse maneuver and firing a propulsion system in deep space, and long-range space communication. Each task was successfully accomplished by the spacecraft.

An early in-flight failure disabled the Ranger IV spacecraft, prohibiting performance of the designed maneuvers. Fortunately, the craft had been placed upon a near-perfact trajectory by the Atlas-Agena booster. The 1/20-watt transmitter in the seismometer capsule was tracked all the way to the Moon, and after a flight of 63 hours, 59 minutes, the craft impacted on the far side of the Moon at almost 6,000 miles per hour.

Ranger V has completed assembly, and is scheduled to launch this fall. In checkout facilities at Cape Canaveral, the spacecraft will be given repeated system tests and dummy runs, simulating the launch and flight sequence that the craft will perform.

Following the lunar seismological experiment flights, four spacecraft, Rangers VI through IX, will carry an advanced television mission to the Moon. The TV-mission hardware will be mounted on top of the Ranger bus. The structure is now being subjected to the environment of launch and space flight. The structure will mount multiple television cameras. The craft will not survive impact; it will complete its mission before crashing, sending pictures of the lunar surface to Earth receiving stations. Parallel development of the ground equipment which will receive and record the complex telemetered signals is continuing. Detailed visual studies of the lunar surface provided by this mission are vital to the planning of controlled soft landings on the surface of the Moon. Is the surface fine, dustlike powder in which the craft may sink? Or, is the surface covered with boulderlike debris which will toppple and damage a craft when landing.

Tests of a model of the landing-gear scheme are part of the current development program of the Surveyor, the second-generation lunar landing spacecraft. Surveyor is a much heavier craft than Ranger and will use the larger booster capability that is now being developed. Several Surveyors will be launched during 1964 and 1965. Surveyor will land softly on the Moon between 5 and 10 miles per hour, being slowed by a retrorocket and smaller vernier engines. The three landing-gear legs will absorb final touchdown shocks and keep the craft from toppling. This spacecraft is capable of mounting a variety of experiments to be performed in the vicinity of the landing area. Television cameras looking into mirrors will survey the entire area around the craft from 15 degrees above the craft horizontal to 45 degrees below. One television camera will observe the operation of experiments being conducted on the lunar surface.

The experiments to be conducted by the Surveyor spacecraft will define in depth the properties of the lunar soil. Physical, electrical, mechanical, and chemical analyses will be performed. A soil-mechanics instrument will measure the soil bearing and shear strength providing data which will enable us to determine whether wheels or treads, snowshoes or spikes will be the means of locomotion on the Moon. A thermal-diffusivity experiment will measure the rate at which the temperature drops when the soil is shaded from sunlight. Also, during the lunar night, this device will heat the soil and measure temperature rise. Chemical analysis of lunar samples will be performed by an X-ray spectrometer. Samples of lunar material, in a vacuum, bombarded by powerful X-rays, reflect the rays in directions characteristic of the compounds making up the soil sample. Geiger tubes measure reflections from the material permitting scientists to determine the sample constituents. An X-ray diffractometer will also be used in analysis of lunar materials. A rotating Geiger tube measures the diffraction, or bending, of X-rays passing through a sample of lunar material. Comparing the diffraction measured with that of known samples, scientists can determine the chemical composition of the samples. After analysis of soil scooped from the surface, a drill will penetrate the surface, at least 18 inches and supply the analysis equipment with subsurface samples. Tests of the design model of the drill and bits have been completed in a vacuum chamber where dust behaves neither as a liquid nor as a solid.

While the Surveyor structure and instruments continue to be developed, Earth-based equipment to receive data and issue commands to the craft is being prepared. One of the command data handling consoles will be located at each of the deep space net stations to guarantee continuous contact with the Surveyor. Simulated mission operations are being performed to check details of procedure and to simplify operation. The Surveyor craft will be launched to the Moon by the Atlas-Centaur booster.

Reaching farther into space, the planetary program will launch its first spacecraft during the summer of 1962. The first flight will be to Venus. Opportunities to launch flights to Venus occur during a short period of time every 19 months. The mission of this spacecraft, titled Mariner, will be to pass within about 16,000 miles of the planet, performing several scientific experiments and transmitting the results to Earth. The flight to Venus will take approximately 4 months. The Mariner

craft will fly from 160 to 240 million miles while dropping in to cross the orbit of Venus. During the flight to Venus, Mariner will measure interplanetary magnetic fields, charged particle intensity and distribution, solar plasma intensity, and micrometeorites. A radiometer will scan the planet during the encounter to obtain information on two of the most interesting scientific questions about Venus: What is the surface temperature and what is the nature of the cloud layer? Both microwave and infrared detectors will be employed in the radiometer.

Many of the Mariner R bus features were developed on the Ranger bus as part of the lunar program. The Mariner uses a midcourse motor for precise corrections to the flightpath. Solar panels will supply electrical power when the craft is oriented toward the Sun, and a battery will be carried to supply power when the craft is maneuvering and before Sun orientation is accomplished. The high-gain antenna will beam telemetry millions of miles through space to the Earth. Where variable heat output will occur, louvers adjust the flow of heat to be dissipated into space, maintaining the required internal temperature for stable and long-life operation of the Mariner. Two spacecraft will be launched from the same launch pad about a month apart. If both are successful, data will be received from different distances in space at the same time, and perhaps different conditions will exist on Venus during the two passes.

Beyond the Venus experiment will be flights of new and larger craft, reaching to Mars and Venus with new instruments, testing the planetary atmospheres, viewing the surfaces, measuring the temperatures, and eventually landing and determining the chemistry of the planets and looking for life forms.

Rangers I and II first tested the spacecraft engineering principles in orbital flight. The Ranger lunar impact mission first tested the craft maneuvers, commands, communications, and instruments on a deep-space trajectory; the Ranger television mission will tell us more about the lunar surface; and Mariner will reach toward the planets, sending a wealth of information about interplanetary space and answering vital questions about our planetary neighbors. Surveyor will develop techniques for soft-landing complex delicate instruments on the Moon, which will perform physical and chemical analyses on lunar soils.

Vast strides in technological and scientific capabilities have been made—more are coming. And that day is rapidly approaching when man himself first travels beyond the Earth to the ultimate goal—manned exploration of the Moon and planets.

On April 23, subsequent to the preparation of the film from which this narrative was taken, the second Ranger was launched to the Moon. The launch vehicle performed very well, resulting in a lunar impact on the hidden side of the Moon. However, failure in the complex spacecraft rendered most of the Ranger systems inoperative and resulted in loss of the scientific objectives of the flight. The unqualified success of the Atlas-Agena B for the first time in the Ranger series, however, has reassured us of eventual success in this difficult mission.

No country has yet launched a successful probe to a planet. Soviet attempts have met with failure. We have yet to try. This summer will probably see both nations launch spacecraft toward Venus. Ours will be called Mariner R and is shown in figure 2-7.

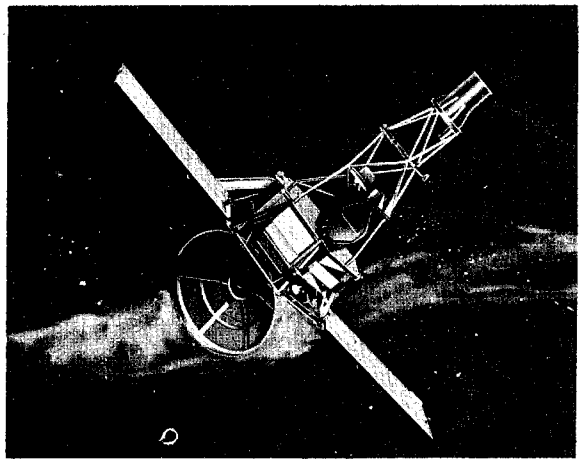


FIGURE 2–7. Mariner R.

Mariner R will be launched with an Atlas-Agena and will weigh about 450 pounds. In addition to several instruments to measure the radiations and fields of interplanetary space and in the vicinity of the planet, a radiometer and infrared spectrometer will be used to scan the planet as the spacecraft flies by. These instruments will make critical measurements of the planet's atmosphere and surface temperatures which will be not only of great scientific interest but will aid us in the design of later landing systems.

Our first planetary landing will have to await an advanced spacecraft called Mariner B (fig. 2-8). Mariner B will be launched in late 1964 with the new Atlas-Centaur rocket. Designed for flight to either Mars or Venus, this 1,200- to 1,400-pound spacecraft will

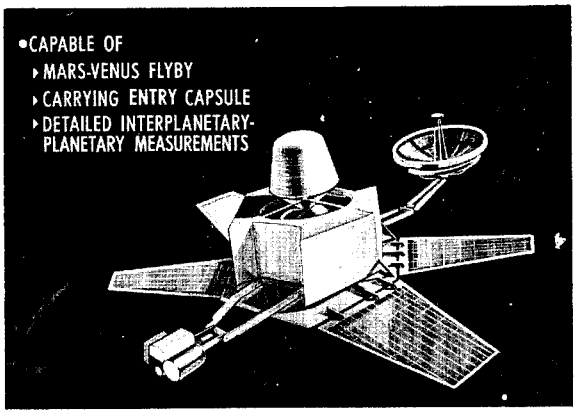


FIGURE 2–8. Mariner B.

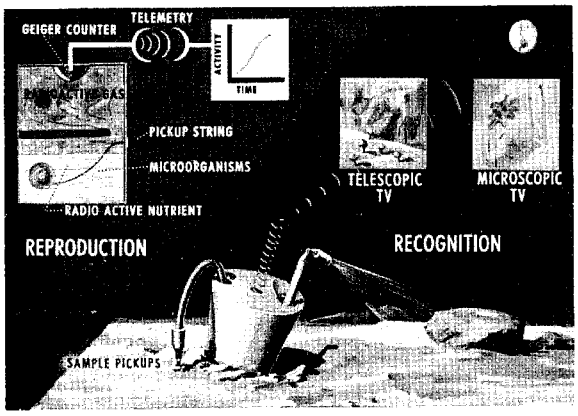


FIGURE 2–9. The search for extraterrestrial life.

first be used in the Mars attempts. As the figure shows, a landing capsule is included in this recent version of the design. This capsule will be guided toward the planet by the basic spacecraft which will then fly by the planet. While the capsule enters the atmosphere and lands, the spacecraft will perform scanning experiments as will the Mariner R on Venus, but with a greater degree of sophistication.

With a capsule on the surface of Mars may well come the first proof of extraterrestrial life! Detection of extraterrestrial life would undoubtedly constitute one of the great scientific discoveries of history. Observations of Mars from Earth have given us reason to believe that some form of life may exist there. What this life might be like, one can only surmise at this time. We are working on a number of experiments to detect such life. Because of the universal interest in this subject, I have elected to discuss it briefly, with the intent of illustrating the type of scientific thinking which is the very foundation of our space program.

Figure 2-9 shows an artist's conception of a capsule after landing on the Martian surface. Two life-detection schemes are illustrated. The simplest to understand is based on recognition of life forms. For this purpose, a television telescope is shown erected and focused on plant life growing by a nearby rock. Such pictures would be radioed to earth for interpretation. Another recognition technique is that of using a television microscope to observe soil samples picked up from the surface and subsurface. Microorganisms might thus be recognized.

In the left-hand portion of the figure is a schematic drawing of a device developed by Resources Research, Inc. This device, like many others under study, depends on detection of reproduction, a function peculiar to living matter. This particular instrument is unique, however, in the manner in which this is done. A string is ejected from the capsule and pulled back into the instrument after dragging across the soil. Once inside, the instrument is sealed and a "universal" nutrient designed to support many types of life is injected into the chamber containing the string. If the nutrient suits the type of microorganisms which may exist on Mars, and if these micoorganisms behave as ours do on earth, they will reproduce and generate carbon dioxide at a rate proportional to the reproduction. Since the food is "spiked", so to speak, with radioactive carbon 14, the generated gas is also radioactive. The radioactivity of this gas is detected by a Geiger-type counter which is otherwise shielded from the nutrient. The resulting count rate is telemetered to Earth and the trace illustrated in the small insert would mean life.

The problem, of course, is not as simple as I have described it, but enough competent scientists are working with us to insure eventual detection of life if it is really there.

The following table is designed to illustrate the great involvement of the scientific community in the national space program:

	Participating scientists		
	University	Government	Other
Lunar photography	2	3	1
Lunar surface analysis.	26	16	1
Planetary Atmospheres and surface.	29	19	3
Interplanetary radiations and fields.	31	27	1
Extraterrestrial life	12		7
Lunar and planetary (Total)	100	65	12
Geophysics and astronomy (Total)	113	76	59

The scientific participants in the lunar and planetary program total about 100 from universities, 65 from Government laboratories, and 12 from industrial laboratories. The geophysics and astronomy program currently involves about 113 university scientists, 76 Government, and 59 from industrial and nonprofit organizations. (Some scientists working on several experiments appear more than once in these statistics.)

It is on these men that the ultimate scientific value of the program rests. Their efforts will not only yield a host of new scientific discoveries, but will breed a new generation of scientists.

3. Space Vehicle Research

By MILTON B. AMES, JR., *Director of Space Vehicles, Office of Advanced Research and Technology, NASA*

Mr. Ames, a native of Norfolk, Virginia, was born on September 21, 1913. He attended the Norfolk Division, College of William and Mary and Virginia Polytechnic Institute, where he studied mechanical engineering. He received a bachelor of science degree in aeronautical engineering from Georgia Institute of Technology in 1936.

Mr. Ames was formerly an aeronautical research engineer at the Langley Research Center, National Advisory Committee for Aeronautics (predecessor of the NASA). While at Langley he was also an instructor in aerodynamics and engineering principles of aircraft design at the Norfolk Division, VPI.

In 1941 he was transferred to NACA Headquarters in Washington where he was on the technical staff of the Director of NACA. He has served as Engineering Assistant to the Chief of Military Research in Washington, Chief of the Aerodynamics Division, and Chief of the Aerodynamics and Flight Mechanics Research Division. He was formerly Assistant Director of Research for Aerodynamics and Flight Mechanics and Deputy Director of the Office of Advanced Research Programs at NASA Headquarters.

INTRODUCTION

Many people have experienced, either by means of television, radio, movies, or the press, the breathtaking drama of a major space flight launching. However, to set the stage for my remarks, let's turn back to October 27, 1961, at Cape Canaveral.

At 10:05 a.m. e.s.t. our country's largest space vehicle, the Saturn (SA–1) was launched. (See fig. 3–1.) Four seconds after ignition the 1,300,000 pounds of thrust of the eight engines lifted this 162-foot-high rocket off the launch pad. This enormous vehicle accelerated through the atmosphere and out into space to a maximum altitude of 85 miles on this highly successful first test flight. The flight lasted 8 minutes. On April 25, 1962, Saturn had its second successful test flight. These were "momentous occasions" and major steps forward in our mastery of space. Yet the job is not done—in fact, it has only begun.

After successful flights like Saturn and Astronaut Glenn's three orbits around the Earth in the Mercury-Atlas 6 flight, we are quick to forget our past failures and often fail to recognize the hard work that was required to achieve such successes. There is also a human tendency to overlook the major problems that lie ahead of us.

In this paper an outline is presented of some of our research and advanced technological activities directed at problems which must be solved if our nation is to continue as a leader in the mastery of space. In discussing technical programs it is helpful to relate them to various phases of space flight. A typical space flight mission, for example, might deal with:

(1) Launch and exit from the atmosphere
(2) Flight in space
(3) Atmospheric entry and landing or recovery

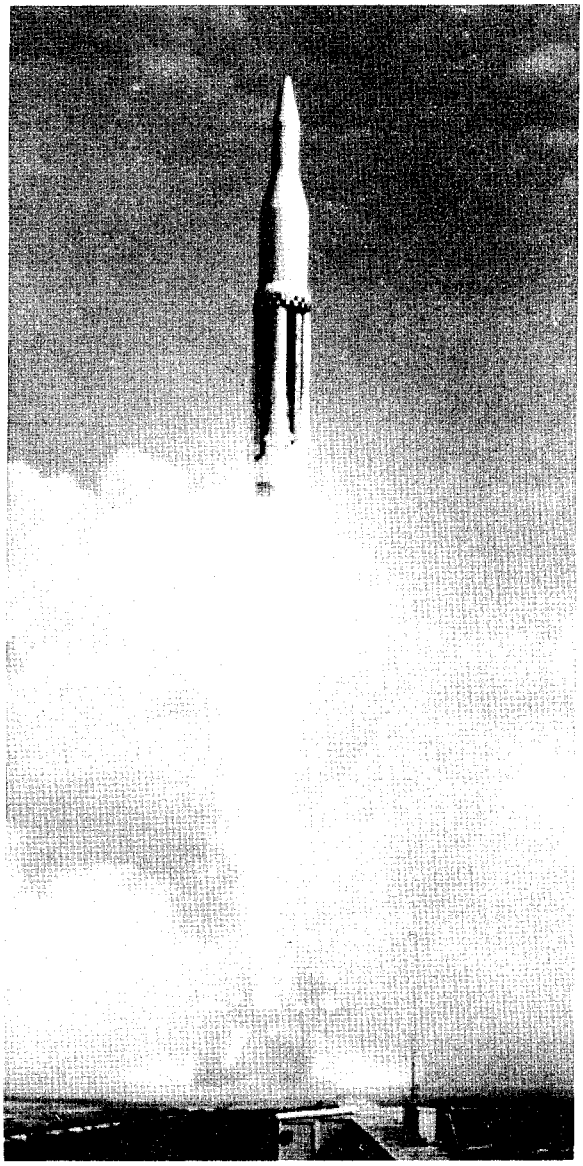


FIGURE 3–1. Saturn SA–1 launch, October 27, 1961.

LAUNCH AND EXIT

The launch and exit phase of any space mission generates research problems in many technical areas. First, consider the structure of our space vehicle.

It is interesting to note that the potentiality for structural failure is greatest in the first 60 to 120 seconds of flight, because the forces or loads which are brought into play on the space vehicle are the greatest during this time. Figure 3–2 shows some of the loads, shocks, and vibrations to which a large launch vehicle is subjected during the

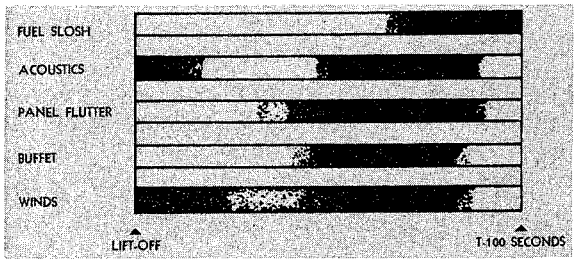


FIGURE 3–2. Loading conditions during first 100 seconds of flight.

first 100 seconds of flight. These include: winds, buffet, panel flutter, stresses caused by acoustic excitation, and fuel slosh. After about 50 seconds of flight, all these loading conditions are acting simultaneously on the space vehicle.

Wind loads.—Space vehicles are tall slender, lightweight structures, and wind loads are troublesome, both on the launch pad and in the atmospheric phase of flight. As the vehicle leaves the pad and accelerates through the atmosphere, high-velocity "jetstream" winds, sometimes as high as 220 miles per hour, impinge (essentially perpendicularly) on the vehicle and induce large loads and stresses. Present information on wind profiles used in design is based on data which were originally derived for meteorological purposes using balloons and are inadequate. A new method for measuring these winds by photographing the smoke trail of a rocket has been developed and is being used both at Wallops Island, Virginia, and at the Atlantic Missile Range in Florida to provide better data on wind profiles. (See fig. 3–3.) The rocket is launched from

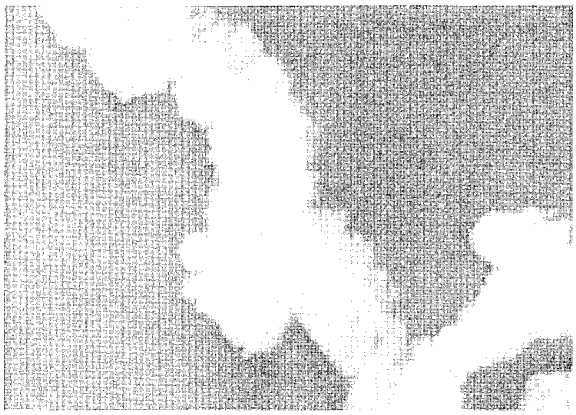


FIGURE 3–3. Wind shear.

the NASA Wallops Island Station. The data are recorded by two fixed cameras, located approximately 12 miles from the launch site, at 6-second intervals for a total time of 5 minutes. Wind profiles are obtained by a data reduction technique using photographs of the smoke trail to maximum altitudes of 90,000 feet. Smoke-trail results have indicated the existence of relatively rapid changes in wind velocities which were not revealed by balloon flights.

Buffeting.—In considering the problem of buffeting, first look at space vehicle launch configurations such as those shown in figure 3–4.

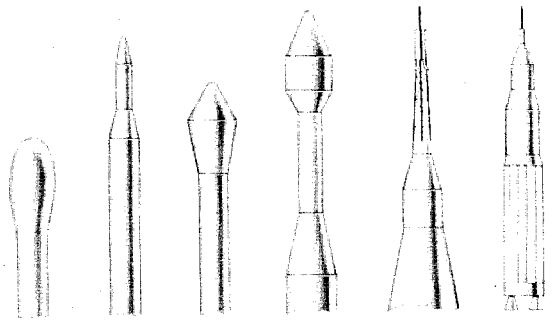


FIGURE 3–4. Space vehicle launch configurations.

One of the basic concepts underlying current NASA space activities is that a limited number of launch vehicles must be employed to serve the purposes of a large variety of missions. These missions, however, employ spacecraft that differ greatly in size and shape. The front or top ends of the vehicle systems appear somewhat as shown. As can be seen, these are not always streamline shapes, so that—as they lift off and push upward at high speeds through the atmosphere—the airflow behind the corners or bulbous forms becomes turbulent and causes buffeting of the entire launch vehicle.

This kind of flow is illustrated in figure 3–5. This figure shows a model of a spacecraft launch configuration seen through a window in a wind tunnel during a test run. The tip of the nose is partially obscured by the tunnel wall. The airflow is from right to left. The nature of the flow was determined by the various colors around the nose of the

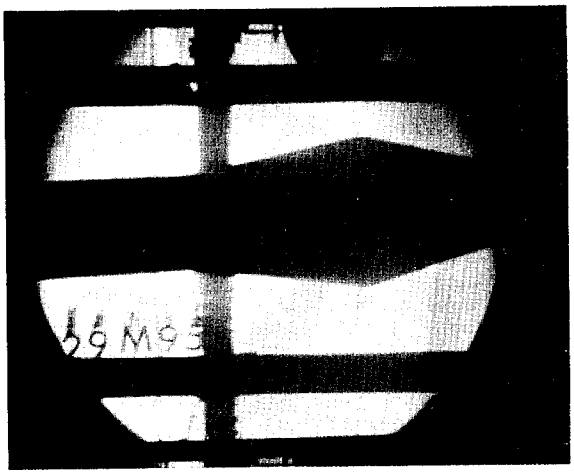


FIGURE 3–5. Launch vehicle buffeting.

model. The flow was turbulent or unsteady, and not only caused buffeting of the vehicle locally but also gave rise to variable forces on the whole vehicle that could excite one or more of its natural vibration modes. Studies of this kind of behavior have to be made on dynamically scaled models in wind tunnels to learn how to avoid serious trouble.

Some of our space vehicles have experienced unsteady flow conditions during launch for periods of about 30 to 100 seconds. Structural vibrations could wreck an actual space vehicle, and some of our failures may have been caused by such phenomena.

Panel flutter.—Panel flutter is a phenomenon very closely related to the familiar waving of a flag in a breeze, and just as a flag eventually tatters, the sheet metal outer skins of launch vehicles and spacecraft sometimes experience failures because of this problem. A part of the outer skin of one launch vehicle was evaluated for panel flutter, and the study indicated that flutter could occur in flight at supersonic speeds. The test was run in the 9- by 6-foot Thermal Structures Tunnel of the Langley Research Center. The test panel was a 25-inch by 25-inch flat sheet of aluminum alloy which was seam welded to a corrugated sheet for reinforcement. (See fig. 3–6.) The test panel had cross-hatched paint patterns for photographic reference. The supersonic airflow was from left to right. The downstream or right end of the panel fluttered and finally failed.

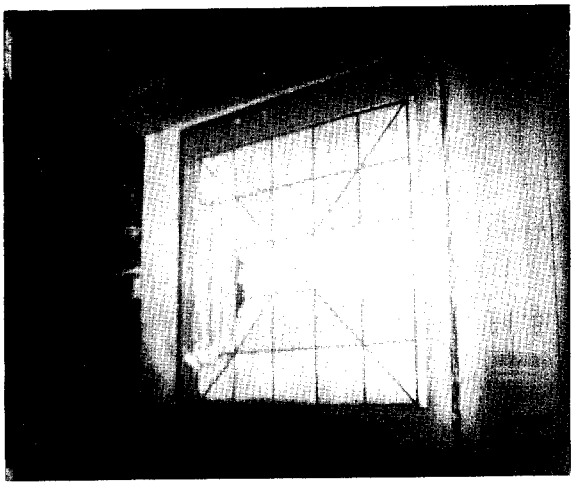


FIGURE 3–6. Panel flutter.

Fuel Sloshing.—Fuel sloshing was another item on our list of important structural loads occurring in the first 100 seconds. A study was conducted to determine the natural frequencies and mode shapes of a liquid in a cylindrical tank model representative of an actual launch vehicle. (See fig. 3–7.) A 12-inch-diameter clear plexiglas model was partially filled with colored water. The testing technique involved the excitation of the model over a wide range of frequencies. When a fundamental mode was developed, the corresponding frequency was read from a tachometer.

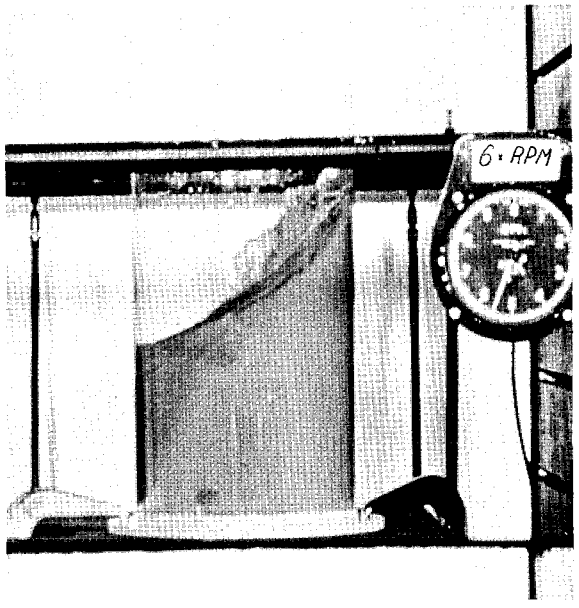


FIGURE 3–7. Fuel slosh.

Thus far, the experimentally measured results have been in very good agreement with those obtained theoretically.

Launch-Vehicle System Dynamics

Perhaps it is now clear that in a structural sense, the booster components of space vehicles are not in themselves separate trucklike machines upon which or in which cargo may be carried into space. Each component of the complete system that stands on the launching pad must be firmly secured to the adjoining parts. When this is done, the combination of loads, forces, shape, mass, and flexibility that results is such that there is no escape from treating each combination as one integral structural system.

One aspect of the problem of space-vehicle system dynamics is the determination of structural modes and frequencies and of the damping characteristics of the structural system in these modes. Calculated properties leave much to be desired, especially beyond the first mode, and full-scale tests are difficult and expensive to make. For these reasons and because space-vehicle configurations have to be established at an early stage, the development of model testing techniques is an attractive approach to this problem. This approach is currently being made through the use of models large enough to permit the introduction of significant structural detail.

The left photograph in figure 3–8 shows such a model of the Saturn C–1 configuration mounted for vibration tests at the Langley Research Center. In order to insure that model tests yield results applicable to the full-scale system, it is necessary—during the course of research to develop model techniques—that some results for comparison be available from full-scale tests, such as those shown in progress at the Marshall Space Flight Center in the right photograph.

Results of such tests have indicated that in simple cases the vibration characteristics of space vehicles can be calculated satisfactorily. In the more complex cases such as Saturn, however, we cannot calculate the vibration characteristics with percision. In addition, we must learn more about how to use model tests to predict with greater ac-

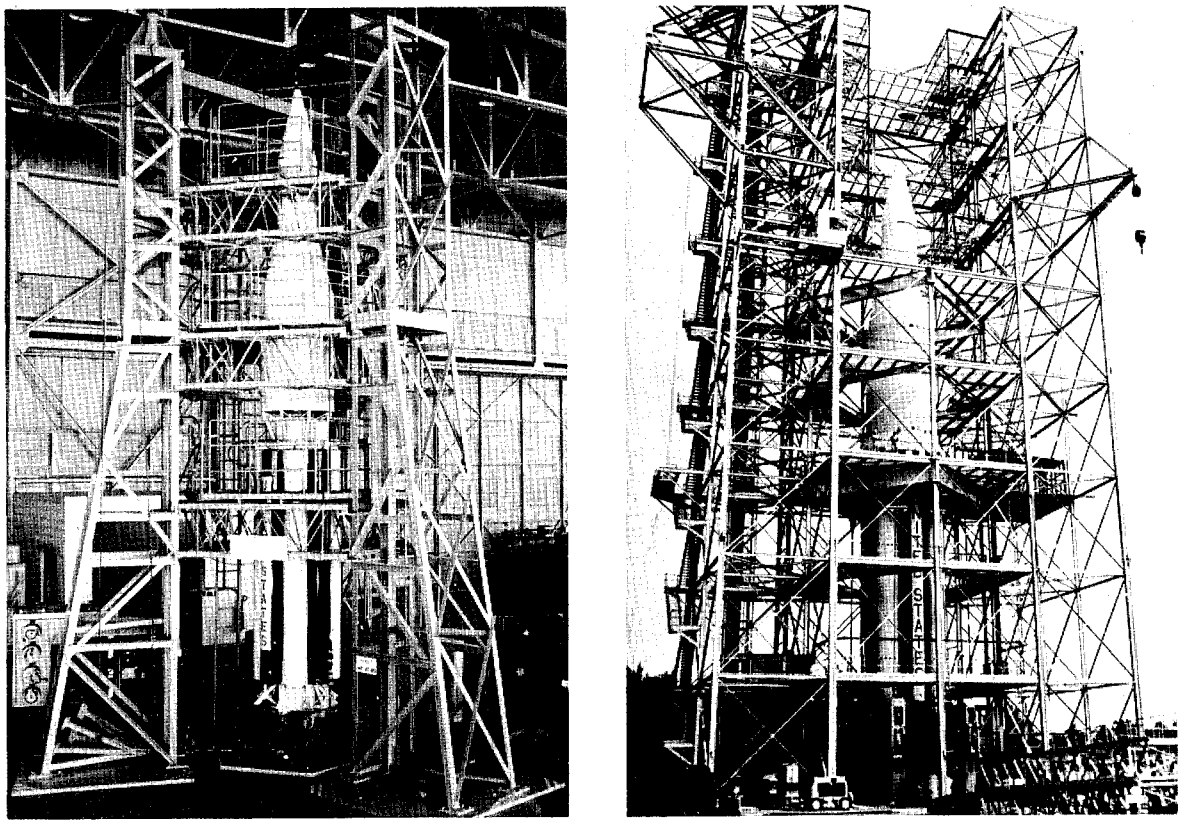


FIGURE 3–8. Photographs of vibration test vehicles. Left, model; right, full scale.

curacy the vibrational characteristics of full-scale vehicles.

Chemical Propulsion

As is well known, chemical propulsion is the only means available to us at this time for space exploration missions. There are more advanced forms of propulsion under study—notably nuclear and electric propulsion—but these are still in a research and advanced developmental stage. For the present, and for some time to come, we must rely on the energies released by chemical reactions to propel our vehicles and spacecraft in space exploration.

In certain respects, however, the liquid rocket engines used in today's launch vehicles are basically the same as, but improved versions of, engines developed 20 years ago. The left sketch in figure 3–9 shows that the 1955 model is bulky. It has many parts which make it quite complex. We cannot control the magnitude or level of thrust. We

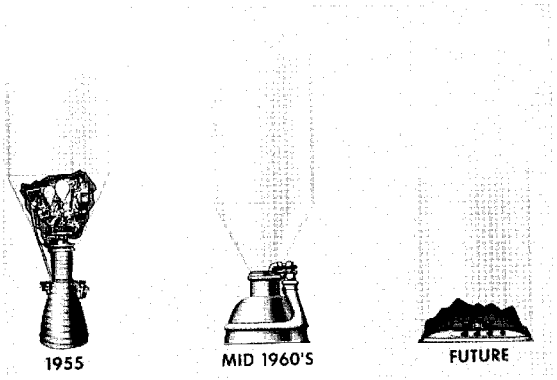


FIGURE 3–9. Liquid rocket technology.

swivel practically the whole engine to vector the thrust in order to stablize and guide the vehicle.

The liquid rocket engines shown in the center and right sketches are clearly indicative of our belief that research and development activities will meet the continuing demands for greater performance, reliability,

and economy. As improvements are made, engines should become less complex, lighter, and more compact. For example, the engine shown in the center will have less than one-half the parts of the earlier one on the left. It is simpler and will have much improved reliability and performance. We anticipate that if we continue this trend in development through research, we might achieve a high-performance engine which would not only be more compact but would also permit us to control both the direction and magnitude of the thrust without swiveling the nozzle. Such a rocket engine would also fit better into the vehicle, as shown by the right-hand sketch, would alleviate some of the structural problems previously discussed, and would have a lower structural weight.

Figure 3–10 summarizes our research and advanced technology activities on chemical propulsion. At present, the thrust of the chemical rocket is, of course, limited by the energy content of the fuel and the oxidizer. Research on high-energy fuels such as hydrogen began at the Lewis Research Center in the early 1950's, and has now resulted in the use of hydrogen and oxygen as the high-energy fuel-oxidizer combination in the Centaur rocket, the upper stages of Saturn, and in the 1.2-million-pound-thrust M–1 rocket engine for advanced Saturn and Nova class vehicles.

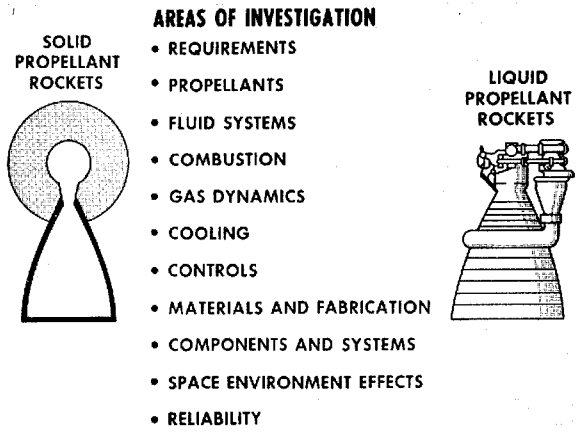


FIGURE 3–10. Chemical propulsion.

In the center of the figure is an outline of the areas now being investigated. In all cases except one, the outline applies equally well to both solid and liquid rocket engines.

Our research plans, in brief, are to conduct theoretical and experimental investigations in these areas, both within the NASA organization and by contract to universities and industry.

Launch-Vehicle Recovery

As we continue to increase the sizes and frequencies of our space flight launchings, we will ultimately reach a point where it will be both economically feasible and desirable to recover at least the more costly part of the launch-vehicle system. Many ideas and concepts have been suggested for booster recovery, and some activities are going on in this area.

One possible means being investigated for recovering the first stage of a large launch vehicle is the use of a flexible wing called a paraglider. In figure 3–11, a model of a flexible-wing-supported launch vehicle is

FIGURE 3–11. Booster recovery.

shown in midair after being dropped from a helicopter at the Langley Research Center. The model was radio controlled from the ground and was being tested to determine the low-speed dynamic stability and control characteristics of such a recovery system.

PROBLEMS IN SPACE

Once the vehicle is in space, there is a completely new assortment of problems.

Meteoroids.—One of the difficult problems posed by the environment of space is the protection of the spacecraft and its contents against catastrophic damage from meteoroids. There are really two problems here. First, we have to find out what the meteoroid content of space is: How many are there in a given region of space? How big are they? How fast do they travel? These are difficult questions, and the answers to them are quite uncertain at this time. The second problem, once the nature and speeds of the meteoriods are known, is to learn how to fend them off or devise spacecraft structures that they cannot penetrate.

The best way to solve the first problem is to send up probes or satellites to measure the meteoroid content of space. In the summer of 1961 we attempted to do this with a small satellite known as Explorer XIII. (See fig. 3–12.) Impacts of meteoroids on various parts of the satellite are first recorded and then transmitted to a data receiving station on the ground. Owing to a malfunction, this satellite stayed in orbit for a very limited period. Consequently, we will launch another meteoroid satellite of this type late in 1962.

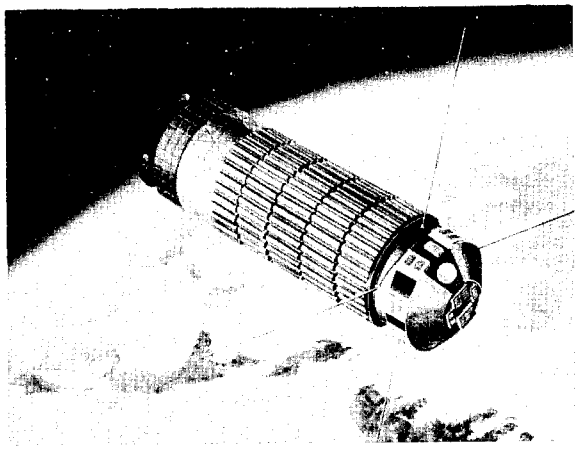


FIGURE 3–12. Artist's drawing of Explorer XIII.

We are also planning other flight experiments such as the two shown in figure 3–13. On the left is a kitelike object called a recoverable probe. This probe is, in fact, a paraglider device that will be shot up outside the Earth's atmosphere and will unfold in space. The glider will have a large surface area held rigid by inflated tubes or ribs. When a meteoroid or micrometeoroid penetrates the surface, its penetrating power can be recorded. The recoverable feature of the vehicle will permit examination of actual micrometeoriods that become embedded in the material.

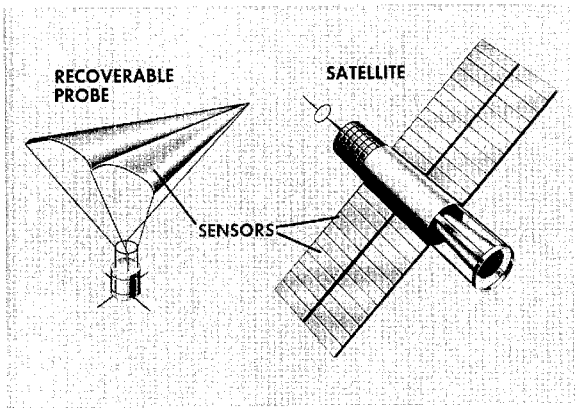


FIGURE 3–13. Meteoroid flight experiments.

The satellite experiment on the right operates on somewhat the same principle as the recoverable probe, but the sensors now consist of layers of stainless steel, plastic foam, and plastic glass cloth. The length of time in orbit will, of course, be much longer than the period of the recoverable probe near peak trajectory; therefore, the sensor of the satellite is designed to record the larger meteoriod particles that occur less frequently. Experiments of this kind should do much to improve our knowledge of the meteoroid content of space.

Tests were made to determine what happens when a small meteoroidlike pellet impinges on thin metal sheets representative of spacecraft structural shells. Films were taken at more than 1,300,000 frames per second of a 1/8-inch sphere or pellet travel-

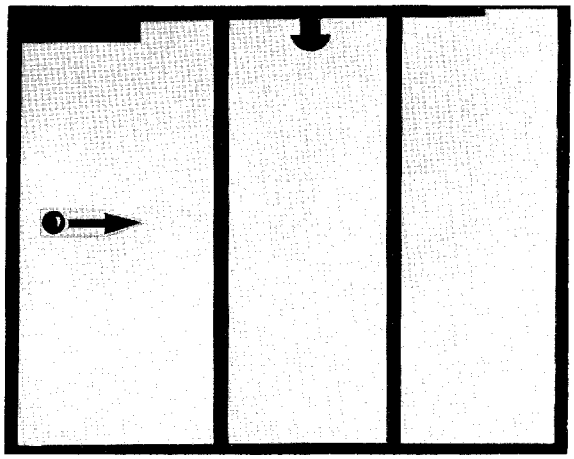


FIGURE 3–14. Test of ⅛-inch pellet impacting two parallel aluminum sheets at a velocity of 23,000 feet per second.

ing at 23,000 feet per second (or 16,000 miles per hour), and impacting two parallel aluminum sheets approximately 1/16 inch thick and spaced 1 inch apart. The ⅛-inch pellet was fired at 23,000 feet per second or about 16,000 miles per hour. (See fig. 3–14.) Upon impact both the projectile and the portion of the target material removed from the first sheet were shattered into fine particles. Upon striking the second sheet, a burst of light was produced and the fragmented material was sent back to the rear of the first sheet.

Studies of this kind are leading to knowledge of how to design meteoroid resistant structures.

Radiation.—Still another hazard of the space environment is radiation, which may cause damage either to human occupants or to the equipment of spacecraft. Human occupants will have to be shielded from radiation, but the shielding of all contents of the spacecraft is prohibitive because it would add greatly to the weight of the spacecraft. Other means will have to be found to protect equipment such as electronic components.

Research on damage caused by nuclear reactor effects has been in progress and effort in this area will continue. Very little work, however, has been done on space radiation damage to electronic materials. Laboratory simulation of radiation bombardment similar to that which occurs in the Van Allen radiation belt, shows (as can be seen in fig. 3–15) that the output of a typical semiconductor may drop more than two-thirds of its original performance after a 25-day period; this, of course, is unacceptable. Research investigations are being expanded to check present materials for radiation damage and to determine what new materials or techniques are required to produce radiation-resistant items.

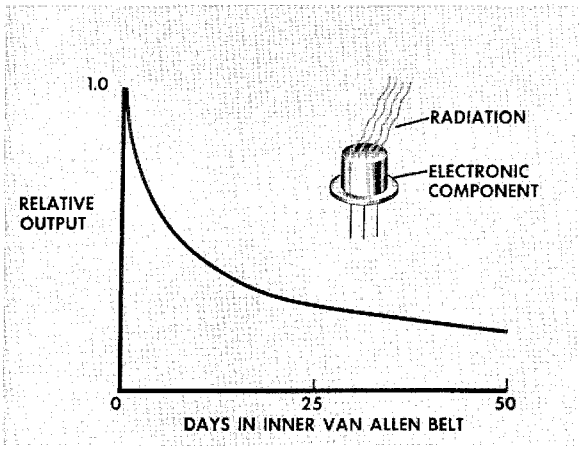


FIGURE 3–15. Radiation damage to electronic materials.

REENTRY VEHICLE TECHNOLOGY

Many missions require the safe return of a spacecraft or important parts of its contents to the Earth. (See fig. 3–16.) This requirement poses an exceptionally difficult assortment of problems, including aerody-

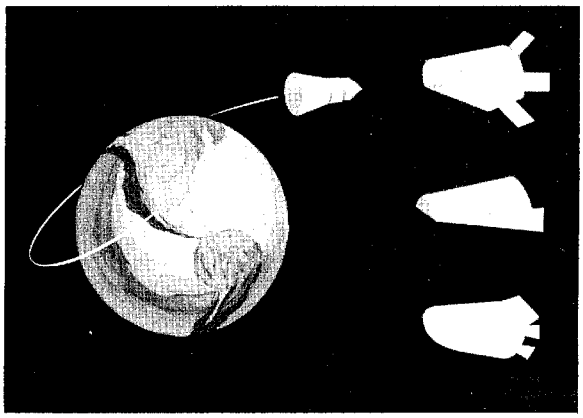


FIGURE 3–16. Reentry vehicle technology.

namic heating during atmospheric entry, landing trajectory control, and energy management. A broad program of study of these problems includes the exploration of the flight characteristics of many possible future spacecraft configurations, as shown on the right in the figure.

These programs will provide information for design of (1) more advanced orbital vehicles, (2) vehicles for lunar missions, and (3) vehicles for interplanetary missions such as to Mars and Venus.

Reentry heating.—It has not been so long ago that the problem of bringing a ballistic missile warhead to Earth without it burning up in its plunge through the atmosphere was regarded as a very difficult one. However, to date, the United States has successfully recovered 15 spacecraft from orbit. Perhaps the most dramatic reentry from orbit achieved by our country was during Astronaut Glenn's flight in the Mercury Freedom 7 spacecraft. Tests simulating the heating of models of the Mercury capsule reentering the atmosphere were run in the Entry Heating Simulator at the Ames Research Center. This facility was designed to test heat-shield materials and is capable of simulating heating for atmospheric entry for both orbital and lunar missions. The convective heat flux, the primary type of heating in entry from orbital flight, is supplied by an arc-type air heater operated in conjunction with a supersonic nozzle.

Tests of two different Mercury capsule models, each 1 inch in diameter, were made: one with the heat shield alone, and one which simulated the Mercury capsule entry with the retropack attached to the heat shield. In the first test, there was fairly steady flow around the model as it heated; the heat shield melted or ablated in a rather steady manner, carrying the heat away. In the second test, a steel retropack was added to the heat shield. Soon after the start of the test, the retropack began to heat and burn. Toward the end of the test, the main body of the retropack melted and pieces of it flew off as molten metal. (See fig. 3–17.) This demonstrated rather vividly the "fireball" that Astronaut Glenn described during the reentry phase of his historic flight.

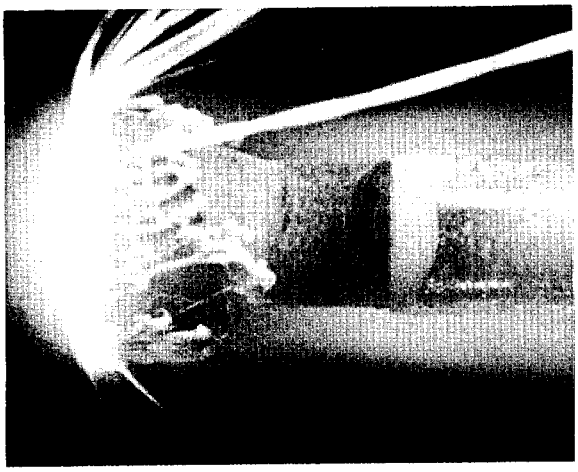


FIGURE 3–17. Heat test of Mercury capsule model.

As the speeds of space flight increase, the heating during reentry becomes very much more intense, as shown in figure 3–18. The heat load is the total amount of heat generated during the plunge of a given reentry vehicle through the atmosphere, and is plotted against speed. In order to show the magnitude of the heat load at the higher speeds corresponding to return from a flight to one of the planets, the curve has had to be drawn very close to the base line at the lower speeds. Even so, it can be seen that the heat load at lunar return speed of 26,000 miles per hour is several times as great as the heat load at satellite speed (18,000 miles per hour). The heat load at 40,000 miles per hour is shown here to be about 100 times that at satellite speed, although there is great uncertainty as to the actual value.

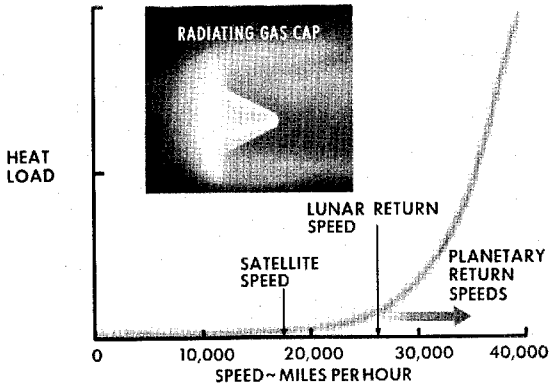


FIGURE 3–18. Reentry heating.

The rapid rise in heating at the higher speeds is caused largely by radiation from the hot layer or cap of gas that lies at the nose of the vehicle (this is shown in the inset illustration in the center of the figure where the vehicle is moving from right to left). Although negligible at the lower reentry speeds, this radiating gas cap shown by the illustration dominates the heating action at the higher speeds. Our knowledge of the phenomenon is, at present, quite imperfect and there is great uncertainty as to the intensity of heating at the higher speeds.

In order to investigate the heating conditions experienced at lunar return speeds, modifications were made to the Ames Entry Heating Simulator to simulate both convective and radiative heating. The radiative flux is supplied by a carbon arc lamp which is positioned at the focal point of two large ellipsoidal mirrors which re-image the heat onto the nose of the model in the arc-heated jet.

Tests on a model having a phenolic-resin and fiber-glass heat shield were made in this facility under conditions which simulate both the convective and radiative components of the entry heating which will be experienced in return from a lunar mission. This type of material produces a tough, porous, black char, which thickens when heated as the entry proceeds. This char can withstand surface temperatures in the 5,000° F range, high enough to radiate as much as half the heat away from the vehicle. This class of material, therefore, appears quite attractive when we consider the heating conditions of reentry into the Earth's atmosphere from lunar missions.

The uncertainty of our knowledge regarding radiation heating phenomena at speeds in excess of those for lunar return missions is caused partly by the inability of currently available test equipment to achieve the heating intensities experienced at speeds on the order of 40,000 feet per second and higher. For this reason, we have to resort to flight test in a program called Project Fire to obtain the required information. The prime objective of Project Fire is to measure the heat inputs from both radiative and convective heating at reentry velocities in excess of 37,000 feet per second (26,000 miles per hour) and to determine the gaseous environment around the spacecraft associated with such conditions. Since the vehicle will encounter significantly increasing levels of radiative heating at these speeds, it will contain suitable instruments and devices for measuring and observing the radiation from the hot gas cap that will form over the nose of the vehicle. Project Fire is a most important next step in our flight research program on the problems of high-velocity atmospheric entry. It is intended to provide us at an early date with a much better understanding of the nature and intensity of reentry heating at speeds between 26,000 and 35,000 miles per hour. The latter speeds approach those for return to the Earth from interplanetary missions.

Manned flight control.—Some of the effects of human occupants on the design of spacecraft and other equipment have been discussed briefly in presenting the problems of space technology. Obviously, the interrelations between man and machine are quite complex and go well beyond the relatively simple examples discussed.

A major problem in manned orbital, lunar, or planetary missions is that of guiding or controlling the spacecraft to the desired landing site on Earth without exceeding the temperature limit of the space vehicle or the acceleration tolerance of the crew. During this phase of a manned flight mission, it is necessary to "bleed off" the spacecraft's tremendous energy and effectively manage that energy to best advantage in reaching the desired landing site. A number of schemes for accomplishing reentry and landing have been studied. They fall into two general categories. One category constrains the spacecraft to fly on a preselected flightpath, and once the entry trajectory is established, the pilot has no further control over his destination or landing point.

The second category, which is depicted in figure 3–19, is an energy management scheme. This figure shows a spacecraft committed to enter the atmosphere and land. The pilot controls the vehicle and is presented with information which indicates that the spacecraft is capable of reaching any

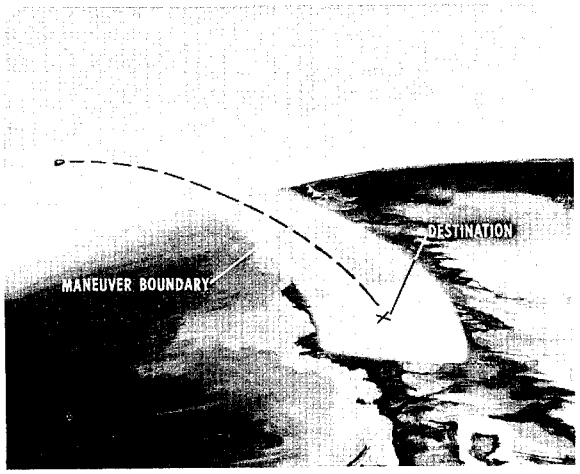


FIGURE 3–19. Manned reentry control.

point within a certain large landing area, as shown in the figure. He is also given information which keeps him advised of the allowable maneuver capability of the spacecraft to reach this landing area safely. Since both the maneuver boundary and the permissible landing area will be changing constantly, that is, getting smaller and smaller as the spacecraft approaches the surface of the Earth, the pilot must be presented continuously with the new information he needs in order to fly the vehicle in such a way that he can reach the final destination safely.

Simulator studies conducted by NASA and others have demonstrated great promise for pilot-controlled reentries during orbital and lunar missions. Also, as our spacecraft get heavier, ultimately they will probably be landed horizontally under pilot control. In fact, this is one of the attractive features of the Dyna-Soar hypersonic glide vehicle which is being developed by The Boeing Company. Energy management is not a new concept. In fact, it has been used skillfully by the X–15 pilots on every flight. A film record of an X–15 flight piloted by Major White to an altitude of 217,000 feet helped to describe how pilots can use energy management to reach a distant landing point, as desired, with lifting vehicles. The X–15 is mounted on the B–52 mother ship and carried to an altitude of approximately 40,000 feet. During the countdown the X–15 is also checked by the pilots of the chase planes. The X–15 is dropped, and as it falls away, the engine is started. The thrust of the engine is 50,000 pounds and in 86 seconds of burning time about 9 tons of fuel and lox are consumed.

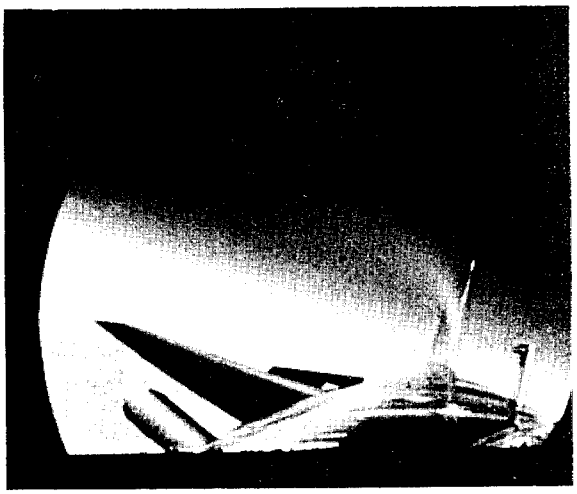


FIGURE 3–20. View from bug-eye camera over tail of X–15.

Figure 3–20 is a view from the bug-eye camera looking over the tail while the engine is operating. After burnout the X–15 continues to climb. The curvature of the Earth is evident as the airplane reaches the peak of the trajectory—more than 40 miles high. At these heights, reaction controls are used.

The pilot now points the X–15 downward, and controls it to reenter the atmosphere and glide back to Edwards Air Force Base several hundred miles away. He actually makes a dead-stick landing from space. In the landing approach the X–15 is aided by the chase planes. Landings are made at about 200 miles per hour, and the ground run after touchdown is about a mile.

Our simulator studies and experience with the X–15 are convincing evidence that pilots and astronauts are quite capable of utilizing energy management techniques to permit manned controlled reentries and landings from orbital and lunar missions, and we plan to extend our research activities in this area.

CONCLUDING REMARKS

In conclusion, it is apparent that the broad range of problems in space-vehicle research and technology confronts us with a tremendous challenge. In response, we are utilizing the talents, brainpower, and skills of industry, universities, other non-Government research institutions, and the NASA Centers. The continuing objective of these programs is to provide the sound technological base which is essential to the advancement of our country's space flight capability.

4. Nuclear Energy: The Space Exploration Energy Source

By HAROLD B. FINGER, *Director of Nuclear Systems, Office of Advanced Research and Technology, NASA*

Mr. Finger is also Manager of the Joint AEC-NASA Space Nuclear Propulsion Office. Prior to his appointment as Director of Nuclear Systems, he was Assistant Director of Nuclear Applications in the Office of Launch Vehicle Programs, NASA. He was formerly Chief of the Nuclear Engine Program, and Assistant Director for Nuclear Applications in NASA. As Manager of the AEC-NASA Space Nuclear Propulsion Office, he is responsible for all aspects of the development of nuclear rocket propulsion. As Director of Nuclear Systems, he manages all aspects of the NASA research and development program on nuclear electric power systems and electric propulsion, as well as the flight testing of these electric systems and of nuclear rocket systems.

Mr. Finger joined the National Advisory Committee for Aeronautics, the predecessor of NASA, in 1944 as an aeronautical research scientist at the Lewis facility in Cleveland, Ohio, where he remained until his appointment to the NASA Headquarters staff in 1958.

A native of New York City, Mr. Finger earned a bachelor's degree in mechanical engineering from City College of New York. He was awarded a master of science degree in aeronautical engineering from Case Institute of Technology in 1950.

Nuclear energy offers the key to extensive space exploration of the Moon and the planets. No other energy source can compete with nuclear energy in providing the potential capability for delivering extremely high payloads on difficult space missions.

Of the various nuclear-energy systems that have been proposed, major program emphasis is being placed on the development of nuclear rockets and nuclear electric propulsion systems. I discussed these programs at the First Conference for the Peaceful Uses of Space in Tulsa in 1961; the purpose of this paper is to update that presentation and give a review and a status report of the nuclear-systems programs being conducted for the space effort.

It is important to recognize that in these advanced nuclear space propulsion systems the oft-quoted advantage of nuclear energy as an "endless source of power" is not fully realized. It is, of course, true that the energy resulting from the fission of a pound of uranium provides 10 million times the energy of a pound of gasoline and, from this simple point of view, it would appear that several pounds of fuel could provide all the energy needed to reach most of the space objectives that have been mentioned in our program for at least the next 10 years, and probably the next 20 years. Unfortunately, in the systems being investigated, the energy that results from the fission of the uranium nucleus is not used directly to propel the vehicle. Rather, the energy is transferred to a propellant which provides the propulsive thrust for the vehicle. When the propellant has been consumed the vehicle can go no farther, even though there may still be sufficient uranium available in the reactor to produce fission energy. The advantage of nuclear propulsion results, however, from the fact that it permits the development of extremely high specific impulse; that is, high thrust per pound of propellant flowing through the system per second. As a result, a lower total amount of

propellant must be stored in the vehicle to accomplish a given mission than would be required for more conventional systems. This permits the addition of extra payload, or it permits the vehicle to travel farther in space.

It is important to recognize that the nuclear-system development programs discussed are being conducted jointly by the NASA and the Atomic Energy Commission. Although the management schemes used in the development of these various systems is not necessarily always the same, the agency responsibilities have been clearly defined. In these developments, the AEC is responsible for the development of the reactor, and the NASA is responsible for the development of the nonnuclear equipment required in the system and for combining the nonnuclear components with the reactor and developing the combination into a reliable and operational system.

I would like first to discuss the joint AEC-NASA Nuclear Rocket Program. A cutaway drawing of a nuclear rocket engine is shown in figure 4–1. Liquid hydrogen is pumped

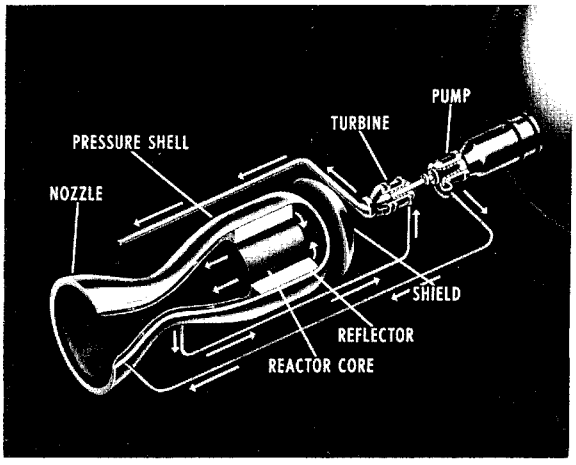


FIGURE 4–1. Nuclear rocket engine.

from the propellant tank and is used to cool the jet nozzle regeneratively. The hydrogen is then heated, first in the reflector, and then heated further to high temperature in the reactor core. The hydrogen is converted from a liquid to a vapor before it enters the reactor core. The high-temperature hydrogen gas leaving the reactor is then accelerated through the jet nozzle to velocities which for solid-fuel element reactors may be two to three times the value of chemical-combustion rocket systems. The high specific impulse results from the low molecular weight of the hydrogen propellant.

The excellent performance potential of nuclear rocket systems fully justifies an agressive and urgently conducted program to develop the technology required. This performance potential is probably best demonstrated in figure 4–2 which indicates the

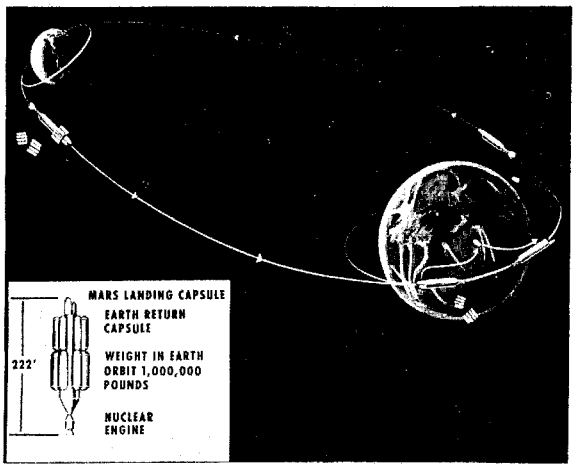


FIGURE 4–2. Mars landing mission, nuclear rocket.

kind of a nuclear-propelled spacecraft which could be used to land men on Mars and return them to the Earth. The nuclear-propelled spacecraft which would be placed into the Earth orbit or assembled in an Earth orbit would weigh in the neighborhood of a million pounds. This weight may vary significantly with the solar-flare proton radiation that is encountered in space. Much more information, however, is required in order to determine the level of shielding necessary to protect the crew during solar flares. In any event, the use of a chemical-combustion rocket system to propel such a manned Martian landing and expedition would require a spacecraft gross weight assembled in Earth orbit of ten times this value.

In addition to providing excellent performance potential for such long-range missions as the one shown here the nuclear rocket is also considered for lunar ferry mis-

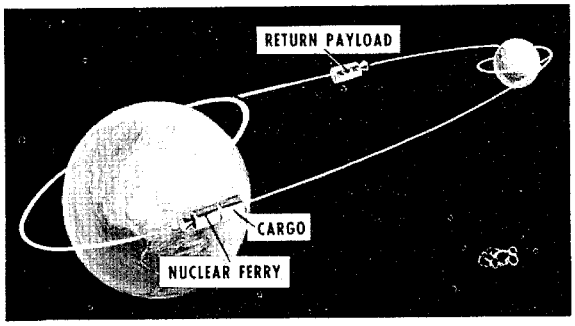


FIGURE 4–3. Lunar ferry mission, nuclear rocket.

sions as shown in figure 4–3. In this application, the spacecraft is propelled by the nuclear rocket from an Earth orbit to a lunar orbit. Payload, freight or men, is then carried to the lunar surface and other cargo is carried from the lunar surface to the nuclear spacecraft which carries the cargo back to the Earth orbit. The cargo is then returned to the Earth's surface and hydrogen tankers refill the nuclear rocket to permit it to repeat its lunar transportation system. Such a reusable space taxi is the type of nuclear application that will permit free space travel.

In addition to performing such missions as this one it is important to emphasize that nuclear rockets, when applied to chemical rocket boosters that are now under development, can provide substantial increases in performance capability of the chemical boosters.

Because the major problems and unknowns associated with the nuclear rocket system are related to the development of the reactor technology required to permit the heating of hydrogen to high temperatures with rapid startup and controlled shutdown under the flight loads that will be experienced, our major effort in this nuclear rocket program has been directed toward the development of the nuclear reactor technology. This work has been conducted by the Los Alamos Scientific Laboratory, under the overall management of the joint AEC-NASA Space Nuclear Propulsion Office.

Four research reactor experiments have been conducted to date. The last of these was run in December 1961 and was the first of our Kiwi B reactor series. A photograph

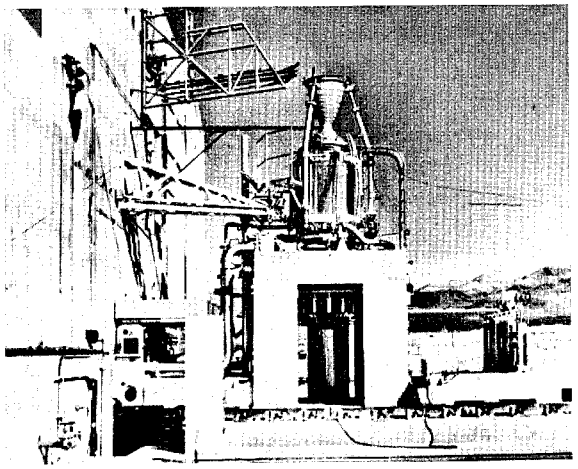


FIGURE 4–4. Kiwi B–1A.

of that reactor at its test stand in our test area in Nevada is shown in figure 4–4. This figure shows the gaseous hydrogen-cooled jet nozzle which was used in this test with hydrogen introduced into the nozzle wall tubes through three ducts. The control rods for this reactor were located in the beryllium reflector and were actuated by motors located below the reactor. All four tests that have been run to date have been fired upward as is the case in this Kiwi B–1A reactor. Such upward firing greatly simplifies the test operations and the test facility and is entirely satisfactory for reactor testing. In addition, all four tests run to date were run with gaseous hydrogen as a propellant and, therefore, the problems associated with the introduction of liquid hydrogen into the nozzle and reflector system were not evaluated.

The next experiment in our program will be a cold-flow reactor experiment in which U^{238} rather than U^{235} will be incorporated into the reactor fuel elements. This system will obviously not provide a fissioning source of energy, but it will provide important information related to the startup of a reactor with liquid hydrogen, as well as provide a checkout of the liquid-hydrogen test facility. That experiment is now being checked out at the test cell in preparation for actual test operations. It will look externally almost the same as this reactor.

None of these Kiwi reactors can be considered flight reactors. They have not been

designed with full consideration of the flight environmental conditions and stresses that will be imposed. Rather, they are a series of experiments intended to define a basic reactor core configuration which, with further engineering development, will be applied in flight systems. This basic Kiwi reactor core, to be selected, will be incorporated in our Nerva engine. The Nerva engine is the first flight nuclear rocket engine being developed by Aerojet-General Corporation with Westinghouse as the principal subcontractor. It is the role of Westinghouse in this program to make the necessary modification in the Kiwi reactor so that it can indeed withstand the flight environment and ground handling loads. A wooden mockup of the Nerva engine is shown in figure 4–5. This mockup stands approximately 28 feet tall. In this figure the control-rod actuators, the reactor section, and the regeneratively cooled nozzle can be seen. The turbopumps are located within the thrust structure. Also shown are the pressure accumulater bottles which accumulate high-pressure gas while the engine is running and then use this same gas to actuate pneumatic control actuators and other engine pneumatic actuators during restart operations. These bottles also may serve to pressurize the propellant tank.

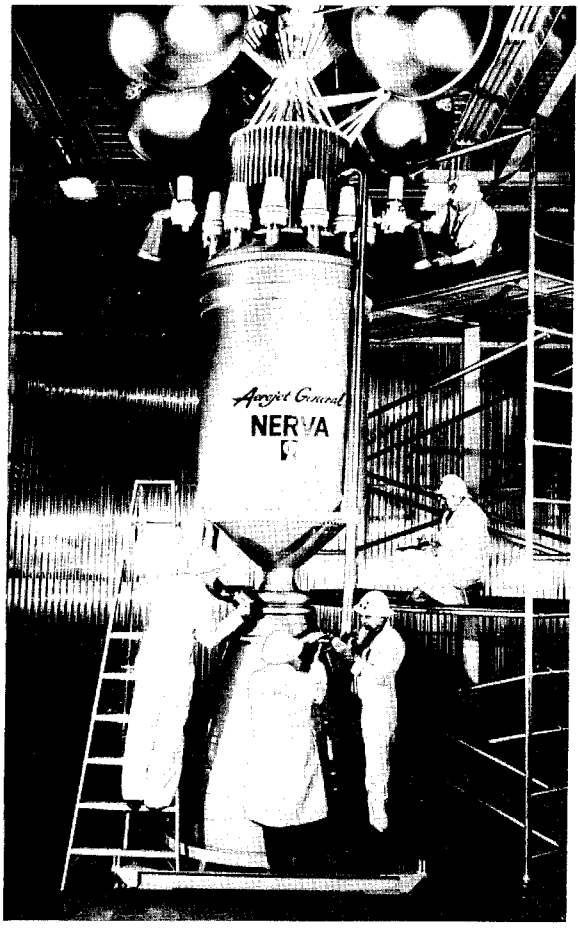


FIGURE 4–5. Wooden mockup of Nerva engine.

Among the many areas, other than the reactor, to be worked out in the development of the Nerva engine is the selection of the working cycle to be used in driving the turbopump; that is, the means of providing gas for driving the turbopump system. Three different nuclear rocket engine cycles have been discussed and are shown schematically in figure 4-6. These three systems are called

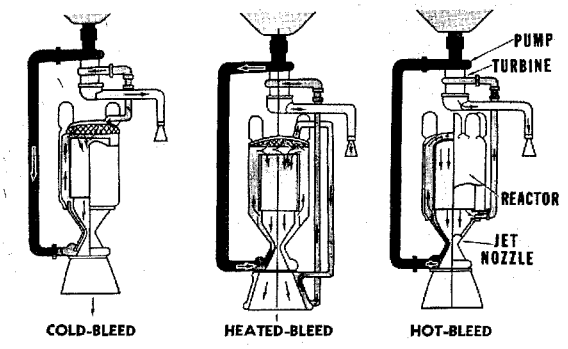


FIGURE 4–6. Nuclear rocket engine cycles.

the cold-bleed, heated-bleed, and hot-bleed systems. The cold-bleed system is one in which hydrogen, after passing through the nozzle and through the reflector, is drawn off before entering the reactor core, is used to drive the turbine, and then is expelled overboard. In the heated-bleed system, a small amount of hydrogen is again drawn off after the hydrogen is passed through the reflector, but this time, the hydrogen is passed back down through a nozzle extension skirt to be heated to higher temperature than was possible in the reflector alone. This higher temperature hydrogen is then used to drive the turbine and again it is ducted overboard. In the hot-bleed system, hot hydrogen leaving the reactor is bled off through the jet nozzle and is immediately mixed with cold hydrogen used to cool the jet nozzle walls. This mixture is then used to drive the turbine and again is ducted overboard. It is

known that the higher the hydrogen temperature used to drive the turbine, the smaller the amount of hydrogen that must be drawn off and rejected overboard. As a result, the high-temperature or hot-bleed system will provide the smallest loss in specific impulse of the system; whereas, the cold-bleed system, which requires a large amount of hydrogen flow through the turbine, will provide the largest specific-impulse loss. In the Nerva program we are evaluating the heated-bleed system and the hot-bleed system. The choice will certainly be made on a reliability basis. The heated-bleed system imposes boundary conditions upon the radiation shield and nozzle design which may too severely compromise the design and operation of these components. The hot-bleed system imposes a requirement to bleed off hydrogen satisfactorily and reliably at high temperatures and immediately mix that hydrogen with liquid to maintain a temperature that can be carefully controlled within allowable temperature limits of ducting and the turbine. Analyses and experiments are being conducted to permit the selection of the appropriate cycle for the Nerva engine.

Because this nuclear rocket engine is the first of a new breed of rocket propulsion systems, we believe that it is essential that the system be flight tested in order to evaluate fully its operating capabilitities and to evaluate all the problems involved in operating the system in a space flight environment. In addition, in order to provide the earliest possible application of nuclear rocket propulsion, we believe the flight test must be conducted in a manner which simulates as closely as possible the stage geometry and operating environment that the system will encounter when applied to useful missions. For that reason, it is proposed that the Nerva engine be flight tested in a Rift vehicle essentially as shown in figure 4–7. Because we believe that the first useful application of nuclear rockets will be as a third stage on the Advanced Saturn 7.5-million-pound-thrust vehicle, we are designing the Rift stage so that, with continued development, it could result in such a third-stage system. For that reason, also, the Rift stage will be boosted by the Advanced Saturn 7.5-million-pound-thrust first stage, with a dummy ballast loaded second stage. After separation, at an altitude of approximately 50 miles, the nuclear stage will be taken to full power and thrust and will propel itself to an altitude of approximately 500 miles. In some of the flights, there will be a shutdown period and one or more refirings, in order to evaluate the restart capability of the system in flight. The total range of the flight will be 500 to 2,000 miles all over water with a total full-thrust firing time of 500 to 1,000 seconds.

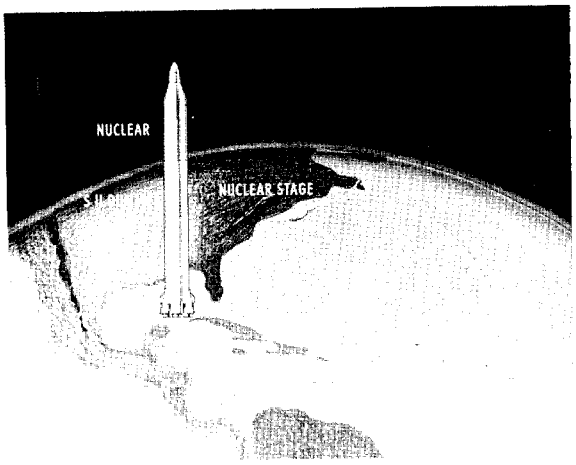


FIGURE 4–7. Reactor in flight test (Rift).

The importance of flight testing in the manner shown on the Advanced Saturn vehicle is best demonstrated by the payload capability of a vehicle made up of the first two stages of the Advanced Saturn with a nuclear third stage as shown in figure 4–8.

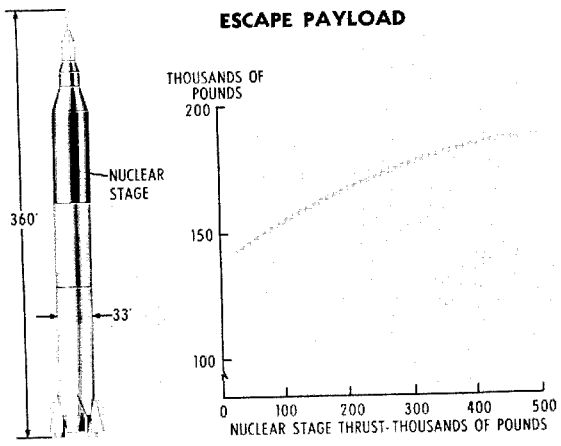


FIGURE 4–8. Nuclear stage on advanced Saturn, Earth escape payload.

In this figure the escape payload of this three-stage vehicle is plotted against the thrust in the third nuclear stage. There is some increase in escape payload as the thrust of the nuclear stage is increased. In essence, the higher thrust permits a higher propellant loading and a higher velocity increment to be taken in this third stage, while the velocity increment of the earlier chemical-combustion stages is reduced. It is important to point out that these escape payloads are the values that have frequently been quoted for the Apollo mission. These data, therefore, indicate that such a vehicle, using a nuclear third stage, could perform a manned lunar landing mission by direct ascent rather than by rendezvous. You will recall, of course, that this Advanced Saturn vehicle has been specifically designed for accomplishing the manned lunar landing mission using the rendezvous approach with all-chemical propulsion. If the nuclear stage is made available, therefore, it may provide an alternate capability for performing manned lunar landing missions. Our program plans for the flight testing of nuclear rocket stages in the 1966–1967 period. Because the Rift flight would supply data directly applicable to this vehicle, we have estimated that approximately 2 years of flight testing and continued development would be required to achieve an operational nuclear vehicle. Such a vehicle might, therefore, be available in the 1968–1969 period.

Our entire program on nuclear rockets is aimed at developing the technology of these systems as rapidly as possible. We have brought, or are bringing, into the program the talents and facilities that are required to insure that we are in a position to take advantage of all successes so that we may start using nuclear rockets at the earliest possible time.

The other nuclear system that is receiving considerable attention is the nuclear-reactor electric-generating system for the production of large amounts of auxiliary electrical power in spacecraft and also for the production of the electric power required in electric rocket-propulsion systems. I would like to emphasize the electric propulsion applications although the need for large amounts of electric power in our future manned space laboratories and in communications systems also imposes demands for nuclear electric-power systems.

The objectives of our work on nuclear electric rocket propulsion are indicated in figure 4–9. Electric propulsion offers us the potential of accomplishing difficult missions to the distant planets, even to Jupiter and beyond. However, in order to achieve such mission capability, it is essential that we learn to build electric propulsion systems that are extremely light in weight and are capable of operating without maintenance for extremely long times.

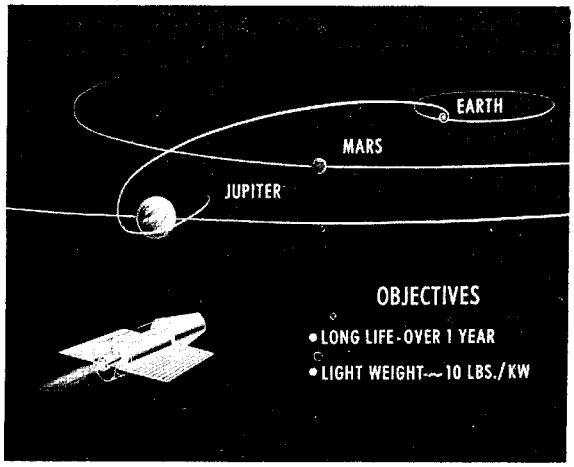


FIGURE 4–9. Electric propulsion objectives.

The type of mission for which electric propulsion appears well suited is illustrated diagrammatically in figure 4–10 for a Jupiter probe trajectory. The Sun is shown at the center of the figure and the Earth is shown on the inner circle. In typical electric-propulsion missions, the electrically propelled spacecraft will be boosted into an orbit around the Earth. Because of its low thrust, the electric propulsion system will gradually propel the spacecraft out in a spiral trajectory, taking approximately 90 days to achieve the transfer trajectory to the planet Jupiter. Propulsion will continue for approximately 250 days at the end of which time the Jupiter velocity will be achieved. A coast period of approximately 120 days is shown. As you can see, the

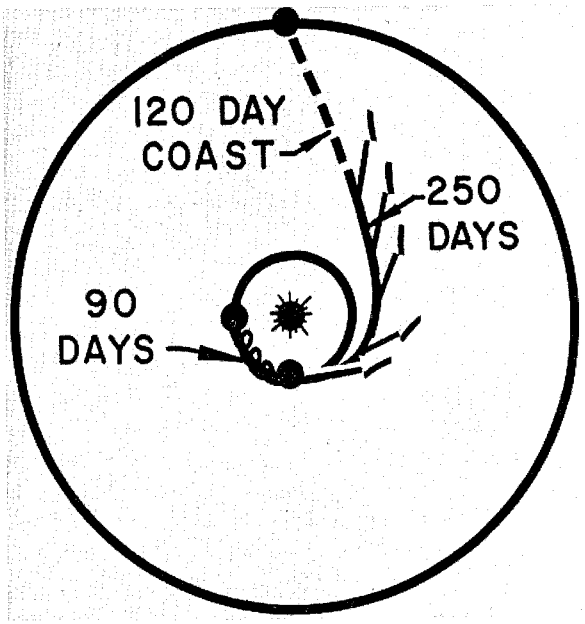


FIGURE 4–10. Jupiter probe trajectory.

coast period is a small part of the total time required to arrive at the planet, or, saying it another way, the small thrust of the electric propulsion system requires that propulsion continue for a large part of the total mission time in order to achieve the velocities required to arrive at any particular space objective. If we wanted to establish a payload in an orbit around Jupiter, another firing period would be required.

The payloads that can be achieved with electric propulsion on a Jupiter satellite mission are shown in figure 4–11. In this case I have assumed that the Saturn C–1 vehicle

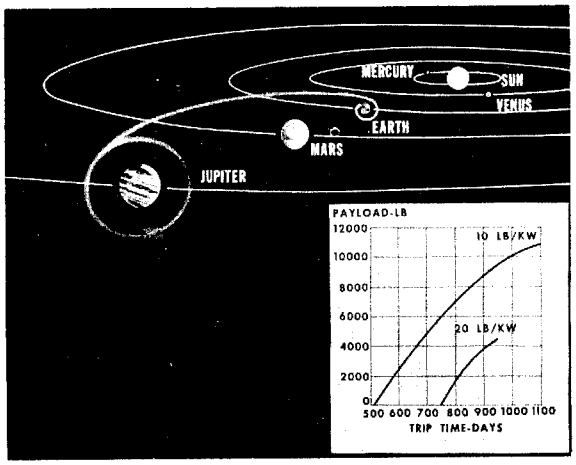


FIGURE 4–11. Jupiter satellite mission with electric rocket; Saturn C–1 launch vehicle.

will place an electrically propelled spacecraft into an orbit around the Earth. I have plotted the payload that is delivered in the Jupiter orbit against the time involved in traveling to Jupiter. The two curves shown are for different propulsion systems that weigh 20 pounds per electric kilowatt and 10 pounds per electric kilowatt, respectively. The most important characteristic of these low-thrust systems is that it requires a significant minimum time to deliver any payload to the planet. For example, with the 10-kilowatt system, 500 days are required before any payload can be delivered to Jupiter. The higher the specific power-plant weight the longer is this minimum payload delivery time. In addition, for a given propulsion time, the lower the specific weight of the engine, the higher is the payload that can be delivered on the mission. This figure indicates that substantial payloads can be delivered to Jupiter with electric propulsion. However, it also illustrates the importance of achieving the requirements of long life and low engine specific weight. Unless long life and low specific weight can be achieved, other propulsion systems will outperform the electric rocket systems, particularly if short trips are desired. Specifically, the nuclear rocket could, under those circumstances, outperform the electric rocket. In addition, if the performance is sufficiently poor, even chemical rockets could outperform the electric rocket. It is most essential that low specific weight and long life be achieved in our electric rocket systems.

Another representative mission for electric propulsion is shown in figure 4–12 as a Saturn probe mission. Again, in this case, I have assumed that the Saturn C–1 launch vehicle has placed the electrically propelled spacecraft into low Earth orbit. The payload that can be delivered to Saturn in this probe mission is then shown for three values of power-plant specific weight. Once again you can see the importance of achieving low specific weight and long life in order to permit the delivery of high payloads in a Saturn probe.

A schematic drawing of a nuclear electric rocket system is shown in figure 4–13 for purposes of defining the principal compo-

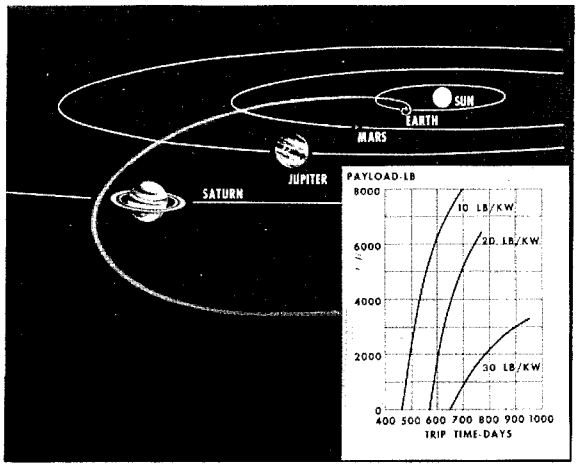


FIGURE 4–12. Saturn probe mission with electric rocket; Saturn C–1 launch vehicle.

nents of the system. (It is not a scale drawing so the components are not in their proper relative size.) The principal subsystems of the nuclear electric rocket are the electric generating section, made up of the reactor power source loop and the heat-to-electric power conversion system, and the electric thrust system, including a propellant tank. Obviously, the AEC is responsible for the development of the nuclear reactor, whereas NASA is responsible for the development of the energy conversion equipment and for the mating of the reactor and the conversion equipment into a reliable and operational system. In addition, NASA is responsible for the development of the electric thrust system.

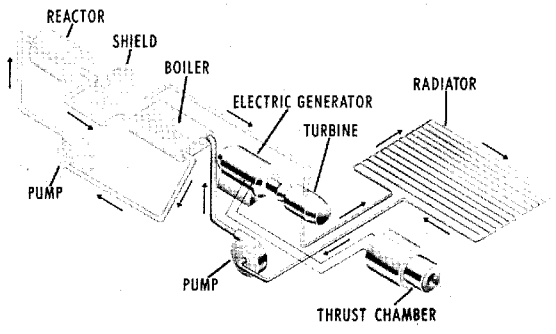


FIGURE 4–13. Nuclear electric power and propulsion system.

In this system, the heat of the reactor is transferred by a liquid metal to the secondary heat-to-electric power conversion loop where another liquid metal is boiled or vaporized in the boiler. The vaporized metal is then used to drive a turbine, much as steam drives the turbine of our ground steam power generating plants. The turbine drives the electric power generator and some of the pumps in the system. In order to reject the waste heat of the cycle and condense the metal vapor back to a liquid so that it may be continuously reused and recirculated through the secondary loop, it is necessary to have a large-area condenser-radiator. It is this radiator that is the heaviest and largest part of the system when we get to systems capable of generating megawatts or thousands of kilowatts of electric power. In order to achieve the low specific weights that I indicated were necessary for successful electric propulsion operation, the radiator must be made as small and as light as possible through the use of high temperatures in the working fluid (above 2,000° F) and through the use of thin walls in the radiator tubes through which the working fluid passes. The use of high temperature is limited by corrosion of the metal surfaces of the system and the many high-temperature mechanical operating problems. The permissible mimimum wall thickness of the radiator tubes is limited by the probability of meteoriod penetration. Much more information is required in these areas and our program is directed at obtaining such information. In addition, for such boiling-condensing systems the zero-gravity conditions in space may have a substantial effect on performance and possibly even on feasibility. The electric power of the system is taken off at the generator and is used to accelerate the propellant in the electric thrust chamber indicated at the lower right of figure 4–13.

For direct power conversion systems which are in an early stage of research and development, the boiler and rotating equipment shown in the turbogenerator system may be omitted. Direct conversion systems are those that convert heat directly to electrical power without requiring the use of this complicated boiler turbogenerated con-

version system. These direct conversion systems still require radiators and, in fact, the radiator may be larger than for the turbogenerator because of the low efficiencies that are now achievable in such devices. The direct conversion system that is receiving the greatest emphasis for high power systems is the thermionic emitter which is much like a radio diode. It is a device in which two plates are closely spaced in a low-pressure atmosphere of cesium vapor. One of the plates, the cathode, is heated to high temperatures causing it to emit electrons which flow to the cold plate, the anode, when load is put on the outside of the device. Much work is still required on these promising direct conversion devices to achieve high power output at the efficiencies and the life that is desired for our electric power systems.

Our major development program on nuclear electric power generation is the development of the Snap–8 electric power generating system. A drawing of this system, in one of the forms in which it is now visualized, is shown in figure 4–14. The compo-

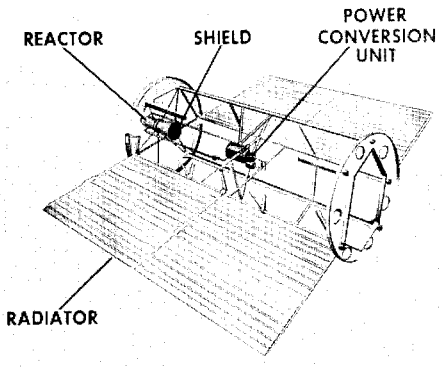


FIGURE 4–14. Snap–8 electrical generating system.

nents are similar to those indicated in the preceding schematic drawing (fig. 4–13); the reactor, the radiation shield, the boiler, the turbines and pumps of the system, and a large-area radiator are shown in the figure. Also shown is the structural support which would bolt to the launch vehicle. In this case, the radiator would be wrapped around the structure and enclosed inside the vehicle nose cone during the ascent or launch from the ground. Once established in an orbit around the Earth, the radiator panels would be released and would form the flat, two-sided radiators shown. The Snap–8 system is not as advanced in performance as the systems that I indicated would be desired for applications required to carry heavy payloads to the distant planets. The Snap–8 system is designed to deliver 30 kilowatts of electric power or, with two of these conversion systems operating with a single reactor, it could deliver 60 kilowatts of electric power. Our major effort at the persent time is the development of the 30-kilowatt system with enough work on the 60-kilowatt version to show that such a system is feasible. Testing has been conducted on all of the components of this conversion system. Each of the components has been set up and tested in component test loops. Continued test time and design and development work are, however, still required to provide for reliable components. The first tests of the full conversion equipment heated electrically rather than by the reactor will be conducted during 1962. The first tests of a developmental reactor will be conducted by the AEC contractor during this year.

The specific weight of the Snap-8 system at 30 kilowatts would be approximately 60 pounds per kilowatt and at 60 kilowatts, about 50 pounds per kilowatt, compared with the 10 pounds per kilowatt that I indicated earlier were desired. The maximum temperature of the working fluid in this system is 1,300° F, compared with the 2,000° F that would be required to achieve the extremely low specific weights indicated for the Jupiter mission. However, the Snap–8 system will still provide us with an important capability to produce large amounts of auxiliary power, in addition to providing us with a capability to perform early electrically propelled missions on comparatively small chemical booster vehicles now being developed.

For example, the Snap–8 used as an electric propulsion power source could raise a communications satellite from a low Earth orbit to the 24-hour orbit as indicated in figure 4–15. It could be placed into a 400-

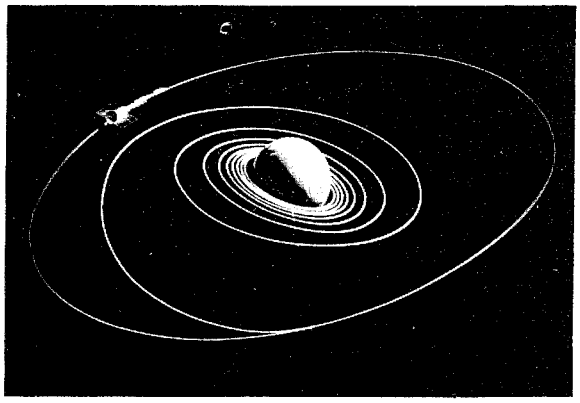


FIGURE 4–15. Communications satellite going from low Earth orbit to 24-hour orbit.

or 500-nautical-mile orbit by the Saturn C–1 vehicle and the electric propulsion system would then gradually spiral the spacecraft out to the synchronous 24-hour orbit. The total weight of the spacecraft in the 24-hour orbit could be over 7,000 pounds. An example of such a possible mission might be a 24-hour orbit mission involving a television communications system where all the 60 kilowatts available would be required to power the TV system after propulsion into the 24-hour orbit was accomplished. These payload capabilities of a Snap–8 60-kilowatt electric propulsion system are significantly higher than the capability of the all-chemical Centaur or Saturn C–1 vehicles being developed. We are planning to flight-test the 30-kilowatt Snap–8 system in 1966 in combination with one of several thrust generators. The three general types of electric thrust chamber that we are investigating are shown in figure 4–16. First, we have the arc jet engine in which an electric arc is struck from a cathode to an anode, heating a gas that passes through the arc. The gas is heated to high temperatures as it passes through the electric arc and is then accelerated in a fairly conventional thermal jet nozzle. We are undertaking the development of a 30-kilowatt flight test engine which could be combined with the Snap–8 system.

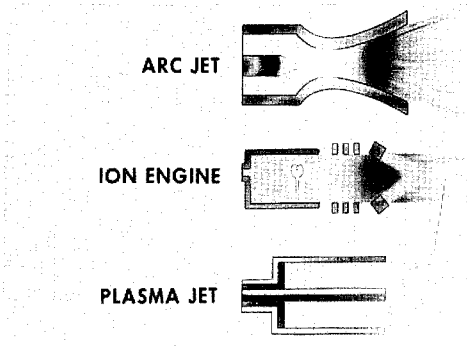


FIGURE 4–16. Electric thrust chamber program.

Next is the ion engine in which electrons are stripped from the atoms of the cesium or mercury propellant, leaving a flow of charged particles called ions. These ions are then accelerated through an electric grid or electric accelerator, producing a high-velocity ion jet. Electrons must be discharged into the jet downstream of the accelerator in order to neutralize the jet, that is, to give it a neutral charge rather than a positive charge that was required to permit acceleration through the engine. We will be developing a 30-kilowatt version of such an engine which may be used with the 30-kilowatt Snap–8 in our flight tests.

Finally, we are doing work on the magnetohydrodynamic accelerators, sometimes referred to as plasma jets, in which a plasma is generated and accelerated. A plasma is made up of both positively charged ions and electrons, giving a neutral stream. This plasma is accelerated electromagnetically, using high-strength magnetic fields to give a high-velocity jet. There have been many concepts proposed for this MHD accelerator system. It is our feeling that it is yet too early, on the basis of our present state of knowledge, to define a suitable engine configuration. As a result, we are continuing our research and technology program and continuing small-scale engine component investigations prior to proceeding into a full-scale development effort.

In order to evaluate fully the performance of some of these electric thrust generators, it is necessary that space flight tests be conducted. There are certain space environmental conditions that cannot be duplicated in any ground laboratory facility. For example, although recent laboratory tests conducted at the Space Technology Labortories give encouraging results on our ability to

neutralize the ion jet, a space verification in a truly uncontained vacuum environment is considered essential. We have, therefore, initiated the developement of systems which will permit flight testing of these electric thrust generators using battery electric power on the Scout vehicle.

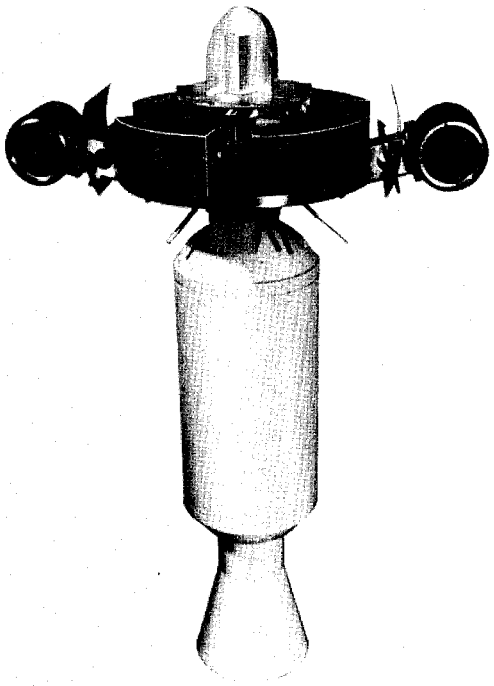


FIGURE 4–17. Ion rocket, flight test model, Scout booster.

A model of the Scout flight test payload is shown in figure 4–17. During launch the arms will be folded up and this package will be installed in the nose cone of the four-stage Scout vehicle. When this payload package is separated from the Scout vehicle, the arms will swing out. The test electric thrust engines are shown on each of the arms. In the first test planned for late this year, an ion engine being developed by Hughes Aircraft Company will be installed on one arm and an ion engine being developed by the Lewis Research Center will be installed on the other arm. The Hughes engine will be fired first for 25 minutes and the spin rate of the spacecraft will be measured; then, the Lewis engine will be fired in the opposite direction and change in spin rate will be measured. The battery power supply, power conversion equipment, and telemetry are housed in the central compartment. The trajectory that is planned for this electric-accelerator flight test is shown in figure 4–18. It will be a high-altitude trajectory in order to give us meaningful vacuum conditions and the long test time desired.

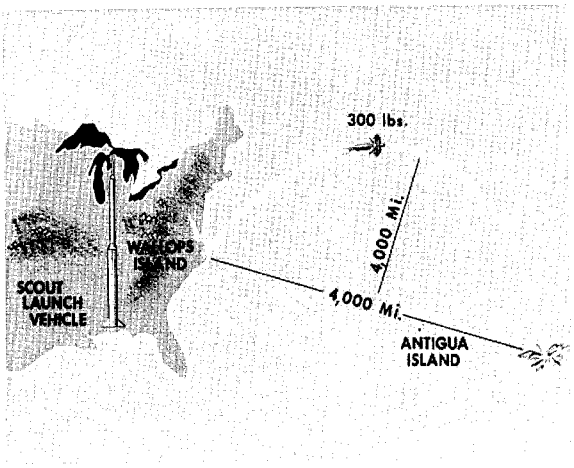


FIGURE 4–18. Space electric rocket test (Sert).

Our program on these advanced nuclear propulsion systems recognizes the large potential performance advantages that will result when they are used for the performance of high-energy long-range missions that will inevitably be a part of this long-term space program. We believe this performance potential provides sufficiently strong justification for conducting the advanced technology programs that I have outlined on both the nuclear rocket and the nuclear electric propulsion systems and power systems on an aggressive basis with a high sense of urgency. There are many difficult problems that remain to be solved and difficult questions that must still be answered. These research and development programs require significant lead time in order to insure that the necessary fundamental information and technology required for effective systems development are obtained in time to permit us to perform the advanced missions that will undoubtedly be a part of the long-term space program.

Session II

Chairman: William H. Pickering

WILLIAM H. PICKERING, *Director, Jet Propulsion Laboratory, NASA*

Dr. Pickering was born in Wellington, New Zealand. He attended the California Institute of Technology and received a B.S. degree in 1932, an M.S. degree in 1933, and a Ph.D. degree in physics in 1936. He performed graduate and postgraduate work in cosmic-ray physics at the California Institute of Technology. He is a member of the faculty of the California Institute of Technology, having been appointed professor of electrical engineering in 1946.

He has been associated with the Jet Propulsion Laboratory since 1944 and has been Director of the Laboratory since September 1954.

He has been a member of the Scientific Advisory Board of the Air Force and has served on a number of other committees of the Defense Department. He is presently a member of the Army Scientific Advisory Panel. During the International Geophysical Year, Dr. Pickering was a member of the United States Technical Panel on the Earth Satellite Program.

He is a member of the American Institute of Electrical Engineers, a Fellow of the Institute of Radio Engineers, the American Astronautical Society, and the Institute of the Aerospace Sciences. He is a Fellow and national president (1962) of the American Rocket Society.

Dr. Pickering received the 1957 James Wyld Memorial Award of the American Rocket Society, the Distinguished Civilian Service Medal, and the first Space Flight Achievement Award presented by the National Missile Industry Conference.

In the preceding series of papers the space-science aspects of the civilian space program, and also the space vehicle research and the nuclear research, were presented.

In this series we have two papers, Meteorological Satellites and Communications Satellites, which will describe some of the work in the areas of application of the space program, and then a third paper on Tracking and Data Acquisition.

5. Meteorological Satellites

By MORRIS TEPPER, *Director of Meteorological Systems, Office of Applications, NASA*

Dr. Tepper was previously Chief of the Severe Local Storms Research Unit, U.S. Weather Bureau.

Born in Palestine in 1916, Dr. Tepper came to the United States in 1922 and became a citizen in 1926. He earned a bachelor of arts degree in 1936 and a master of arts degree in 1938 from a Brooklyn College, and a Ph.D. degree from Johns Hopkins University in 1952.

From 1952 to 1959 he taught fluid mechanics and dynamic meteorology at the graduate school, U.S. Department of Agriculture.

Dr. Tepper has written many papers in technical journals on theoretical and experimental aspects of severe local storms. In 1950, he was the joint recipient of the Meissinger Award of the American Meteorological Society for his work on the application of hydraulic analogy to meteorological problems.

His professional memberships include the American Meteorological Society, the American Rocket Society, and the Washington Academy of Sciences.

This paper presents a status report on the progress of the Meteorological Satellite Program. In this review, I shall try to emphasize primarily the accomplishments since May 1961 when a report on the program was given to the First National Conference on Peaceful Uses of Space in Tulsa, Oklahoma. It is now one year later, and it is fitting that we stop and take stock of what we have been doing and where we are heading.

First—what has been done?

Considering a simple launch count, since last May, we have successfully put into orbit two additional Tiros satellites—Tiros III and Tiros IV. The following table shows the box score since the launch of Tiros I:

Satellites	Launch date	Useful life	Sensors
Tiros I	April 1, 1960	2½	Wide- and narrow-angle television cameras
Tiros II	Nov. 23, 1960	10	Wide- and narrow-angle television cameras; two radiation systems
Tiros III	July 12, 1961	4½	Two wide-angle television cameras; three radiation systems
Tiros IV	Feb. 8, 1962		Same as Tiros III

Tiros IV is still providing excellent observations both from the television sensors and from the infrared radiation systems.

However, what more can we say about these launchings? What have they accomplished? To my mind, the four successful Tiros launches have produced five important results.

First, *the Tiros launches have demonstrated that a spacecraft and supporting ground system could be developed around special sensors like the cameras and radiation detectors and could transmit the measurements of these sensors to the Earth with satisfactory fidelity.* In general, one may say that the quality and quantity of the end product may be considered an excellent indication of the success of a system. Thus, figure 5-1 is a graphic illustration of how successful the Tiros system has been. The

23,000 pictures of Tiros I, the 36,000 pictures of Tiros II, the 35,000 pictures of Tiros III; and the more than 22,000 pictures of Tiros IV, to date, all bear convincing testimonial of a successful Tiros system operation. In addition, the radiation data gathered by the Tiros II, III, and IV satellites cannot be measured in individual pictures and frames but rather in about 2,000 14-inch reels of tape containing interesting and useful measurements.

This excellent system performance involves the successful operation of many interdepedent and delicate subsystems, components, and electronics. Figure 5-2 is an example of the type of equipment required in this operation. It is a photograph of the infrared electronics equipment. From left to right, it shows the power supply, the tape recorder, the main deck electronics, the 2-watt transmitter, and the motor electronics, all of which fit into the canister in the back. If you consider that the canister is only 15 inches tall, you can realize the dense packing of electronics and the extent of microminiaturization.

In several instances new and previously untried technological advances had to be made. Figure 5-3 shows spin rockets attached to the baseplate of the satellite. These are fired in pairs whenever an additional spin rate of the satellite is required. Spin rockets such as these were fired *on ground command* after as much as 10 months in space environment. There has been developed a partial control of the attitude of the satellite—also on ground command—by means of a magnetic orientation coil wrapped around the base of the satellite. In addition, for the successful operation of the infrared radiation detector system, lubricated ball bearings have to operate in space environment over a period of months.

Indeed, from the point of view of an engineering development, the Tiros satellites are tremendously successful.

Second, *the Tiros satellite measurements were found to contain much useful meteorological information.* Figure 5-4 shows examples of cloud patterns viewed by the Tiros satellites. These cloud patterns have been

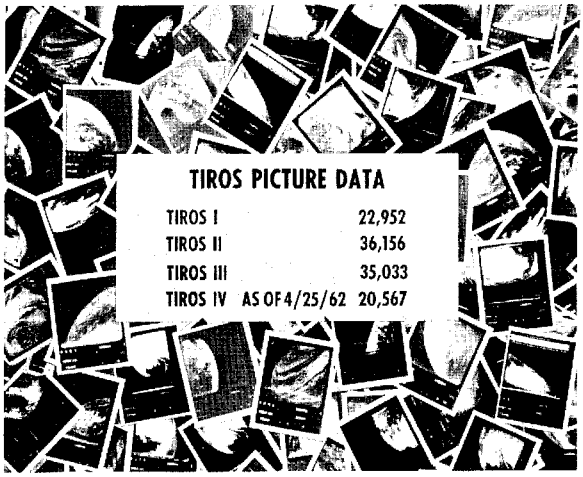


FIGURE 5–1.

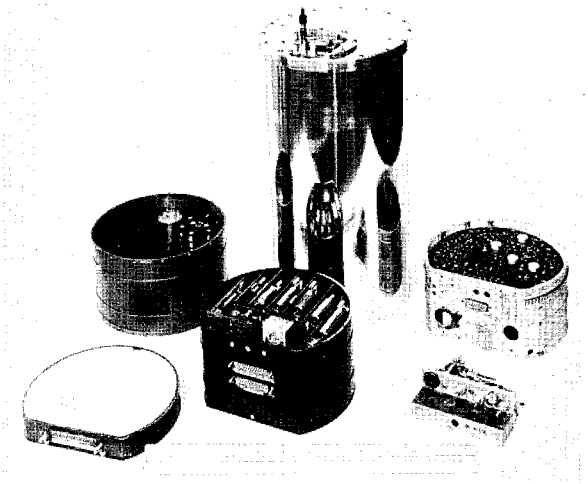


FIGURE 5–2. Tiros II infrared electronic equipment.

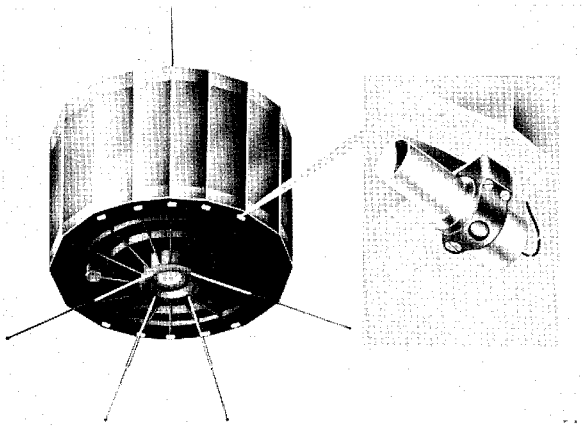


FIGURE 5–3. Tiros II spin-up rockets.

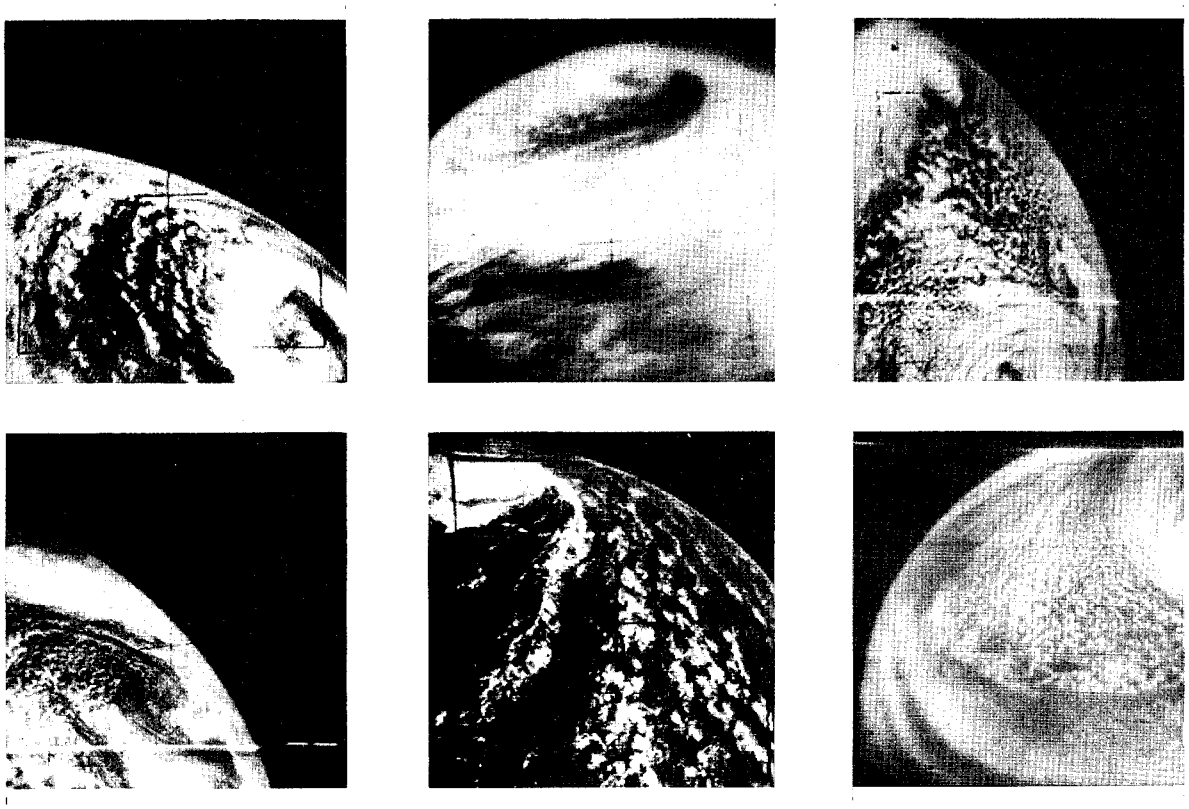


FIGURE 5–4. Tiros cloud patterns.

found to be related to, and characteristic of, the atmosphere in which they are embedded. In particular, cloud vortices were found to be the signatures of rotating storms. Figure 5-5 is now a classic picture in the archives of meteorological-satellite data results. The top picture is a mosaic of photographs viewed by Tiros I; in the bottom picture the clouds have been drawn in their proper geographic location. Superposed on the clouds are the weather fronts of the day. The close relation between the cloud positions and the weather fronts is remarkable.

Figure 5-6 shows other information produced by the Tiros satellites—sea ice conditions. Note in the upper photographs, showing the mosaic of pictures taken on March 23, 1961, there was sea ice to the east (to the right) of Anticosti Island in the St. Lawrence River. Six days later on March 29, the same region was photographed by Tiros III and the area to the east of Anticosti Island is now clear of ice. Thus, the Tiros satellites have been shown to yield valuable information on the formation, state, and melting of sea ice.

Figure 5-7 compares the infrared data taken by Tiros with the analysis of cloud heights as computed from reports of weather stations over the United States. In the upper picture, the regions marked with "C" represent areas where the Tiros satellite measured cold cloud temperatures and the regions marked with "W" represent areas of warm cloud or ground temperatures. In the lower picture, the areas of cloud heights are given in thousands of feet. Comparing the upper and lower parts of the figure, we see that on the east coast, for example, the cold-temperature regions measured by the Tiros satellites coincide with the regions of the very tall clouds, indicating that Tiros was measuring the temperatures of the tops of the clouds. There is also correspondence through the Plain States where the areas of warmer Tiros measured temperatures correspond to areas of low clouds or no clouds at all.

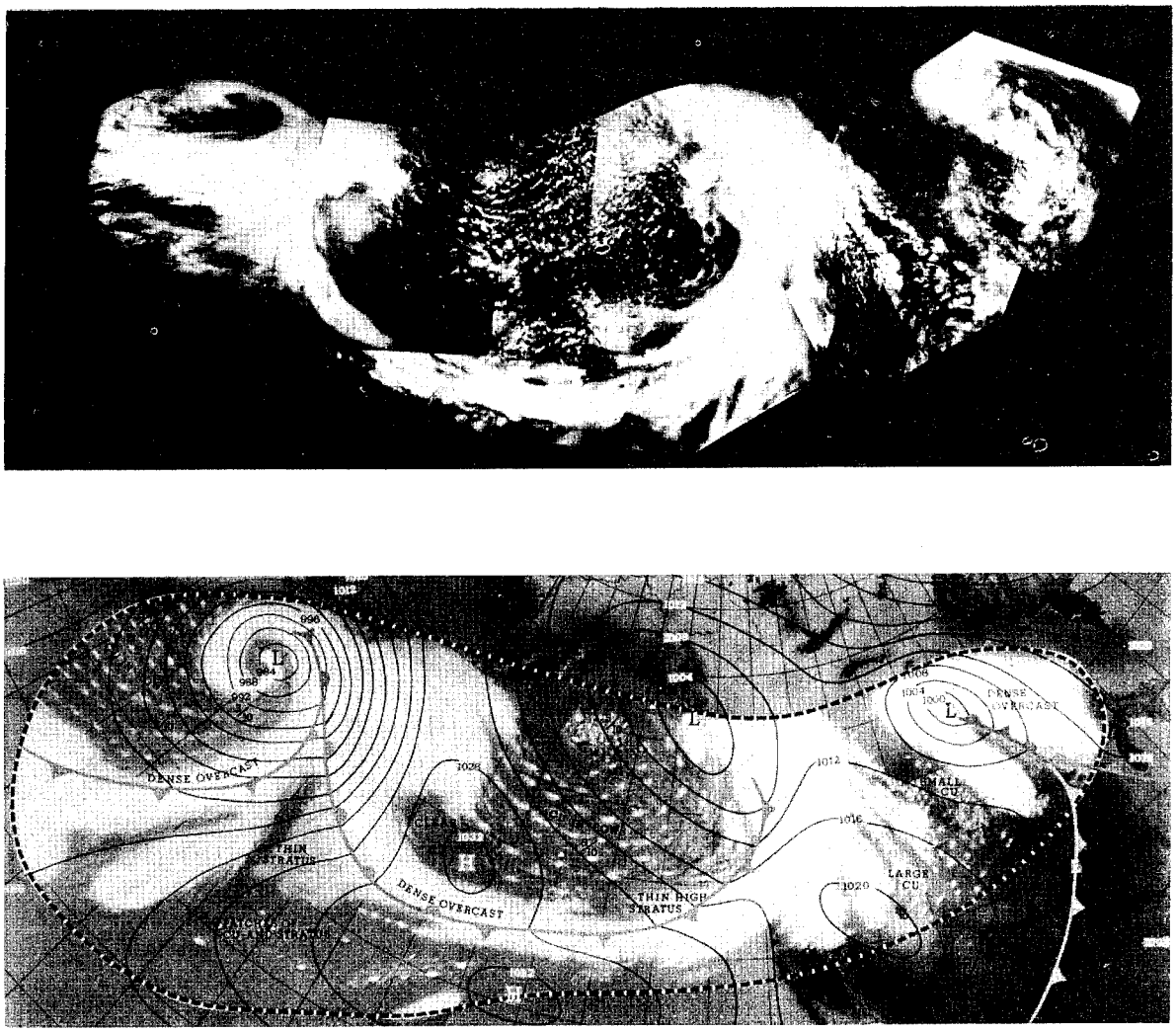


FIGURE 5–5. Storms and fronts; a family of weather systems. Top, mosaic of Tiros photographs; bottom, weather map, May 20, 1960, with Tiros cloud data.

Figure 5-8 gives the number of publications of Tiros results in scientific journals, technical reports, portions of books, and semipopular books as of the beginning of 1962. From these numbers it appears that Tiros has produced a vast amount of useful and interesting scientific information.

The third accomplishment of the Tiros satellites was that *this useful information was extracted and transmitted to weather services in time to be of value in weather analysis and forecasting.*

In anticipation of the possible utilization of Tiros data for immediate use by forecasters, teams of civilian and military meteorologists were stationed at the data acquisition stations to study the incoming data in "real time". Within 60 hours after Tiros I was launched, picture data less than 6 hours old were being interpreted and analyses forwarded via facsimile transmission to the National Meteorological Center at Suitland. Figure 5-9 shows how this picture information is analyzed in the form of a cloud analysis. Each enclosed area represents the analysis of the pictures taken by the satellite over that region.

Information such as this has been incorporated into the regular analyses and forecasts of the Weather Bureau; direct copies

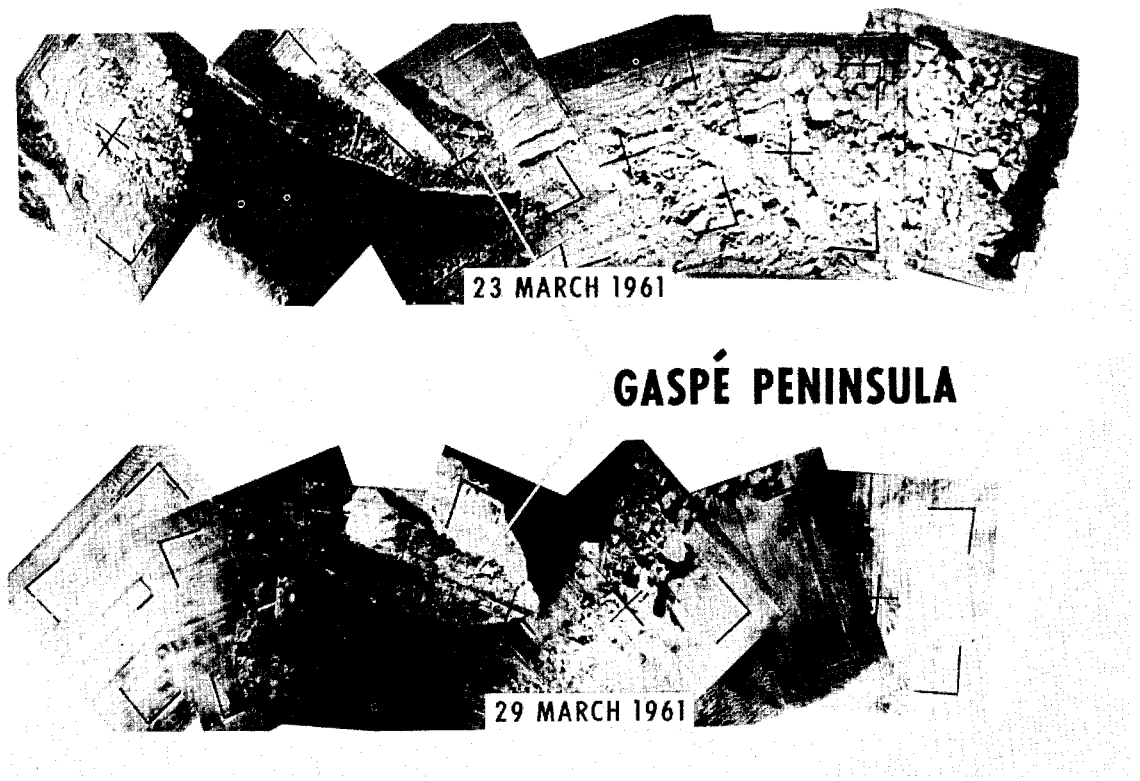


FIGURE 5–6. Tiros II sea-ice data.

or coded representations are also relayed to our air and naval services both in this country and overseas, and to other national weather services where they prove to be very useful. These weather services have indicated that such cloud analyses "establish, confirm or modify surface frontal positions; assist in the briefing of pilots on accurate weather; are used in direct support of over-water deployment and aerial refueling of aircraft; give direct support to the Antarctic resupply mission; confirm the position of Pacific typhoons; verify and amplify local analyses particularly over areas with few reports", and so forth. The quality of the infrared (IR) radiation data has also been excellent. However, these data have to be reduced and plotted on maps before they can be properly interpreted. From this point of view, until rapid processing techniques can be developed, the IR data are not as useful as the picture data for immediate use by forecasters.

Fourth, *there has evolved useful and active participation in international programs.* From the very outset of the program, and reflecting the spirit of the very Act which gave birth to the NASA, the sharing of our results with other countries and working with them in this field have been active portions of our program. As has already been indicated, the analyzed results of the picture data are transmitted internationally to assist forecasters everywhere in describing and forecasting the weather. We have also made the basic observation data available to any foreign research group. Copies of the Tiros picture data may be acquired by any country in the form of 35-millimeter positive transparencies for projection or 35-millimeter duplicate negatives from the National Weather Records Center at Asheville, North Carolina.

We realize that satellite information is more useful when combined with other mete-

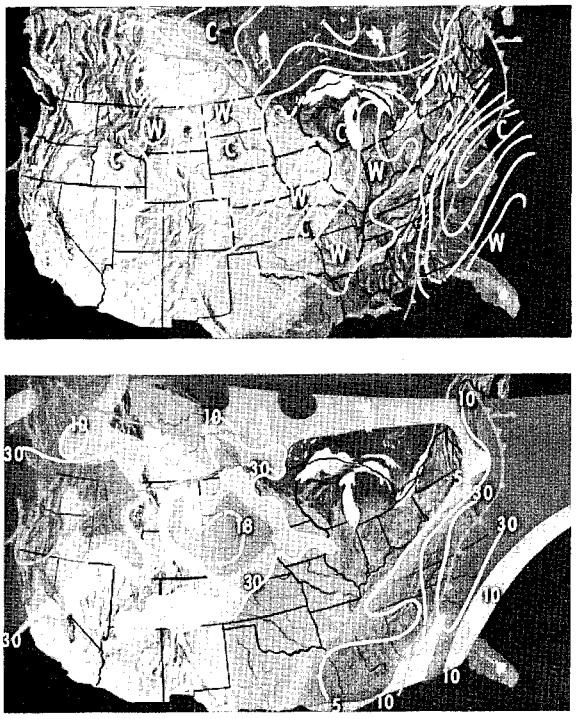
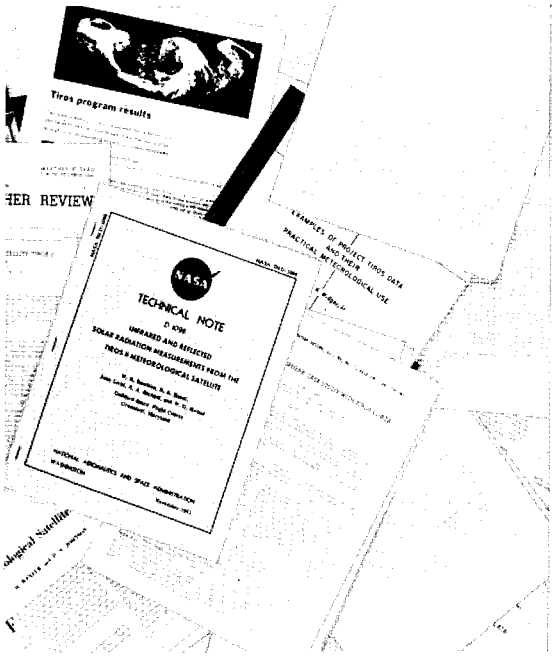


FIGURE 5–7. Map (top) of Tiros II infrared data and cloud analysis (bottom) simultaneous with infrared data.

orological observations; for example, special upper air soundings, aircraft observations, rocket observations, special radar coverage, and others. Consequently, we have contacted other national meteorological services and have offered them the necessary satellite orbital information in the event they wish to make special observations which could be correlated with the satellite observations over their locality.

In November 1961, an International Meteorological Satellite Workshop was held in which about 40 representatives of about 30 countries attended. The objective of the Workshop was to "present directly to the foreign weather services the results of the U.S. meteorological satellite activity to date and the possibilities for the future so that the program may be more completely known and understood by the scientific world community; that the present activity may be put in its proper perspective relative to future operational programs; and, finally, that the foreign weather services may acquire a working knowledge of the Tiros data for assistance in their future analyses programs, both in research and in operations and guidance in their own national observational support efforts". This Workshop was an overwhelming success and now others are being planned to be held at periodic intervals.

Finally, there was yet another accomplishment. *A firm groundwork has been laid for*



SCIENTIFIC PAPERS	OVER 30
TECHNICAL REPORTS	OVER 16
PORTIONS OF BOOKS	2
SEMI-POPULAR ARTICLES	OVER 4

FIGURE 5–8. Publications of Tiros results.

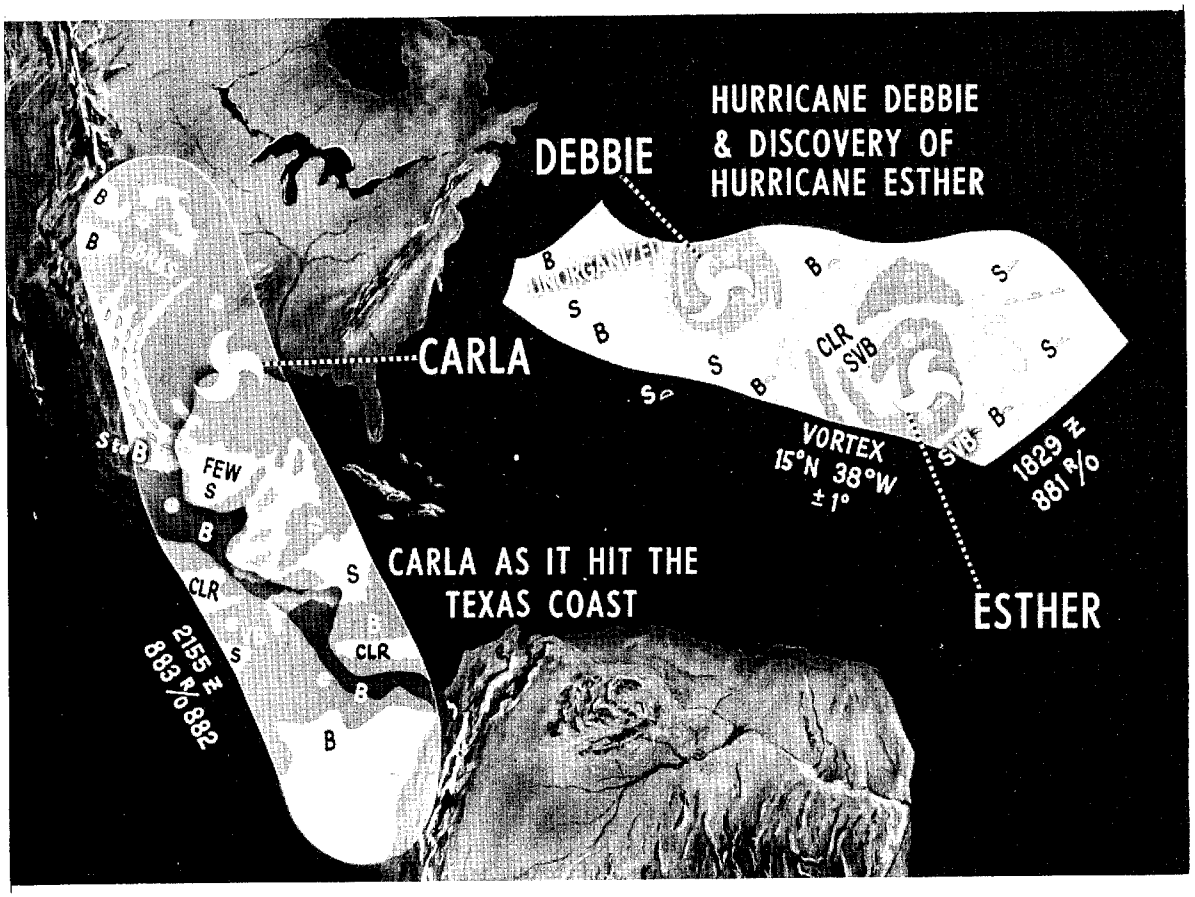


FIGURE 5–9. Detailed cloud analysis, September 11, 1961.

the establishment of a National Operational Meteorological Satellite System—NOMSS. The operational utilization of the Tiros data captured the imagination of the weather services and made them all the more impatient for the establishment of an operational meteorological satellite system to provide such data continuously over the entire Earth. Plans for the implementation of such a system were developed in the Spring of 1961 and the President asked Congress for funds to implement such a plan. Congress appropriated $48 million to the Weather Bureau for the implementation of this system. In its role as the national weather service, the Weather Bureau has general management responsibility for this system. More specifically, the Weather Bureau is responsible for coordinating the meteorological requirements of the weather data users, and for the meteorological data processing, analysis, dissemination, and archiving. By transfer of funds from the Weather Bureau, NASA will develop the spacecraft, procure the launch vehicles, arrange for the launch, establish the ground stations, acquire the data, and transmit them to the National Meteorological Center.

Thus, our accomplishments have been significant:

(1) We have demonstrated the feasibility of a meteorological satellite as an engineering system.
(2) We have taken important scientific measurements of the atmosphere.
(3) We have made use of the satellite measurements in day-to-day weather analysis and forecasting operations.
(4) We have embarked on an active international program of cooperation in meteorological satellites.
(5) We have assisted in launching a National Operational Meteorological

Satellite System for providing satellite data on a regular basis for the use of the weather services.

Now, what about the future?

Our continuing long-range goal, of course, is to contribute to the understanding of atmospheric motions and processes both in the research sense and in the immediate daily use by the forecaster.

In order to proceed towards this long-range goal, we have set for ourselves six immediate objectives for the coming months:

I. *To improve the satellite itself as an observation platform.* The Tiros satellite (fig. 5-10), despite its extraordinary performance,

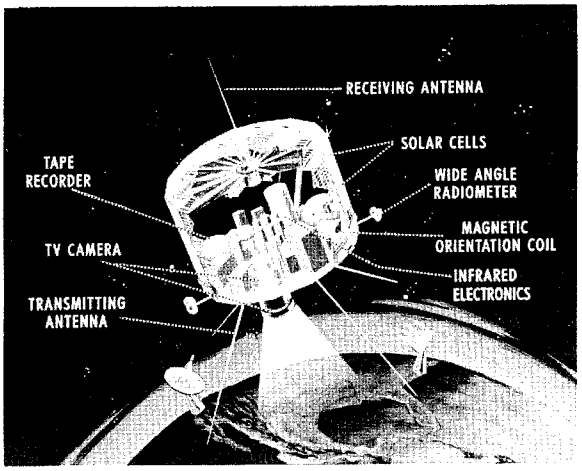


FIGURE 5–10. Tiros satellite.

is really a very simple and relatively unsophisticated satellite. It is relatively small, 42 inches across and 19 inches tall, and shaped like a pill box. Except for the base plate, it is entirely covered with solar cells which feed power to storage batteries. All the sensors are fastened to the base plate and the entire satellite is spin stabilized.

The next generation of satellites—the Nimbus satellite—will be larger and much more complex (fig. 5-11). It will be about 10 feet tall and about 5 feet across at the base. It will consist of three relatively independent major subsystems. The solar paddles will rotate so as always to face the Sun when the satellite is in sunlight and thus provide a more efficient utilization of the solar cells.

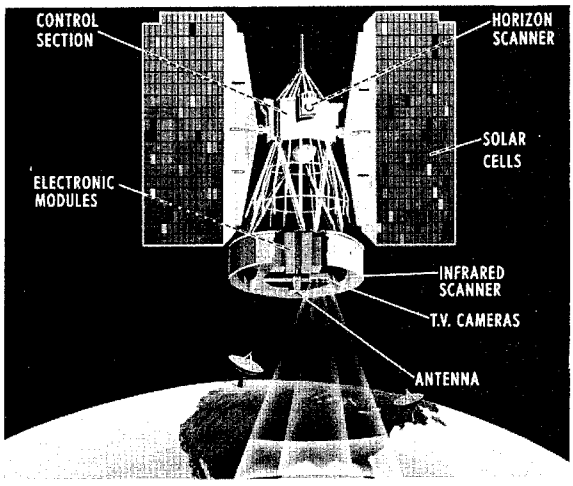


FIGURE 5–11. Nimbus meteorological satellite.

The control system will stabilize the satellite relative to the Earth. It is interesting to note that the control system in itself has been considered to be as complex as the entire Tiros spacecraft. Finally, we have the sensory ring at the bottom. It has been designed on a modular concept so that modifications and changes in the experiments or subsystems that it contains can be effected without requiring a redesign of the entire spacecraft.

Figure 5-12 gives an approximate concept of the comparative sizes of the two families of spacecraft—the Nimbus and Tiros. The picture was taken during a recent visit to the Goddard Space Flight Center of foreign meteorologists at the International Meteorological Satellite Workshop. The Nimbus is a

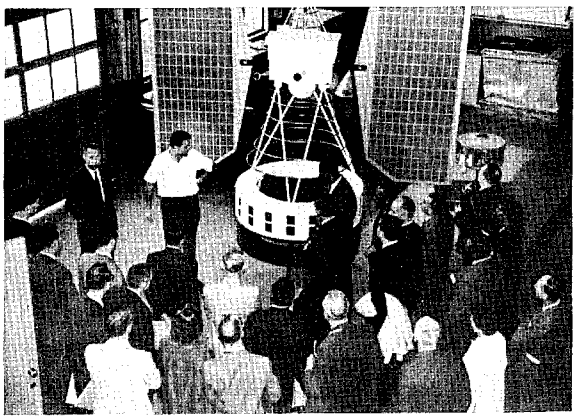


FIGURE 5–12. International Meteorological Satellite Workshop participants view Nimbus model at Goddard Space Flight Center.

full-scale model and can be seen in its relative size to the people standing nearby. The Tiros model is only half scale so that the relative sizes are exaggerated.

II. *To increase the observational area coverage of the satellite.* It has been estimated that the Tiros satellite views less than 25 percent of the Earth's surface over which it passes. The reasons for this low figure are explained as follows.

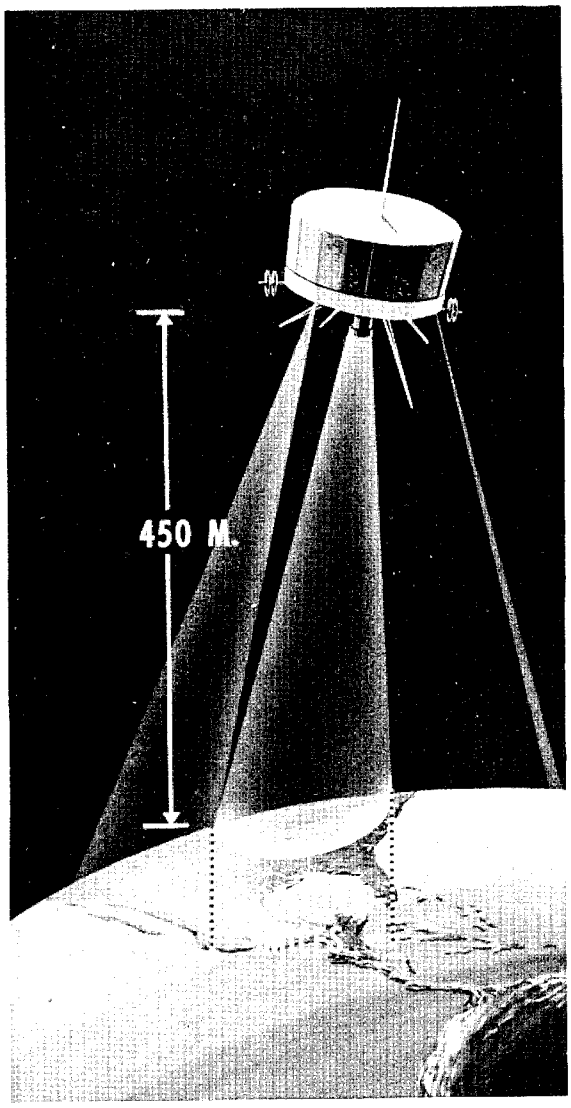


FIGURE 5–13. Tiros Sensors. Two TV cameras detect cloud cover; multichannel scanning radiometer detects water vapor, night clouds, reflected sunshine, and emitted heat, and permits low-resolution cloud mapping; nonscanning radiometers detect total radiation and thermal radiation.

Figure 5-13 shows the camera view of the Tiros satellite. When the optical axis is perpendicular to the Earth, the camera views an area of about 800 miles in diameter. However, when the optical view becomes more oblique the coverage increases but the associated resolution decreases proportionately. This picture shows how much of the Earth's surface is viewed at any one instant.

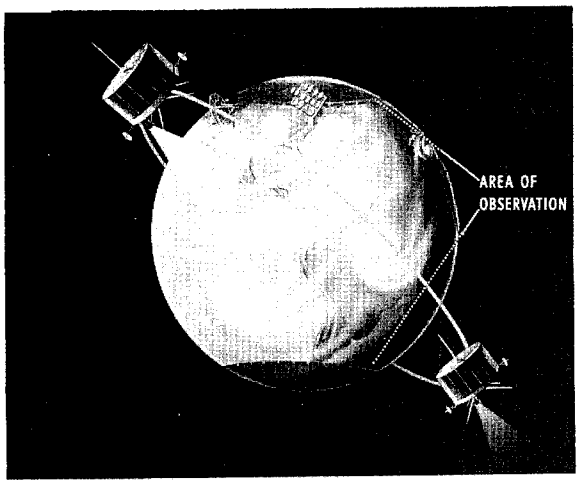


FIGURE 5–14. Tiros in inclined orbit and space oriented.

Figure 5-14 shows two other features of the Tiros system which limits the spatial coverage. The first is the fact that Tiros is in an inclined orbit of approximately 48°. This means the polar regions are not readily available for observation. The second reason is due to the spin stablization of the satellite with respect to space. This restricts useful observations to only those periods when the satellite is viewing the Earth and the regions viewed are sunlit. Due to the Earth's oblateness the satellite's orbit plane precesses and associated with this precession there is a migration of the area favorable for picture taking from the Northern Hemisphere to the Southern Hemisphere and back again.

Figure 5-15 shows this migration northward and southward. It was drawn for Tiros III and begins on July 12, 1961, the launch date. Note that this launch date was selected so that later during the period from mid-August to late September—the hurricane season—Tiros III would be in the proper

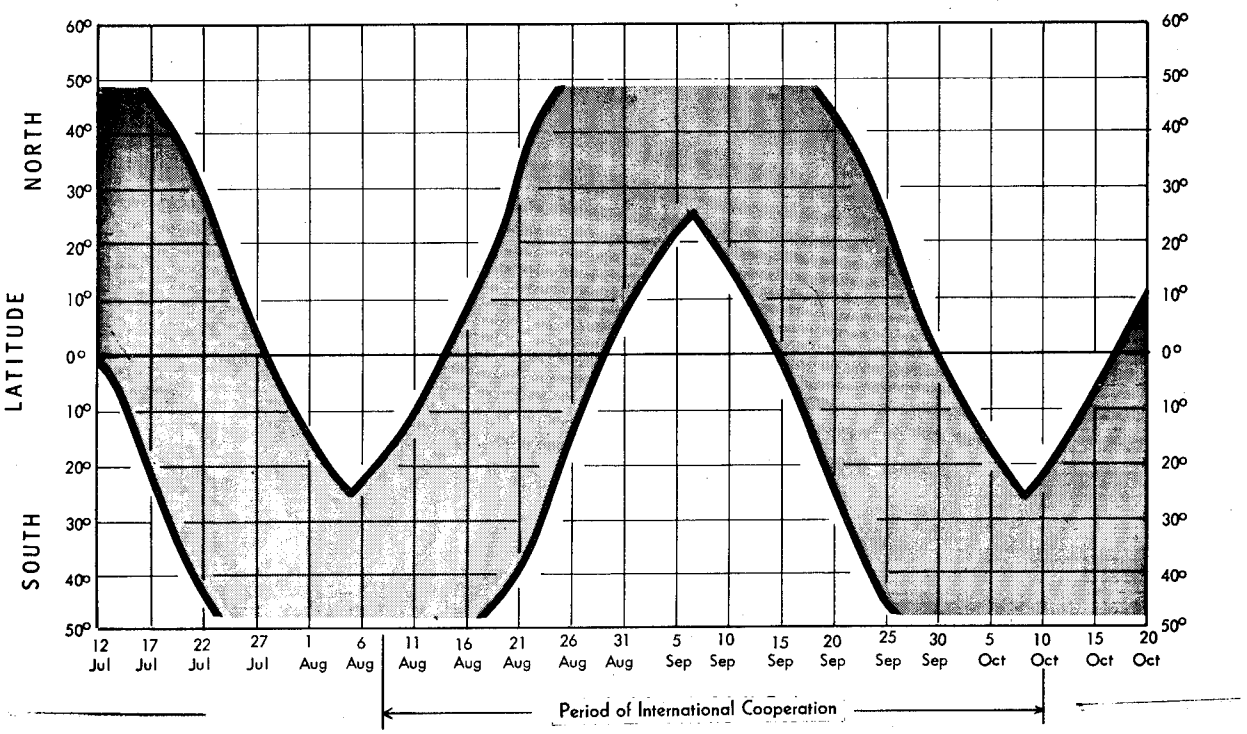


FIGURE 5–15. Illuminated latitudes, Tiros III.

latitudes for viewing the hurricanes. The period of migration northward and southward is approximately 9 weeks.

In order to increase the spatial coverage toward the poles the remaining Tiros satellites—Tiros V, due to be launched during the summer of 1962, and the two Tiros scheduled to follow it at about 5-month intervals, Tiros VI and Tiros VII—will be launched into a higher inclination orbit of 58°. Our colleagues in England and the Scandanavian countries are particularly pleased about this higher inclination orbit because it will afford them the opportunity of studying the weather over their areas. The sea ice studies will also greatly benefit from this orbit.

The true total coverage of the Earth will not come about until the launch of the first Nimbus. (See fig. 5-16.) Nimbus will have a three-camera system and the area viewed by these cameras at any one time will be roughly 1,500 miles by 500 miles. These dimensions will insure contiguous observations at the equator from one orbit pass to the next so that the entire Earth will be viewed by the three-camera system. Nimbus will be in polar orbit and thus will pass over every point on Earth as the Earth rotates beneath it. As stated earlier, Nimbus will be Earth oriented and will always view the Earth vertically.

The following table is a comparison of the Nimbus and Tiros families. This table shows both the nature of the growth of the spacecraft and the increase in coverage as we proceed from Tiros to Nimbus.

	Tiros	Nimbus
Geometry	Pillbox	Dumbbell
Weight, lb.	300	650
Orbital altitude, nautical miles	380	600
Orbital inclination	40° equatorial	80° polar, retrograde
Stabilization	Spin stabilized	Three axes Earth oriented
Earth coverage	10 to 25	100
Camera raster	500 lines/frame	800 lines/frame
TV resolution, miles	1	½
Maximum power available, watts	20	400
IR sensors (resolution), miles	MRIR (30)	MRIR (30), HRIR (5)

FIGURE 5–16. Nimbus in near polar orbit and earth oriented.

III. *To increase the frequency of observations of an individual area.* Objective II referred to the spatial coverage of the satellite. This objective refers to the time coverage.

Figure 5-17 shows the time-coverage problem that has existed for the Tiros satellite. Here are depicted selected orbits of Tiros in relation to readout stations at Wallops Island and the Pacific Missile Range. Each circle surrounding the two readout stations represents the area where contact can be made by the readout station with the satellite. You will note that orbits B, C, and D all lie outside of these intercept circles. In all, there are 6 to 7 such orbits so that under the most favorable conditions we are able to read out only 8 of the possible 14 orbits of Tiros by means of our two Command and Data Acquisition (CDA) stations. Thus, while some areas may be read out on successive days some cannot be read out at all for long periods at a time. We have added a clock-start capability at Santiago, Chile, which permits us to select a particular one of the seven orbits for storage and later readout. However, it does not increase the number of orbits read out.

Nimbus, on the other hand, will be in polar orbit. Figure 5-18 shows the possible 14 daily orbits of Nimbus relative to the established CDA station at Fairbanks, Alaska. All but four orbits are available to this station. The addition of another CDA station in northeastern North America will permit the acquisition of practically all the orbits every single day. Thus, every point on Earth will be covered at least once every 12 hours, once in the daytime and once at night. In the polar regions the frequency of observations will be much greater.

This frequency of observations unfortunately is still not adequate for some meteorological problems. Figure 5-19 illustrates diagrammatically some properties of various scales of atmospheric systems. The vertical axis is a measure of the typical size of a weather system in miles on a linear scale and the horizontal axis is a measure of the lifetime of the weather system in hours on a logarithmic scale. Notice that cyclonic storms

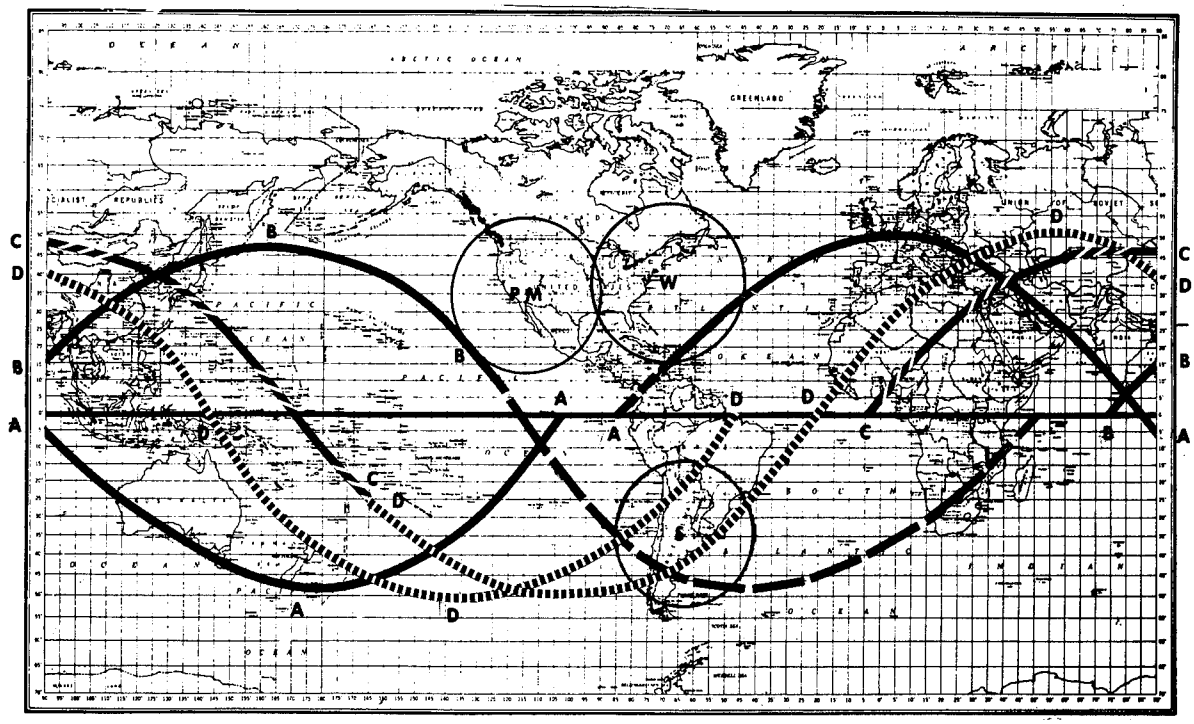


FIGURE 5–17. Selected orbits of Tiros in relation to readout stations at Wallops Island and the Pacific Missile Range.

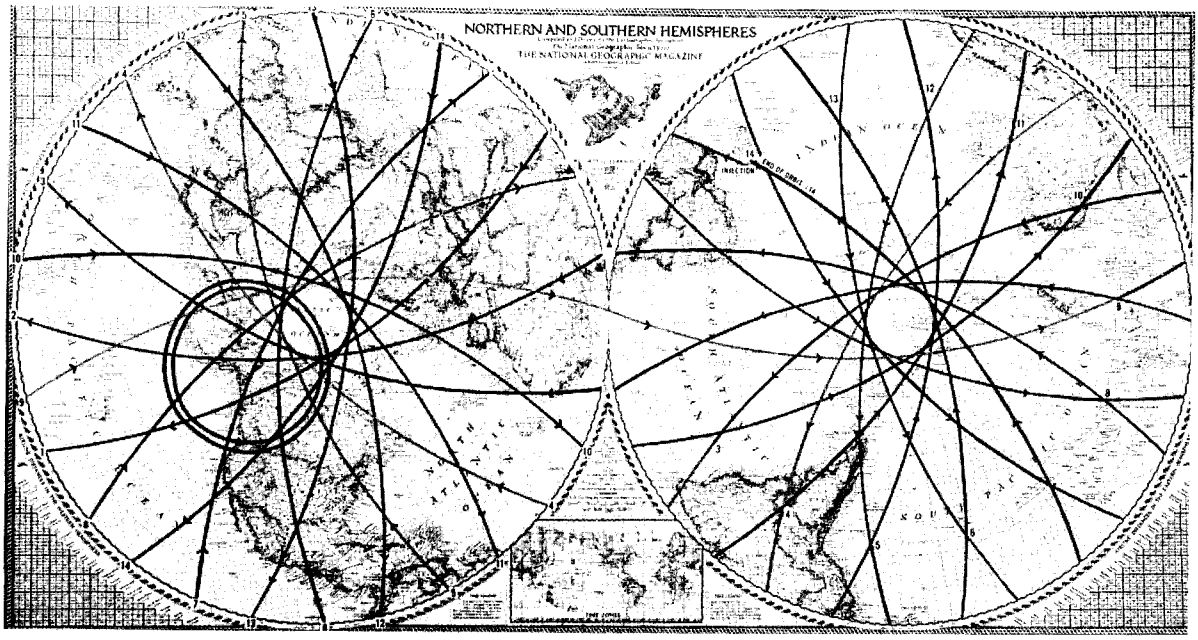


FIGURE 5–18. Orbital paths and acquisition range.

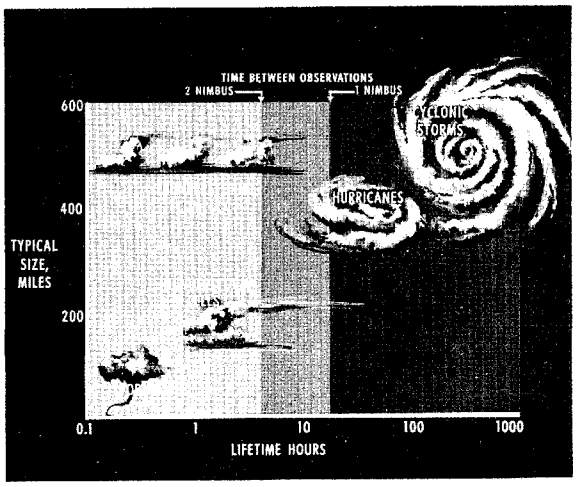


FIGURE 5–19. Lifetime of typical weather systems.

are quite large and last many days. Hurricanes are smaller and their duration is less. Tornadoes on the other hand are of a very small size and have extremely short duration —on the order of minutes. With one Nimbus satellite aloft, hurricanes and larger storms will readily be observed. Two Nimbus satellites, providing local observations every 6 hours, would improve matters only slightly. The severe storms, thunderstorm cells, and tornadoes whose lifetime is less than 5 hours could develop and dissipate entirely between two successive observations in the Nimbus system. Thus, what is required is a more continuously observing satellite.

Figure 5-20 shows our thinking with regard to such a satellite—the Aeros satellite. This satellite is still in the study stage and does not constitute an approved NASA program. It will be launched into a synchronous orbit, that is, an equatorial orbit, and will appear to remain stationary over the subsatellite point. Its sensors will give gross observations of the Earth's cloud cover and detailed observations of selected areas of potential or observed storm activity.

IV. *To continue the development of new flight sensory systems.* An important part of our research and development program is to continue the search for useful meteorological sensors to fly onboard the meteorological satellites. Because, characteristically, meteorological satellites can view the atmosphere only at a distance, we rely entirely on the measurements of radiations from the atmosphere. Thus, for the new sensor development we must search in the electromagnetic spectrum for regions in the spectrum that are related to the physics of the atmosphere. We have been working in the visible region and certain IR radiation bands. There is work going on in the study of CO_2 absorption bands, the microwave region, and the ultraviolet. For each of these significant radiation regions, suitable flight hardware has to be developed. Our program includes developments in such instrumentation as: TV vidicons, electrostatic tape cameras, image orthicon cameras, improved IR radiation detectors, IR spectrometer, radar, and sferics.

Nimbus (fig. 5-21) has been deliberately designed to accept these new sensors as they become developed. This figure shows a possible configuration of a radar antenna mounted

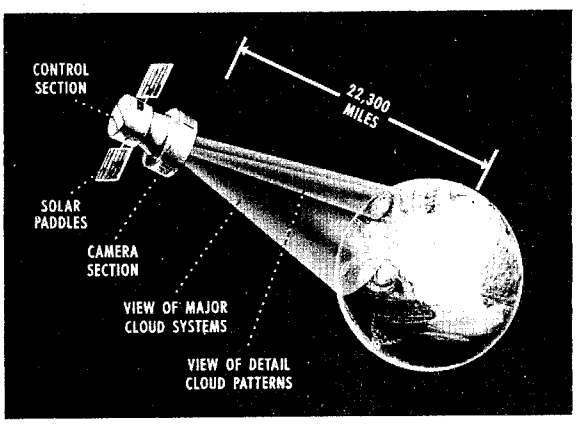


FIGURE 5–20. Aeros meteorological satellite.

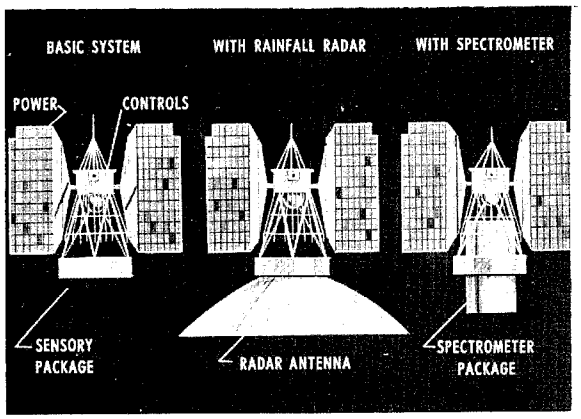


FIGURE 5–21. Nimbus spacecraft versatility.

on the Nimbus and the IR radiation spectrometer also included in the satellite, each without a complete redesign of the satellite.

We clearly understand that it is progress in this field, of developing new and useful sensors, that will determine the scientific growth of the program and we are always ready and eager to welcome the assistance of the scientific and industrial community in providing ideas and solutions of problems in this area.

V. *To continue to provide data from meteorological satellites in orbit for real time use by the forecaster.* As was mentioned previously, within a very short time of the launch of Tiros I, the data produced by this experimental satellite were transmitted to field users. This operational use of the Tiros data has continued and has improved. The number of instances where these data have been helpful to the forecaster in his analysis of existing weather data are too numerous to mention and have been well documented elsewhere. Therefore, just a few illustrations are presented herein. Figure 5-22 shows an analysis of the clouds off the west coast of the U.S. Since weather in midlatitudes moves from west to east, this is a particularly important region and unfortunately a data-sparse one. This figure shows that Tiros viewed a vortex (indicating the presence of a rotating storm) lying off the west coast of California, a matter which would be of considerable interest to the California forecasters and the residents on the west coast.

Figure 5-23 shows the photographs which Tiros III took of the first five hurricanes of the 1961 season. The identification and tracking of hurricanes are very important activities of the Weather Services.

Figure 5-24 is a global cloud analysis for September 11, 1961. This is a Northern Hemisphere polar projection. The cross in the center represents the North Pole. Each of the swaths represents the analysis of one Tiros orbit. The data show that in 1 day

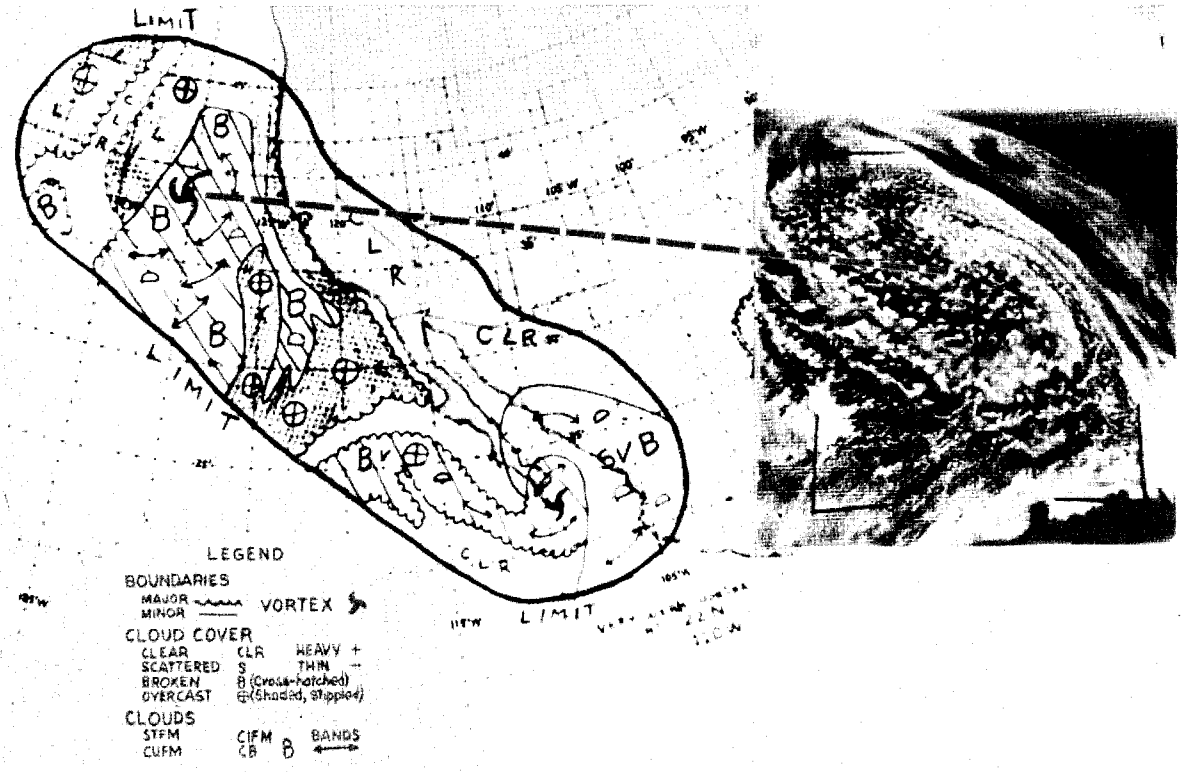
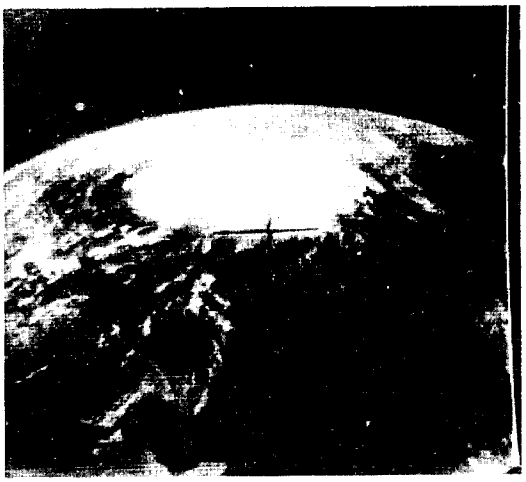
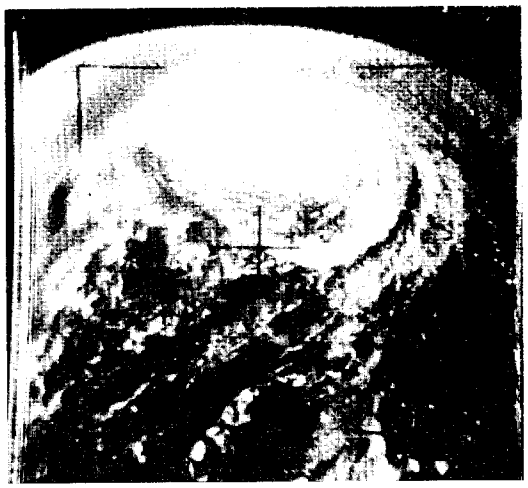


FIGURE 5–22. Tiros III observations in data-sparse area.



ANNA

DEBBIE



BETSY

ESTHER

CARLA

Figure 5–23. Tiros III hurricane data

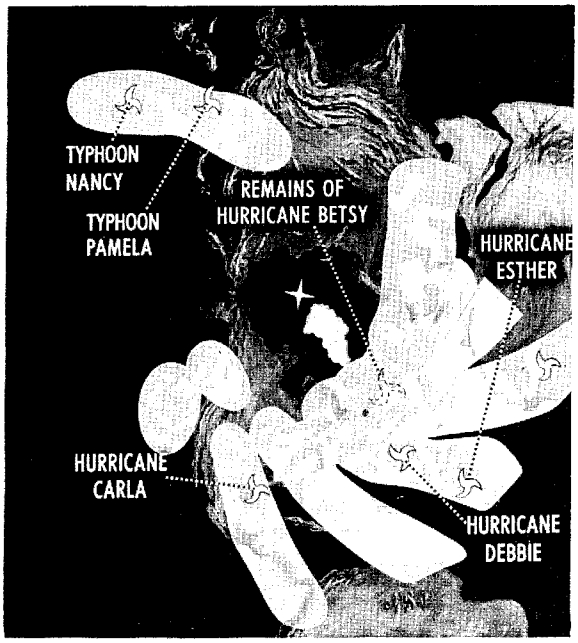


FIGURE 5–24. Global cloud analysis, September 11, 1961.

Tiros viewed five individual hurricanes in the region from North America to Europe, as well as typhoons Nancy and Pamela in the Pacific. We do not know whether storms of such proportions existed in the remainder of the areas since we cannot read out every Tiros orbit. Information such as this is provided immediately to the forecast centers for their use in charting the weather events.

For maximum real-time use of the data, solutions must also be found for optimum methods of data presentation and transmission from the satellite to the CDA station, from the CDA station to the weather central, and finally from the weather central to the user. Methods must also be found for data compression and perhaps also for onboard data analysis in order to reduce the quantity of data being transmitted along the communications channels.

VI. *To engage in active international programs.* With a full realization that the atmosphere is a global phenomenon and that the fulfillment of any one country's responsibilities in meteorology is closely linked to the extent that it participates with other countries in similar activities, we are working actively in the direction of the development of a comprehensive international program. In addition to the activities already described and including

(a) transmission of cloud analysis

(b) provision of satellite data through the National Weather Records Center

(c) encouragement of supporting observations and

(d) sponsoring international workshops we are pursuing two other activities, namely:

(e) planning for ultimate direct readout. We hope to be able to provide, from American satellites, the opportunity for any country to read out its own local cloud information. We also are working on the possibility of a nondestruct readout of the satellite storage tape. This will permit any country having proper receiving equipment to interrogate the satellite and read data out without destroying the contents of the satellite.

(f) planning for a global operational system. A start in this direction has already been made as a result of United Nations Resolution 1721 and the bilateral discussions being conducted by the United States and Soviet Union resulting from the exchange of notes between President Kennedy and Premier Krushchev.

Finally, our planned flight schedule for the next few years is as follows:

Satellite	Launches per calendar year						
	1960	1961	1962	1963	1964	1965	1966
Tiros	2	1	3	1			
Nimbus (research and development)				2	1	1	
Nimbus (operational)					2	2	1
Aeros							2

For planning purposes we are considering the first launch of Aeros no earlier than 1966.

This, then, represents what we have been up to and what we are planning to do. At the Third National Conference on the Peaceful Uses of Space, we will report the extent to which we have succeeded in meeting our immediate objectives.

6. NASA Communications Satellite Program

By LEONARD JAFFE, *Director of Communications Systems, Office of Applications, NASA*

Mr. Jaffe was formerly Chief of the Data Systems Branch, Lewis Research Center. He has specialized in research in the fields of electronic instrumentation, data and information transmission, and data processing by means of computers.

He joined the National Advisory Committee for Aeronautics, predecessor of the NASA, in 1949 as an aeronautical research scientist at the Lewis facility.

A native of Cleveland, Mr. Jaffe was graduated from Ohio State University in 1948 with a bachelor's degree in electrical engineering and did graduate work at Case Institute of Technology in Cleveland.

Mr. Jaffe is the author of several scientific publications and articles for technical journals. He is a member of the Institute of Radio Engineers.

The first transatlantic telegraph cable connected America and Europe in 1866. Transatlantic radiotelephone circuits were established 6 decades later, in 1927. The unreliable radiotelephone circuits were supplemented 3 decades later, in 1956, by the transatlantic telephone cable. Now it is forecast, by many, that the use of satellites for providing global communications will be realized no more than a decade after the installation of the first submarine telephone cable.

Satellites, thousands of miles above the Earth's surface, can relay not only telegraph and telephone messages in large numbers, but also television pictures. Not only will satellites be able to link major countries and continents, but they—as President Kennedy noted in his policy statement of July 1961—will provide efficient communication service to the farthest corner of the globe.

Economic studies which have already been undertaken indicate that communications satellites can provide services comparable in performance to those of the undersea cables, at lower costs per channel of capacity, and that in a decade or so communications requirements will exceed those which can be provided by today's conventional techniques. This future need is rather dramatically pointed out when one realizes that a line across the United States, anywhere, would cut across 100 times more communications facilities than the total communications facilities emanating today from the United States to other parts of the world.

It would be a mistake to minimize the technical problems of establishing a communications satellite system. As we shall see, they are many and great, but equally great are the incentives to get the job done. Shortwave radio circuits across the oceans depend on radio reflection from the ionosphere and are of extremely poor quality. These sometimes fail completely. Submarine cables are greatly superior in quality, but lack the broad band or large capacity requirements of the future.

Although the usefulness of the communications satellite and its importance in worldwide communications is clear to all, it is not immediately apparent which of the technical approaches to the problem will turn out to be the most rewarding in arriving at the design of the operational systems of the future. Accordingly, NASA is endeavoring to determine, as rapidly as possible, which of the

various system designs that have been proposed should be used in the establishment of operational communications satellite systems. To do this we must first determine which technique has the greatest promise of reliability and economy of operation, so that the development of the commercial system can be pushed forward as rapidly as possible.

The three major communications satellite systems which offer sufficient promise to warrant continued detailed investigation are (1) a system using low- or intermediate-altitude passive reflectors, (2) a system using low- or intermediate-altitude active repeaters, and (3) a system depending on high-altitude, synchronous, active repeaters. The passive, or reflector, satellite does not carry with it any power supply, receiver, or transmitter. It is in effect a radio mirror in the sky, and it is used simply to reflect the radio energy from one terminal of the communications satellite system to another. Active repeaters draw their name from the fact that they carry receivers, transmitters, and sufficient power supply so that the message to be transmitted is received, amplified, and retransmitted to the far terminal. By low or intermediate altitudes we mean from several thousand miles to as much as 12,000 or so miles. By high-altitude, synchronous is meant the 22,300-mile orbital condition in which the satellite apparently remains fixed over a point on the Earth's equator.

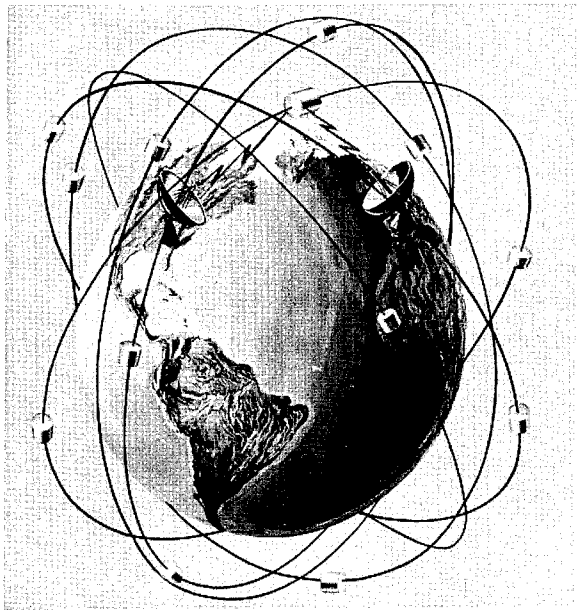


FIGURE 6–1. Active communications satellites, low-altitude orbits.

Figure 6-1 shows the elements of a low-altitude active communications satellite system. It is characterized by terminal stations with large antennas located, for example, on the European and the American continents, and by a number of satellites orbiting at low altitude. The reason for the large number of satellites indicated in the figure is that the time that any one of these satellites is visible to both of the terminal stations is limited when the satellites are in orbit at low altitude. Consequently, to get continuity of transmission between the two terminals, a number of satellites must be put into orbit, and these must be so distributed in space that at all times at least one can be used as a communication link between the terminal stations.

A realistic appraisal indicates that unless fairly complex provisions are included for controlling the position of the individual satellite in its orbit, it must be expected that the satellites will come after a period of time to an essentially random set of spacings. Estimates of the number of satellites required for substantially continuous service between terminal points are, therefore, generally made on the assumption that the satellites are distributed in a random manner in orbit.

An example of the results of calculations on the number of satellites that are required for the maintenance of communications at several orbital altitudes is given in figure 6-2. Here we see how many satellites are needed for substantially continuous service between ground terminals located some 3,000 miles apart. Note that if we were to orbit the satellites at an altitude of only 1,000 miles as many as 400 randomly distributed satellites would be required. If we plan to use the 5,000-mile-altitude range, then we can immediately cut the number of satellites required to 40. Satellites are not inexpensive, and launch-vehicle costs are at least comparable if not higher. Consequently, even 40 satellites in orbit will represent a considerable investment for the communications satellite system. If fewer satellites can be

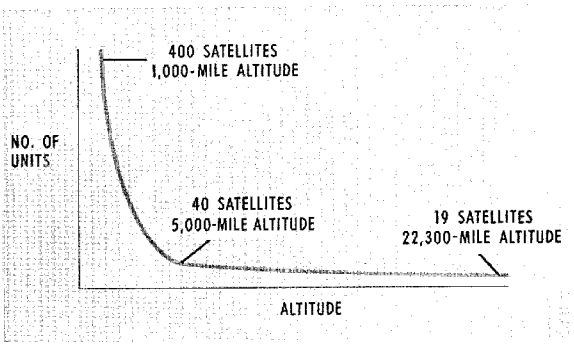


FIGURE 6–2. Communications satellites, randomly spaced. Substantially continuous service between ground terminals 3,000 miles apart.

used, we can cut the initial costs somewhat and keep the replacement charges down. Suppose we plan on using the 22,300 mile altitude, which is about as high as we would wish to go for reasons discussed subsequently; 19 satellites are shown to be required by the analysis, which assumes that the satellites are randomly distributed in orbit. In actuality, if we were to orbit the satellites at 22,300 miles, and it were possible to exert effective precision control of their orbital velocity, we would not use randomly distributed satellites at all, but would establish what is known as a synchronous satellite system.

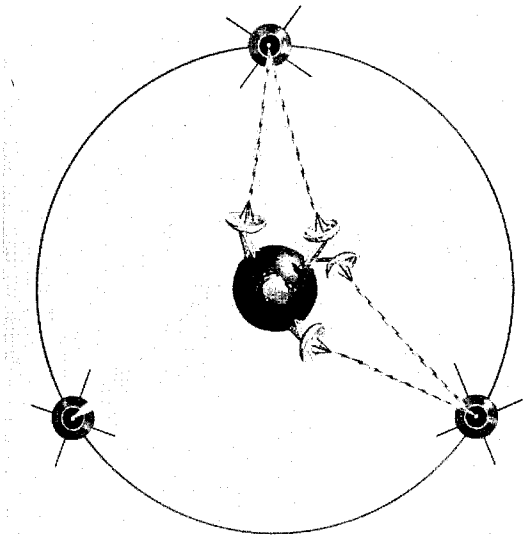


FIGURE 6–3. Active communications satellites, synchronous orbit.

The synchronous satellite system is illustrated in figure 6-3. It is of great interest in communications work because, at the 22,300-mile altitude, the spacecraft will remain fixed over a point on the equator and it is necessary to have only three satellites in orbit to provide for basic worldwide coverage. At this altitude a satellite will continuously see one-third or more of the Earth's surface. Consequently, if we can put a satellite up at such a longitude that it is visible to both America and Europe, continuous communications can take place between the two continents through just a single satellite. Similarly, the establishment of another satellite further to the west will permit us to establish communications between the American continent and Japan, Australia, and the Far East. A third satellite would round out the coverage for messages between the Far East and the European and African nations. To realize this type of system, the problems of providing a satisfactory attitude and position control system for the satellite must be met. As it is by no means certain how long it will take to arrive at a control configuration of adequate reliability and precision, research on the synchronous system is being conducted parallel with that on low-altitude systems.

I have already mentioned that a communications system with the satellites at low altitude will require a number of satellites in orbit simultaneously, and that spacecraft and launching costs are likely to accumulate rapidly with such a system. We are studying techniques whereby we can launch a number of satellites into orbit from a single launch vehicle and have initiated work in this area which we expect will lead to a flight experiment within the next few years. The multilaunch concept, which is illustrated in figure 6-4, calls for the insertion of a number of satellites into orbit with a single launch vehicle; the example shows three. The launch vehicle leaves the launching pad and goes into an elliptical orbit. This puts the spacecraft, which is carried by the launch vehicle and which has within it the three communications satellites, also into the elliptical orbit.

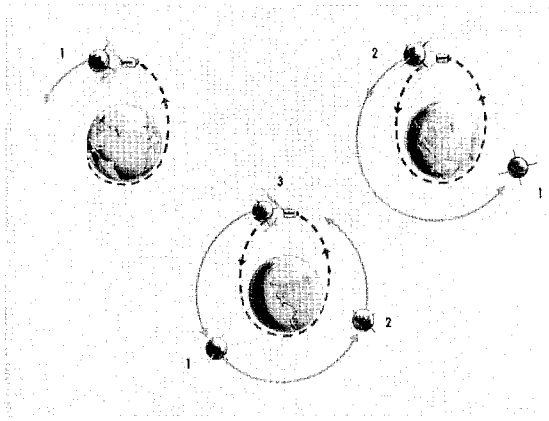


FIGURE 6–4. Multilaunch concept.

When the spacecraft carrying the three communications satellites reaches its apogee, the first of the communications satellites is ejected and an additional rocket propulsion unit attached to the satellite is fired. This satellite is therefore put into a circular orbit about the Earth because of the additional velocity that has been given to it. At the same time, the spacecraft, now carrying two communications satellites, continues in its elliptical path as shown in the figure. It takes longer for the communications satellite to orbit once than it takes the spacecraft carrier and the next time the spacecraft reaches its apogee it is in the position shown by the upper right-hand sketch in figure 6-4 relative to the first ejected satellite. At this point the spacecraft unit again ejects a communications satellite which is also given sufficient additional velocity by an appropriate rocket for it to maintain a circular orbit. Once again the spacecraft makes its elliptical orbit. On reaching its apogee it again ejects a satellite and so it has, in the course of three elliptical orbits, put three communications satellites into circular orbit.

Obviously, this carrier is a fairly complex spacecraft, since it must maintain its attitude throughout the time of each injection, so that the injection of the individual communications satellites will take place into the preselected orbit. Also, it must either contain within itself sufficient sensory mechanisms to determine when apogee is reached, or it must carry a command unit to respond to signals from an appropriate ground control system. This is needed to insure that the injection of the individual satellites will take place at the proper times. A procedure for multiple satellite injection seems to be a necessity if we are to proceed with operational low-altitude communications satellite systems. Although I have discussed the multilaunch concept in a general way and have indicated that it can be used with either active or passive low-altitude satellites, it is probable that its first test will be with passive satellites in the carrier. This activity has been designated Project Rebound.

Having discussed some of the reasons for the different orbital configurations proposed for communications satellites, let me now review the satellites themselves. Basically, the simplest of all the communications satellite techniques is the passive reflector—the radio mirror in the sky. The passive reflector can take many forms and over the years a number of specific configurations have been suggested. At the present time NASA is investigating four of these configurations, inasmuch as they appear to have the most promise for immediate application. These four are shown

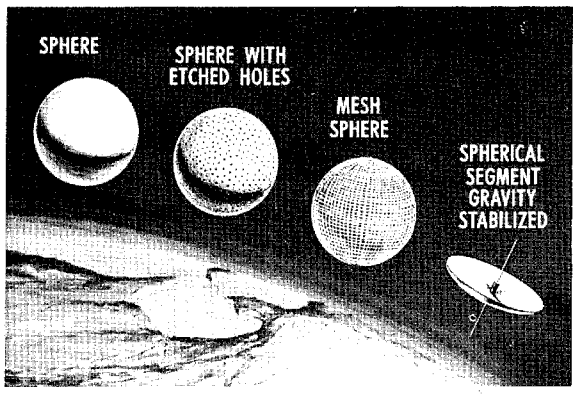


FIGURE 6–5. Forms of passive communications satellites.

in figure 6-5. The first is the simple reflecting sphere. This, of course, has been tried already, in Project Echo, which will be discussed subsequently. As a followup to the simple sphere with a continuous surface, there are two varieties of surface structure which promise better overall performance so far as the passive reflector communications

system is concerned. One of these is a sphere which has been lightened by etching holes in the metallic foil which constitutes the reflecting surface. This reduces the weight and makes it possible to orbit a large satellite, which will have correspondingly improved performance, with the same launch vehicle. An alternative method of reducing the weight of the sphere is to make the sphere of an appropriately sized wire mesh. We are not sure at this time which of the two techniques for lightening the sphere will actually prove to be the most effective. Since we wish to make the sphere very much larger insofar as its reflection characteristics are concerned, we are also looking into the possibilities of effectively accomplishing this without actually orbiting the whole sphere. In normal circumstances only the bottom face of the sphere, the portion facing the Earth, is actually used in reflecting the signal from one station to another. For this reason it seems rather unnecessary to orbit the upper portion, which serves no purpose in the communications satellite system. The problem then becomes one of erecting, and then stabilizing, the spherical segment that is placed in orbit. With a complete sphere, regardless of stabilization there is always a lower surface available to act as a reflector, whereas the spherical segment, shown over in the lower right-hand portion of the figure, if not provided with stabilization, very often would not face in the proper direction. As a result, the reflecting area that the antenna on the ground would see would often be very small, just as if you were looking at a shallow bowl, edge on, and it would not be possible to establish an effective transmission path. Therefore, to use the spherical segment, it is necessary that we add a stabilization device, which will hold the reflecting face toward the Earth. Studies of the spherical-segment reflector and of the stabilizer will therefore be carried on together, because without the second the first is of little use.

The NASA's passive satellite program includes several flight tests. The properties of the sphere as a communications reflector are being evaluated in these flight tests. The first of these tests was the Echo I project. Many people have seen Echo moving across the sky and may be interested to learn that we are continuing to measure its reflection characteristics to see if any more significant changes in its shape or surface conditions

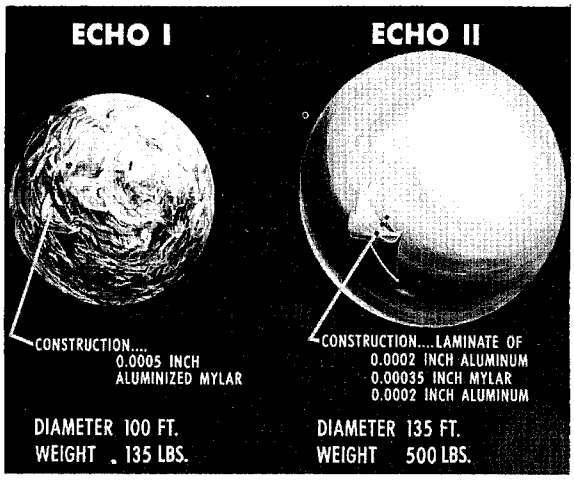


FIGURE 6–6. Comparison of Echo I and Echo II communications satellites.

occur. The left side of figure 6-6 shows that Echo I was 100 feet in diameter, weighed 135 pounds, and was constructed of mylar plastic film 5 ten-thousandths of an inch in thickness. This is approximately 500 millionths of an inch in thickness. The mylar film was made reflective to radio waves by evaporating an aluminum film onto the plastic in a vacuum chamber. The aluminum was therefore extremely thin and contributed no structural strength to the sphere. After the Echo sphere had been in orbit for some time it exhibited a certain amount of wrinkling, and there were small changes in its shape which are associated with the loss of the original volume of inflation gas. As the sphere wrinkled, it became less acceptable as a communications reflector, since a smooth surface is the best reflector. Accordingly, we have now built a new version, Echo II, which is shown on the right side of the figure a sphere which will maintain a fairly smooth surface characteristic. In designing this reflector, we took advantage of the availability of a large launch vehicle to make the sphere larger. It will now be 135 feet in diameter and will weigh about 500 pounds. In this case the sphere is made of a laminate, a combination

of two layers of aluminum foil and one of mylar. The total thickness will be 750 millionths of an inch. This is 50 percent thicker than Echo I, but is appreciably stiffer because of the presence of the two layers of aluminum foil. When this sphere is inflated and somewhat overpressured, it takes on a permanent set, and does not tend to resume its earlier wrinkled condition when the gas pressure drops. Consequently, it is our hope that even though the inflation gas will not remain within the sphere for any appreciable period of time, as a result of the punctures which will occur from micrometeorites, that the fairly smooth surface that is shown in

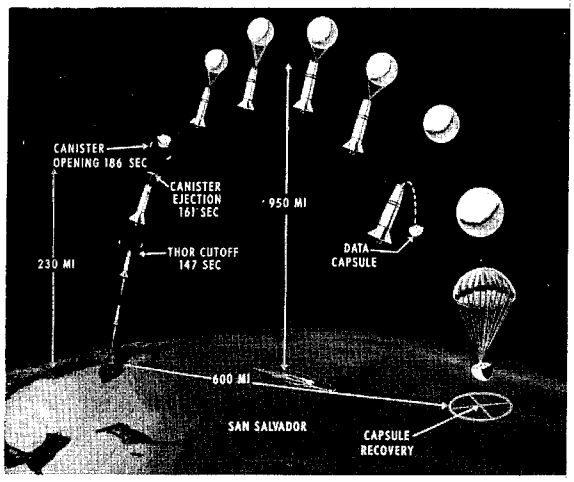


FIGURE 6–8. Testing of Echo II.

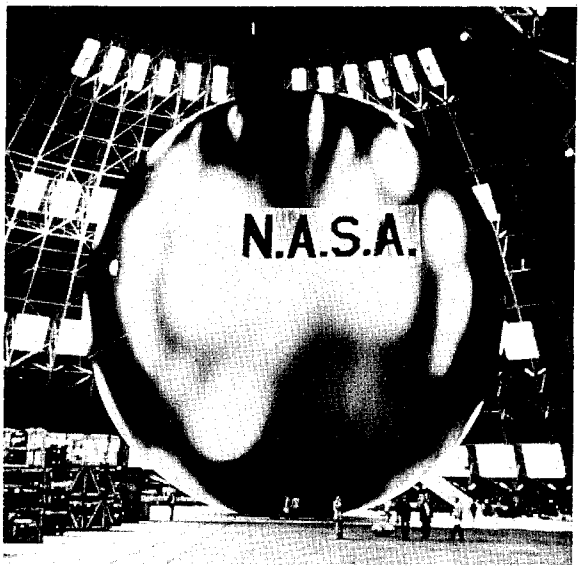


FIGURE 6–7. Echo II.

figure 6-7 will be maintained for some time, and the effectiveness of the reflector will be demonstrable over a long period. The major objective of the Echo II project is to show that a rigidized structure of this type is practical as a passive reflector.

In figure 6-8 we show the very interesting procedure which is followed in testing the Echo II sphere. In developing Echo I a number of tests were run at the Wallops Island Station to prove out the packing and inflation techniques for the sphere. In the course of these tests we learned a great deal about the details of the techniques required to build the canister containing the sphere, how to inflate it, and how to make sure that it was not damaged in the inflation process. Our experience with Echo I convinced us that similar procedures must be followed with Echo II. The first of the Echo II tests was conducted on January 15, 1962.

The sphere ruptured during the test. In the case of Echo II, because the sphere alone without its container weighs about 500 pounds, a large rocket vehicle is needed to get the sphere to the proper altitude for inflation. A Thor rocket is used and launched at the Cape Canaveral range. At 147 seconds after lift-off, as shown in the figure the shroud at the nose end of the vehicle is ejected, and at 161 seconds the canister containing the sphere is freed from the booster. At 186 seconds the canister is opened by an explosive device and the sphere, which has been folded within the container, starts to inflate as the solid gas generating material within it begins to evaporate. At it inflates, it may be observed in detail how the process proceeds. For example, we want to know whether the loose metallic parts which are in the vicinity after the separation of the canister halves interfere with the unfolding of the sphere or perhaps even puncture it. The unfolding and inflation take place at an altitude of over 200 miles. It is obvious that it is not going to be possible to make the

detailed observations with optical instruments back at the Cape. Accordingly, we made provision for the installation in the Thor vehicle of a television observation system and a camera observation system. Both of these devices record continuously as the canister is ejected and opened and as the sphere inflates. The chart indicates that observations from the Thor vehicle continue as the sphere rapidly reaches full inflation and then follows a ballistic trajectory to a peak altitude of 950 miles and then drops back to the terminal atmospheric reentry. Both the Thor and the sphere are outside the atmosphere in this phase, and they will maintain their relative positions as they move along the trajectory. Before the vehicle gets too far back into the atmosphere on reentry a data capsule is ejected. This capsule contains the data-recording camera and recovery aids and is lowered by parachute to the predicted impact area where a recovery team is waiting. At the same time the TV camera mounted in the Thor has been transmitting data to the Cape, so that if by any chance the data capsule is lost, we will not lose all the information from the test flight. A second sphere inflation test is to be run before the first attempt to launch Echo II as a satellite will be made. I have already mentioned that Echo II will probably be the satellite used in the Project Rebound multilaunch test.

Turning now to the active-repeater program, the general configuration of an active repeater is shown in figure 6-9. The satellite contains storage batteries which are kept charged by the external solar cells. These are used to power the receiver and the transmitter. An antenna system consisting of two units, one for the Earth-to-satellite link and a second for the return link, is also necessary. Ground terminals with steerable, high-gain antennas and associated transmitters and receivers are needed to complete a point-to-point channel. With this statement of the general concept of the active repeater, let us look at the specific versions in the NASA communications systems program.

The Relay developmental spacecraft is shown in figure 6-10. This is the test model

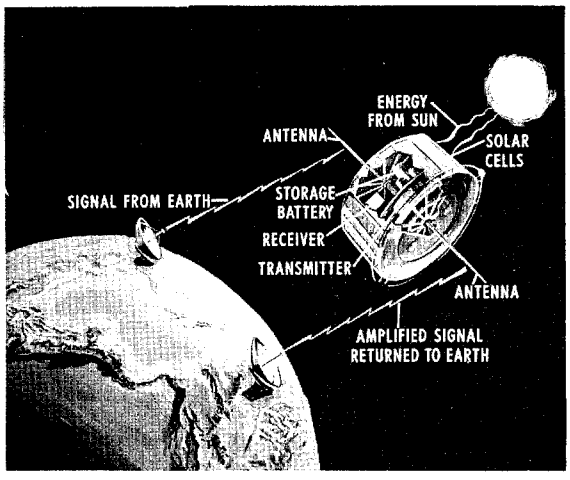


FIGURE 6–9. Active repeater satellite.

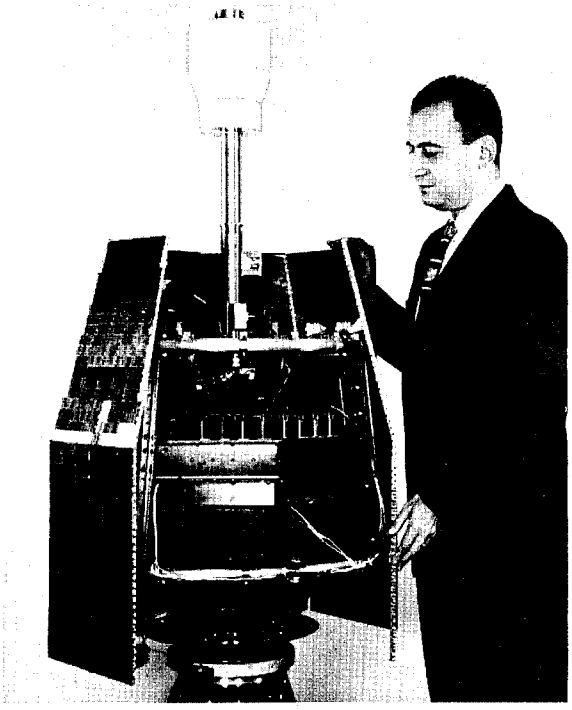


FIGURE 6–10. Relay spacecraft.

which has been built by the Radio Corporation of America, the prime contractor for Relay. An artist's conception of the Relay satellite in orbit is shown in figure 6-11. The shaded area indicates the antenna patterns of the Relay satellite. Notice that it is doughnut-like in form so that even though Relay spins on its long axis, some of its energy will be radiated toward the Earth. A magnetic at-

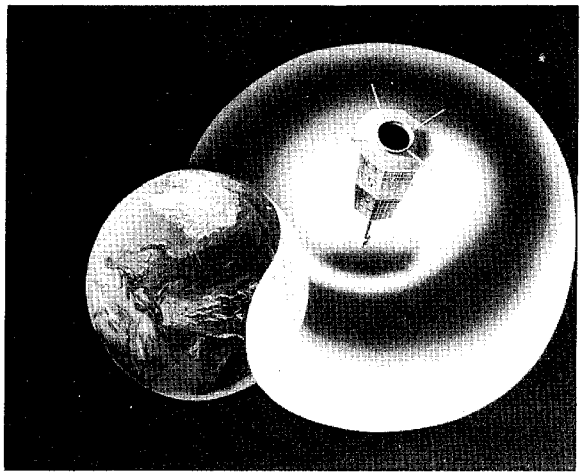


FIGURE 6–11. Relay spacecraft antenna pattern.

titude coil similar to that used in Tiros will be used periodically to adjust the orientation of this axis to a favorable position with respect to the ground stations cooperating in the Relay experiment.

NASA is cooperating with the American Telephone and Telegraph Company on the Telstar project. This project was initiated by AT&T and also has as its objective the investigation, in orbital flight, of the technical and operational problems of transmission of wide-band communications by an active communications satellite. The Telstar satellite which is being built by the Bell Telephone Laboratories is of a different configuration and has a number of technical details which differ from those of the Relay satellite. Figure 6-12 is a photograph showing the configuration of Telstar. It is also a spin-stabilized satellite such as Relay and will be placed in an orbit similar to that of Relay.

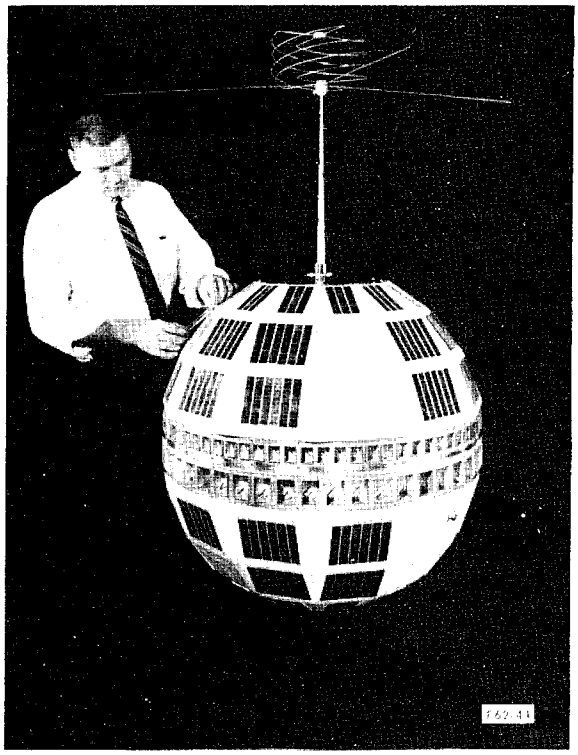


FIGURE 6–12. Telstar spacecraft.

The Bell Telephone Laboratories is building, at Andover, Maine, a very interesting facility for its ground systems support of the communications satellite. Figure 6-13 gives an artist's view of the facility which is now virtually complete at that location. You will note that a large horn type of antenna is contained within a flexible radome. The radome is to be 210 feet in diameter. NASA will use this facility on a contract basis for its Relay program. NASA will also provide for its own purposes two smaller antennas and ground communication stations which will be used in checking out the Relay system performance. These will probably be located at the Goldstone Facility in the Mojave Desert of California and at the Wallops Station on the Eastern Shore of Virginia.

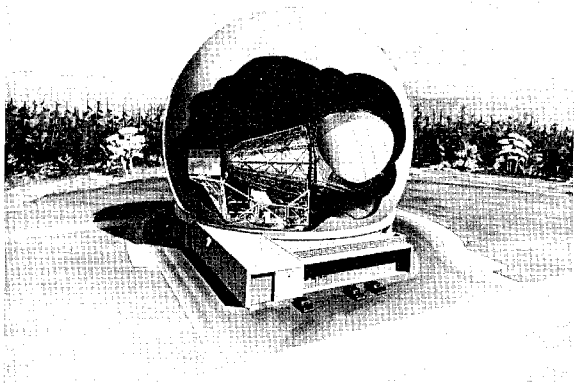


FIGURE 6–13. Artist's view of the AT&T Andover facility.

Both Relay and Telstar have already given rise to a great deal of international interest, and NASA has entered into agreements for experimental work using the Relay satellite with Great Britain, France, Germany, and Brazil. Agreement has recently been reached with Italy. Discussions with other countries have taken place, and it is expected that additional agreements will result. At present, the stations which are preparing for the Relay operations are shown in figure 6-14.

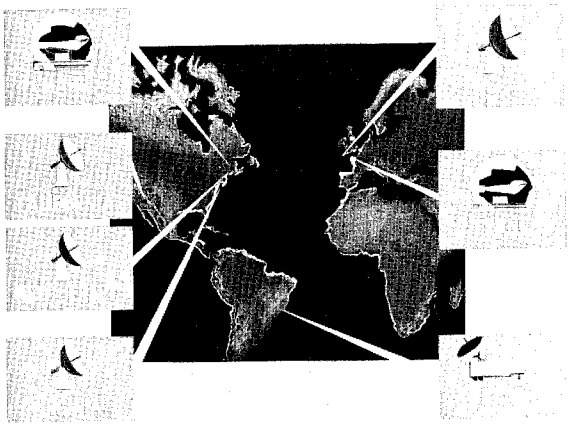


FIGURE 6–14. Relay ground stations.

Those in Maine, England, and France will also take part in Telstar tests.

The third active satellite project in our present program is Syncom, which is being built by the Hughes Aircraft Company. This is NASA's initial effort directed to the development of the synchronous satellite. Its objectives are to provide experience in using communications satellites in a 24-hour orbit at the earliest possible time, to develop the capability of launching satellites into the 24-hour orbit using existing launch vehicles plus additional "apogee kick" rockets, and to test the life of communications satellites components at the 24-hour-orbit altitude. An artist's conception of the spacecraft itself is shown in figure 6–15.

The conventional components, the solar cells for power supply, the antennas, and the drumlike structure, can be seen. The interesting part here is the addition to the spacecraft of the apogee rocket motor, the control jets for orientation and positioning,

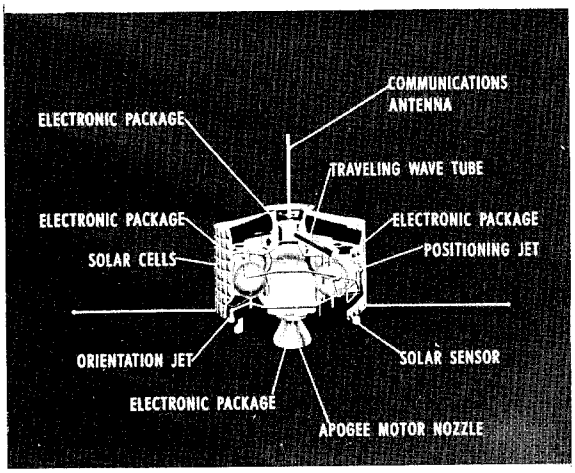


FIGURE 6–15. Syncom spacecraft.

and solar sensors. The traveling-wave tube is a particular type of electronic tube used in the transmitters of the three active satellites because of its excellent performance characteristics. It is particularly useful when a wide range of frequencies is to be amplified as is the case here. The way in which it is intended to place the Syncom satellite into a satisfactory synchronous stationary orbit at an altitude of 22,300 miles may be outlined as follows. The initial injection of the satellite will be from the Cape into a very highly elliptic orbit. (See fig. 6-16.) The planned apogee of this elliptic orbit will be at 22,300 miles. As a result when the satellite reaches the apogee altitude, it will be at the desired

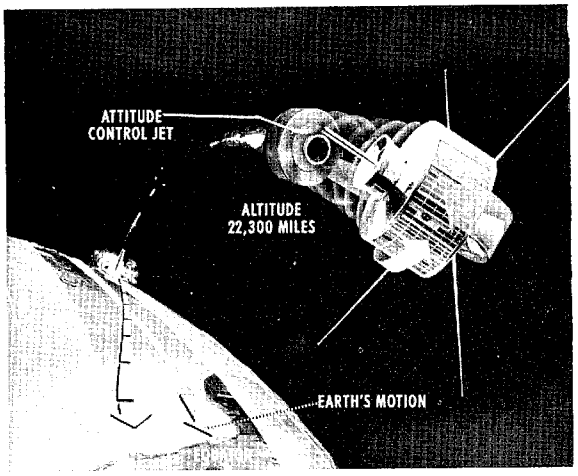


FIGURE 6–16. Syncom sequence, launch and attitude control.

altitude for synchronous rotation with the Earth. However, it will not have had enough energy imparted to it to stay at that point, and the internal apogee rocket must be fired to add the energy required.

Since the launching will take place from Cape Canaveral, we can launch directly only into an inclined orbit, as a launch into an equatorial orbit would require an extra velocity impulse at an angle to the original direction of motion. This is one of the constraints resulting from limited vehicle performance which we must accept at this time. When the satellite is separated from the lower stages of the Delta launch vehicle, it is spun about its axis and so it is rotating much as a gyroscope would rotate as it comes up to altitude. The gyroscopic effect holds the axis of the satellite in the attitude at which it was separated from the Delta booster, so that when, through either ground control or by proper timing, the apogee rocket is fired, the satellite will be injected into a circular orbit. At this time the attitude control jet in the end of the satellite can be actuated by ground control to provide a force to turn the satellite. The result of this operation is indicated in this view. The satellite then appears to be rotating on its axis like a wheel as it moves in its orbit.

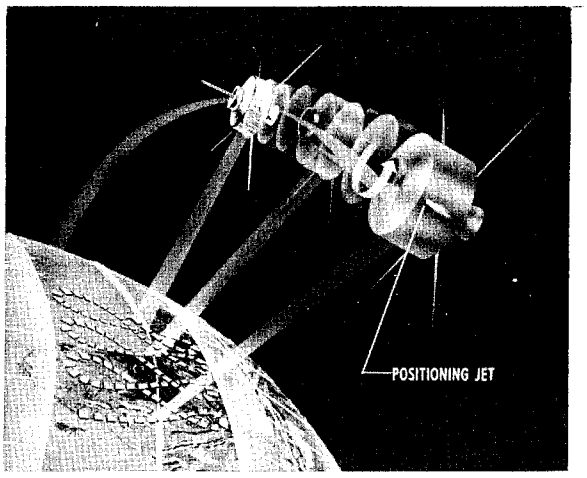


FIGURE 6–17. Syncom sequence, position control.

Figure 6-17 shows the satellite in its orbit above the Earth. I have already remarked that the orbit is inclined. It is more than likely that the satellite's speed in orbit will be somewhat too fast or too slow for an exact match with the Earth's rotation and it will tend to progress or retrogress around the Earth. A result of the inclination of the orbit is to make the point below the satellite trace a path resembling a series of connected figure eights as shown here. An additional element of ground control is then available. Data from the solar sensor are transmitted to the ground and there a control signal is computed which will activate the positioning gas jet in the side of the satellite. This force will slow the satellite down or speed it up in its orbit, depending upon the direction in which the jet is pointed when it is operated. This controllable jet can be used to reposition the satellite from its original injection point close to the African coast to a location somewhere over the Atlantic Ocean, where we would like to have it for communications experiments.

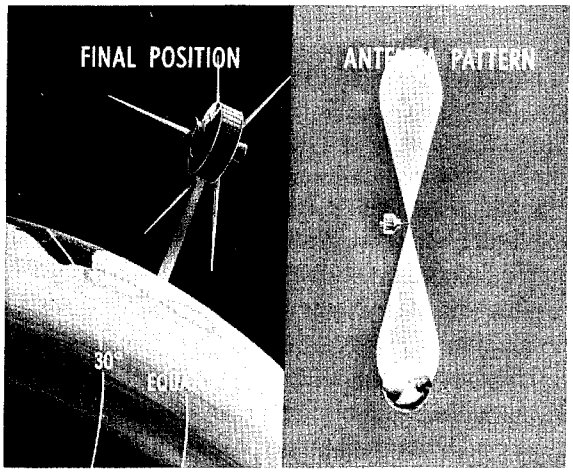


FIGURE 6–18. Syncom sequence, final position and antenna pattern.

Figure 6-18 indicates the final position of the Syncom satellite. It will still be rotating about its axis and will be moving back and forth in a figure-eight pattern about 30° above and below the equator. The antenna pattern of Syncom is indicated in the right-hand portion of the figure. It resembles that of Relay in that it is uniform around the satellite axis and so the rotation of the satellite will not affect its performance. With

this antenna pattern we should achieve effective coverage of almost all that portion of the hemisphere which can be seen from the satellite.

Where do we go from here? The steps proposed for the advanced satellite flight program which will follow Relay and Syncom are shown in the following table:

Systems	Launch vehicle	Weight, lb	Orbit		Channel	Stabilization	Percent of time available	Number of stations
			Statute miles	Shape				
Low altitude Relay	Delta	150	700 to 3,000	Elliptical	1 television	Spin	10	2
Advanced satellite	Atlas-Agena B	600	Up to 12,000	Circular	4 television	Earth oriented	25	Many
Synchronous Syncom	Delta	55	22,300	Inclined	1 telephone	Spin	75	2
Advanced satellite	Atlas-Agena B	500	22,300	Equatorial	4 television	stabilized	100	Many

Performance improvement of the active satellite systems is the primary objective. The first step in this direction is to take advantage of the growth that can come about as we move to larger launch vehicles. Relay uses the Delta vehicle. Delta will put a Relay satellite weighing 150 pounds into an elliptical orbit with 700-mile perigee and 3,000-mile apogee. With this type of orbit most of the data transmission can take place only when the 3,000-mile apogee is in the proper position with respect to the two terminal ground stations. The advanced low-altitude satellite we are proposing will use a larger vehicle, the Atlas-Agena B. Here we can expect to put a 600-pound spacecraft into a circular orbit at an altitude greater than 6,000 miles and perhaps as high as 12,000 miles. The advantages to be gained from these weight and orbit changes are shown in the table.

Insofar as the synchronous systems are concerned, Syncom also uses a Delta as a launch vehicle. The satellite weight, including the apogee rocket, is 125 pounds, of which the communications package itself is 55 pounds.

The Delta-plus-apogee-rocket combination can be used to get the 55 pounds into a 22,300-mile-altitude inclined orbit. By changing to the Atlas-Agena B we expect to bring the weight of the communications package for the advanced systems up to about 500 pounds and at the same time should have enough booster performance to get a truly equatorial orbit at 22,300 miles altitude.

The preceding table shows that the Relay satellite is designed to handle a single TV channel. Relay is spin stabilized and, with the presently planned orbital altitude, only about 10 percent of the time in orbit is usable for communications between the two major terminal points. Also, Relay is essentially a two-station system. By two-station I mean that the system capacity is limited because communications can be passed back and forth only between a single pair of stations. Actually, a number of telephone conversations could take place at the same time, but they all would have to be routed between the two terminals that were selected for the given operating period. As we develop more advanced techniques for application to the low-altitude system and change to the larger launch vehicle, it is our objective to bring the capability of the system to that shown in the table for the advanced satellite. That is, we hope to increase the capacity to four TV channels or the equivalent in telephone channels. We would like to have the satellite Earth oriented so as to take advantage of the improved performance of directed antennas. By increasing the altitude in orbit by several thousands of miles, the time available for transmission between a pair of typical sta-

tions should increase to 25 percent, and we would like to rework the electronic design of the satellite and the ground stations so that many stations can simultaneously have access to the satellite and thus can then transmit to any of the other stations with a minimum of constraints.

The Syncom plans now call for a capability of transmitting at least one telephone channel. This restriction on message handling capacity is a result of having to work with a very lightweight satellite. We therefore are concentrating our experimental effort on getting the satellite into the synchronous orbit and on testing out orientation and position control techniques. Syncom will be launched into an inclined orbit and will be available for transmission between stations only about 75 percent of the time, chiefly because of its motion to either side of the equator. It, too, is a two-station system. An advanced synchronous system should increase the message handling capacity to four TV channels. With increased vehicle performance, we should obtain the true equatorial orbit, and the satellite should be available 100 percent of the time. As in the low-altitude system, the system design will be modified to provide for multiple-station access to the satellite.

The problems in developing communications satellites are many, but they are being pursued vigorously. When Arthur C. Clarke, a British science writer, first proposed the use of satellites for communications in The Wireless World in 1945, 12 years before Sputnik I, he hypothecated the use of manned space stations for this purpose. If, indeed, it were possible to rely upon man to keep communications satellites working, many of our current problems would vanish. We cannot rely on man to repair failures in space. The satellites of the near future must be designed to exhibit reliability and dependability, unattended in the space environment, for many years if we are to have economically viable communications satellite systems. This is the problem and it should not be underestimated, for the rewards are great. We shall see demonstrations of transatlantic television and telephone via satellite this year, but there is still much to be done. It takes time to develop systems which can survive unattended for years in the somewhat hostile environment of space, of which we still have much to discover.

7. Tracking and Data Acquisition

By EDMOND C. BUCKLEY, *Director of Office of Tracking and Data Acquisition, NASA*

Mr. Buckley was previously Assistant Director for Space Flight Operations.

Reporting to the Associate Administrator, Mr. Buckley is responsible for planning and directing the use of support systems for space research activities, including global tracking stations, data acquisition systems and networks, ground communications networks, and launch site instrumentation.

Born in Fitchburg, Massachusetts, in 1904, Mr. Buckley earned a bachelor of science degree in electrical engineering from Rensselaer Polytechnic Institute in 1927. He joined the National Advisory Committee for Aeronautics (predecessor of NASA) at the Langley Research Center in 1930. He was formerly Chief of the Instrument Research Division at the Langley facility, NACA.

Mr. Buckley is a member of the Instrument Society of America, is on the Steering Committee of the Inter-Range Instrumentation Group, and is vice chairman of the Space Flight Ground Environment Panel of the Aeronautics and Astronautics Coordinating Board.

Data Acquisition is the term used to cover the collecting on the ground of the very valuable data brought down by telemetering from the space vehicle. An explorer of days past had to return to civilization in order to report his findings for the benefit of mankind. Explorers of modern days, whether exploring the poles of the Earth, diving several miles into the sea, or climbing the highest mountains, are kept in close touch with the world or with their bases by proper communications. A deep-sea dive, such as the one made by Picard and Walsh to the 7-mile-deep Mariana trench in the western Pacific, can be terminated if an emergency arises; similarly assistance or advice can be provided as has been found necessary in various polar explorations. So, too, our space explorers, whether human beings or unmanned spacecraft, require continuous contact with, and support from, the Earth if the experiment is to be a success and if the new knowledge is to be recorded for use by scientists. The function of tracking and data acquisition is to provide the critical radiofrequency links that tie the spacecraft to the Earth and make possible the transfer of information between the hostile environment of space and the laboratory.

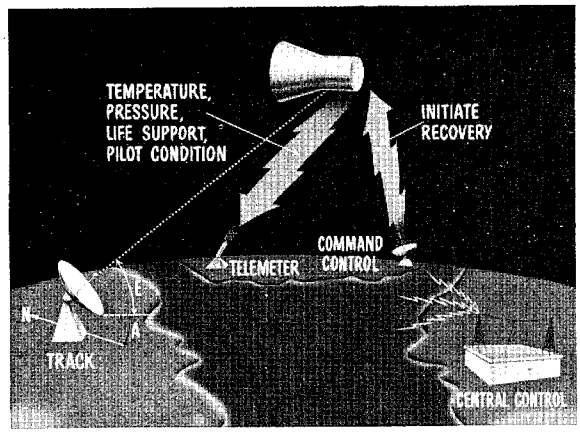


FIGURE 7–1. The four basic functions.

Figure 7-1 represents the nature of the support services provided to all the NASA flight programs. These services are tracking, telemetry, command, and control. *Tracking* provides information on the location of a satellite, a deep space probe, or a rocket vehicle. Location is important for an experimenter in that he must correlate an event measured by the spacecraft with, for example, its distance from the Earth or its

position relative to the Sun or the Moon. Location information makes it possible to establish a spacecraft's precise orbit for scientific analysis of the perturbing forces acting on the spacecraft in space. Location must be known for guidance evaluation and correction and also for reentry and recovery. *Telemetry* is the remote measurement of events and conditions, ranging from the astronaut's blood pressure to the strength of the lunar gravitational field. The flight instruments, called sensors, react to an event; this reaction is transformed into a coded electrical signal which is transmitted to the ground. There it must be received, recognized as an information-beam signal, recorded, decoded, and the resultant information made available to the experimenter in charts or tabulations. *Command* is the function of using a ground transmitter to send a coded signal to the space vehicle in order to initiate an event such as the starting of a camera, the firing of a retrorocket, or the cessation of transmission of data. *Control* is the ability to direct the operations of the spacecraft and of the entire network of ground stations in a flexible and responsive way to carry out the desired mission successfully. Some flights require that all information be gathered and centrally displayed in near "real time"; others require that each station be able to inform the next as to the predicted spacecraft position on a subsequent pass; others require control of telemetry sequences based on specific events such as solar flares or atmospheric storms. In the case of the weather satellites, proper controls tell them when to take pictures of storms and when to transmit the pictures to stations on the Earth.

The nature of these services is dictated by the character and type of mission. These may be divided into four categories as shown in figure 7-2: (1) the sounding rocket, (2) the Earth satellite, (3) the deep space probe, and (4) the manned Earth satellite. Each generates its own peculiar instrumentation requirements with respect to timeliness of data, distances of data transmission, and geographical coverage required in the collection of the data. These differences give rise to the different types of instruments used in each case. This will become clearer as the various networks used to support these missions are described.

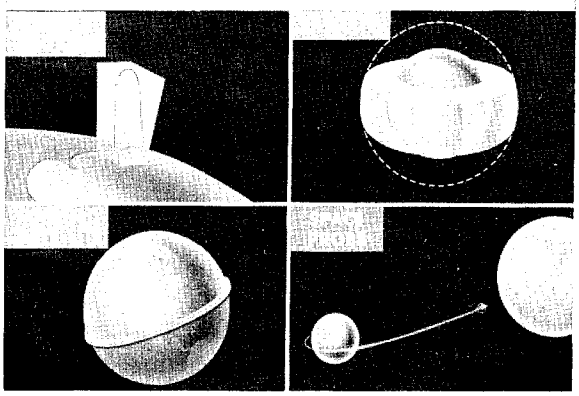


FIGURE 7–2. The four basic missions.

Figure 7–3 shows the locations of the electronic Earth satellite stations. The symbols on the chart represent minitrack stations, which are general purpose tracking sites with telemetry reception capability. The original concept of the minitrack system was that of a North-South fence from Maryland at 33° north latitude to Santiago at 33° south latitude. Later, as we began to put spacecraft into higher inclination orbits, including the 90° polar orbit, we added extra stations. We have greatly increased the ability of these stations to receive telemetering because of two requirements: first, the necessity to receive data from the apogee of elliptical orbits, and second, the need to receive more telemetering data from the spacecraft. This has resulted in the use of large 85-foot-diameter parabolic antennas at a few locations.

FIGURE 7–3. Earth satellite instrumentation.

The minitrack stations are located in Australia, South Africa, England, Newfoundland, Peru, Ecuador, two in Chile, and in the following states: Alaska, Minnesota, Maryland, Florida, and California (indicated by the crossmarks in fig. 7-3). Two 85-foot-

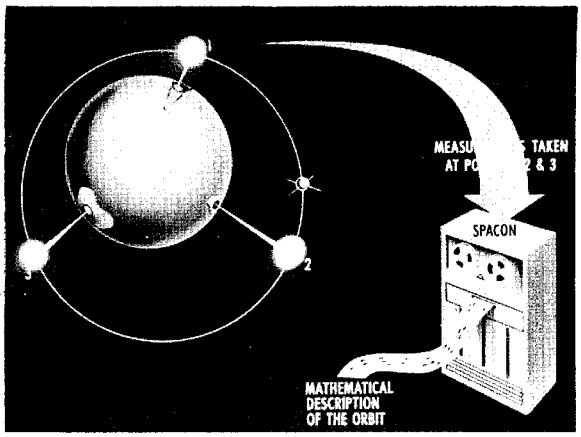


FIGURE 7–4. Minitrack.

diameter antenna sites are in Alaska and North Carolina (indicated by the solid circles in fig. 7-3). The unmanned Earth satellites are in orbit for days, months, even years. Because of this, we can afford to use what can be termed a "sampling" system for keeping track of the satellite while in orbit. Figure 7-4 illustrates how the minitrack system functions. Pictured on the left side of the figure is a South Polar projection of the Earth, indicating the minitrack stations in Australia, South America, and in the Republic of South Africa. Also pictured, is the fan-beam type of antenna pattern. The minitrack radiates no energy as does a radar. It simply has a receiving antenna whose reception pattern is formed in such a way that an extremely narrow fan results, and we know that the spacecraft has to be in this very narrow fan if its signal is to be heard. The position of a satellite, carrying a tiny transmitter, is determined with great accuracy as it passes through this narrow fan. The measurements, taken at points 1, 2, and 3, or for that matter, over any of the minitrack stations shown in the previous figure, are then transmitted to the Communications Center (known from its call letters as SPACON) at the Goddard Space Flight Center at Greenbelt, Maryland. Upon receipt at SPACON, these measurements are fed into the computers located at Goddard and a mathematical description of the orbit is produced.

We need this orbital data for three reasons: (1) we must have a record of just where the satellite was at any time in order to interpret the scientific data recorded by the telemetering system; (2) for operational purposes we need to have position data from which we can predict in advance where the spacecraft is going to be in order that we can point telemetering antennas in the right direction to pick it up; (3) finally, the orbital data, if adequately precise, have a scientific value all their own, because from them we can calculate the shape of the Earth more exactly and evaluate the effect on the spacecraft of the unknown forces which are pressing on it in space. The minitrack stations provide sampled data that gradually refine the description that can be made of the orbit. Since, however, this minitrack system requires on the order of hours to achieve this refined orbit, it can be appreciated why the minitrack system cannot support manned flights where the mission lasts for approximately 4½ hours only and requires immediate position information. This is why we have used highly precise radars in the Mercury network that can accumulate data very quickly.

The minitrack network has another great advantage over radars. The stations do not have to be told exactly when and where to look for something. Their fans sit there passively as sort of gates in the sky and any vehicle with this tiny transmitter aboard sort of automatically reports as it goes by.

Figure 7-5 shows another method by which we obtain tracking information to establish the spatial position of the Earth satellites. This figure shows an NASA/Smithsonian Astrophysical Observatory Optical Tracking Network. It consists of 12 specially designed satellite tracking cameras known as Baker-Nunn cameras. A picture of the Baker-Nunn camera is shown in the upper left-hand corner of this figure. It has a three-axis mount to permit it to point in any direction. In the upper right-hand side of the chart is a facsimile of the kind of picture this camera takes. The dots on the dark background

FIGURE 7–5. NASA–SAO optical tracking net.

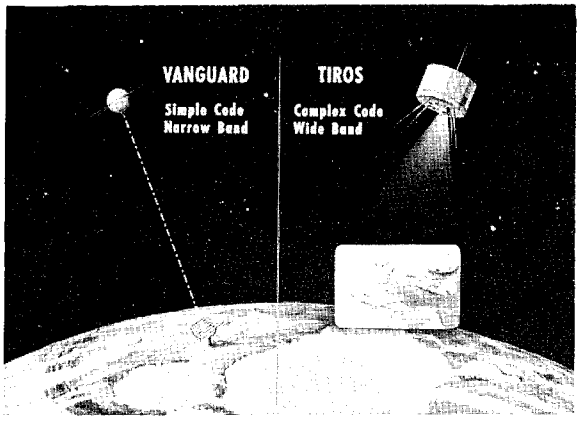


FIGURE 7–6. Growth in data requirements.

represent the light from stars, shown in this figure as the Big Dipper. The traces are made by the satellite moving across the star background. This trace is divided or cut up by the "chopping" action of a timed shutter. At any point on one of the segments, the angles between the stars and the satellite can be measured to fix the position of the satellite at that particular time. The map shows the locations of these cameras distributed around the Earth between latitude 33° N and 33° S and all at places of good seeing. Cameras are currently the most accurate method of fixing the position of a satellite in space. The positional fixes of the orbits derived from these cameras are the standards we use to determine the accuracy of our electronic methods of tracking. These cameras, however, can only be used at dawn and dusk and, of course, only in clear weather, and are limited to close-in satellites. Both of the foregoing systems are general purpose; that is, they can be used by any or all satellites. During the entire useful life of the satellite we keep track of it.

Figure 7-6 illustrates the growth in data requirements for unmanned satellites, from the inception of the Vanguard to the present-day Tiros satellite. Tiros transmits at 500 times the Vanguard data rate. In order to handle the higher data rate, we had to turn from the relatively simple and low-gain antennas used for the Vanguard satellite to antennas of the TLM–18 type which are 60 feet in diameter and operate on frequencies in the 200-megacycle region. The significance of this, of course, is that we are getting away from simple exploration and going to a phase where our vehicles allow a much more thorough scientific exploration. The next generation of scientific and weather satellites, such as Orbiting Astronomical Observatory (OAO) and Nimbus, have data-rate requirements that are up to three times greater than those of Tiros.

To meet this increased flow of data, antennas of the type shown in figure 7-7 must be used. This is a photograph of the large data receiving antenna which is being installed in Alaska as indicated on the map which showed the minitrack locations. The antenna is a carefully built parabola, or dish,

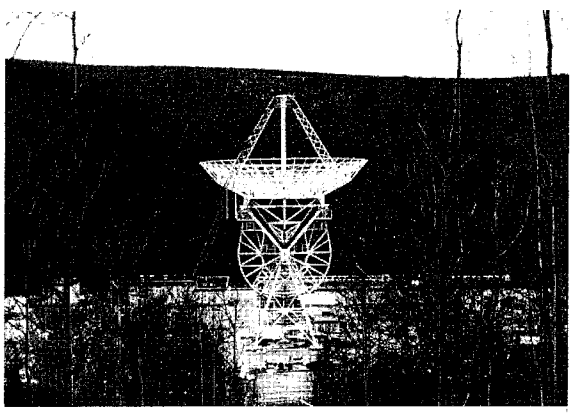


FIGURE 7–7. Alaska data acquisition facility.

85 feet in diameter, covered with a precisely positioned fine-wire mesh. This acts as a high-quality reflector for the radio signals and focuses them on the very sensitive receiving apparatus mounted above it at the juncture of the quadripod support. The parabola is mounted on an axis that allows it to tip back and forth. All this assembly is mounted on a second axis which allows it to turn in a direction that is right and left in the picture. This mount is designed to let the antenna point almost from horizon to horizon in any direction without mechanical interferences while following a satellite. It operates on frequencies in the 1,700-megacycle region to accommodate the requirements of the OAO and Nimbus satellites.

As can be seen in the photograph, the antenna is located in a wooded valley, or bowl, in order to minimize any possible interference from radio stations, industrial or mining machinery, or from transmission lines.

In figure 7-8 examine the coverage requirements for 85-foot antennas generated by the large scientific satellites, and consider a case

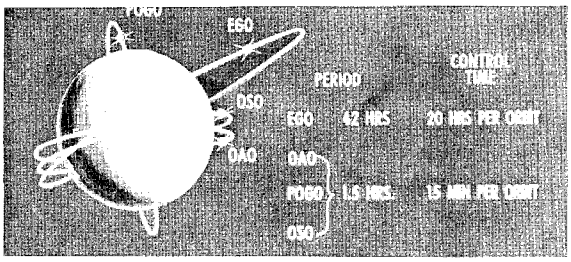


FIGURE 7–8. Data requirements from large satellites in 1964.

that will be very real by the year 1964. Seen circling the Earth are the Polar Orbiting Geophysical Observatory (Pogo) in a polar orbit, and the Orbiting Solar Observatory (OSO) and the Orbiting Astronomical Observatory (OAO) in their near-Earth low-inclination orbits. Also note the Eccentric Geophysical Observatory (EGO) in its highly eccentric orbit. Listed on the right side of the figure are other particulars of the orbit and data collection requirements for these missions. EGO makes one orbit every 42 hours. To fulfill the experimenters' objectives requires 20 hours of data collection per day. The others have a period of 1½ hours. For these, the experimenters' objectives can be realized by collecting data for 15 minutes out of every orbit. These data reception times represent a compromise between the data coverage that is technically possible, regardless of cost, and the data coverage below which the experiments with the satellite program would simply not be justified. This compromise is the result of very detailed study conducted by the tracking and data acquisition engineers and the scientists who understand the nature of the experiment and the results they hope to achieve from the experiment planned for the satellites. Knowing the amount of data that must be collected and knowing the locations on the Earth where these data can or must be received, it is next important to determine where these new facilities should be located. The facilities required to support the scientific satellite programs just mentioned are shown in the following table; projects are listed on the left and the facilities, on the right.

Project	Facilities	
EGO	Rosman, N.C.	Far East
OAO	Rosman, N.C.	Far East
Pogo	Rosman, N.C.	Far East
OSO	Rosman, N.C.	Far East

The Rosman, North Carolina, station is needed for all the programs. To complete the ground facilities in support of the EGO and the OAO, a Far East station is also needed. It will provide coverage for one-third of the orbits of OAO and will essentially double the coverage on EGO over that of the North Carolina station by itself, which is necessary if we are to meet the requirements of 20-hour-per-day data collection. The station in Alaska to complete the support for Pogo is, of course, already available. The second station to complete the support for the OSO is also required in the Far East and will be the same station required by EGO and OAO. In this manner the needs of the four programs, from the point of view of locations, can be satisfied with a single new location in the Far East. The multiple use of the stations

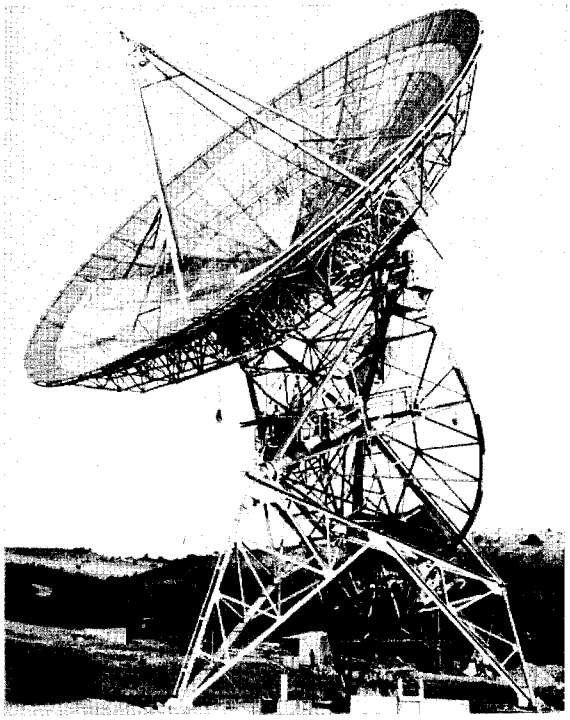


FIGURE 7–9. Deep space net. Station locations: Goldstone, California; Woomera, Australia; Republic of South Africa.

and the need for geographic distribution are also illustrated.

Figure 7-9 introduces the deep space network. The three stations listed use these specially mounted 85-foot-diameter antennas both to receive data from the spacecraft and to determine its location in space. They are polar mounted which provides better tracking of vehicles far out in space since primary antenna motion is required in only one axis.

Figure 7-10 illustrates the coverage provided by the deep space net after a space vehicle has reached approximately 20,000 miles. The trajectory of a typical Ranger mission during the first 20 or so hours on its way to the Moon is plotted in the figure.

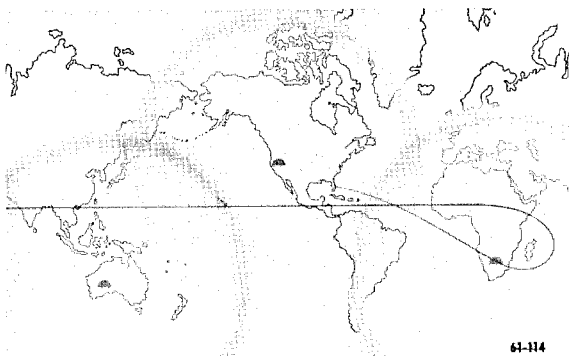


FIGURE 7–10. Deep space station coverage.

After launch at Cape Canaveral, the Atlas expends itself and the Agena stage injects itself and the Ranger space probe into a 100-mile-high Earth orbit known as a parking orbit. The Agena stage fires again in the Ascension Island area and starts the Ranger on its lunar trajectory. The point where the trajectory seems to reverse itself is where the spacecraft is so far out that the Earth rotates under it faster than it circles the Earth. Therefore, its relative motion with respect to the Earth is in the opposite direction, causing the apparent looping back in the flightpath. At the tip of this apparent loop, the vehicle is at an altitude of approximately 19,000 nautical miles. The station in South Africa has acquired the probe and follows it into its coverage overlap area where California picks it up and commences to track and receive data. The probe is about 50,000 miles in altitude by this time. The California station follows it into the overlap area where Australia takes up the track and data collection function. And so goes the steady following of the probe as it moves toward its goal and the Earth rotates under it with our instruments keeping track of where it is, what it is doing, and when it is accomplishing its objectives.

The Jet Propulsion Laboratory (JPL) in Pasadena, California, has the mission within NASA of the lunar and planetary scientific exploration program and operates the deep space net. The computation and communications subcenter for these three stations is located at JPL. In addition to the reception of very faint signals from far out in space, these specialized antennas allow control to be exercised over the spacecraft during flight; figure 7-11 demonstrates one type of control. The spacecraft is proceeding as indicated by the short-dashed-line arrow. The mission objective is for the spacecraft to land on the Moon. However, it may be determined from tracking data that if it continues on its present course it will miss the Moon; it will pass ahead of it. Therefore, the course must be changed if we are to reach the point of

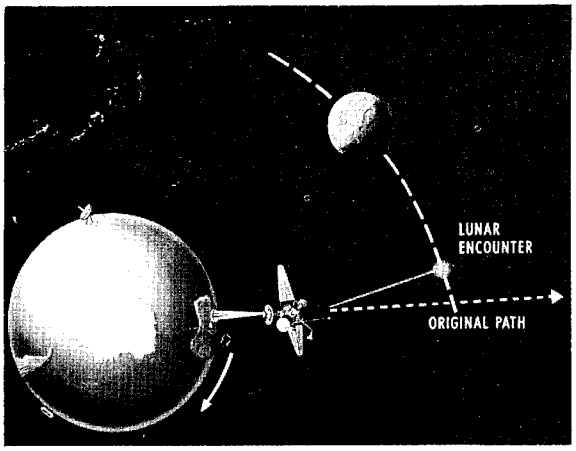


FIGURE 7–11. In-flight control.

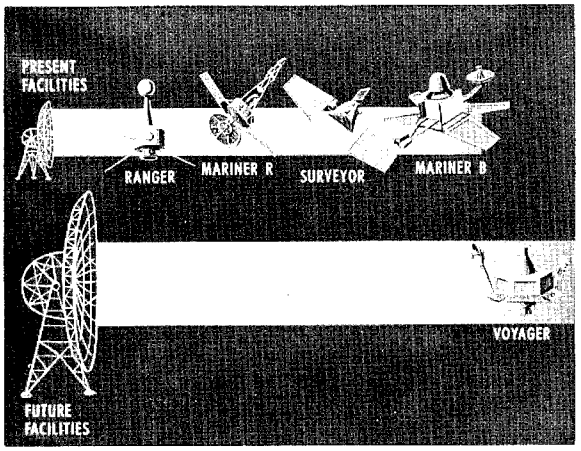


FIGURE 7–12. Deep space data requirements.

lunar encounter at the right moment. The amount of this required change is computed and sent to the spacecraft as a command signal. Its flightpath is then changed and aimed along the solid line, thus effecting a lunar landing. In a recent Ranger firing toward the Moon, the Atlas failed to shut off at the proper time and the correction incorporated in the spacecraft was not enough to correct the flightpath so that the craft would intersect the Moon in space and time. The spacecraft passed ahead of the Moon. It must be pointed out that the derivation of these measurements requires observation of the spacecraft by these deep space net stations over long periods of time. We do not want to lose contact with the spacecraft because it is on the other side of the Earth. This is why we have three of these stations located about 120 degrees apart around the Earth: in the United States, in Australia, and in South Africa. As a result of the Earth's rotation, one or another of these stations can observe the spacecraft in flight at all times. As the spacecraft goes below the horizon for one station it rises above the horizon for the next station. At times such as when a vehicle is close to an encounter with the Moon or a planet or when the vehicle is transmitting after a landing, we will have to keep a continous watch on the vehicle; we will want to listen to it continuously. This will, of course, require the full and continuous attention of the station.

Our present facilities, as shown in figure 7-12, can only support the lunar and planetary flight program through the early Mariner B launches, starting in 1964. Later spacecraft will transmit much more information back to the Earth. They will carry far more instruments of greater complexity resulting in more information being transmitted per unit of time, and we will need new facilities capable of handling this increased information flow. This increase in information transmission and reception and the fact that the 240-foot antenna can provide the ground equipment for Voyager are represented pictorially in figure 7–12. This point may be further illustrated in figure 7-13 which shows that, as time goes on, our reception capability must be increased to satisfy the growth in mission requirements. The chart shows that these requirements increase by a factor of 200 over

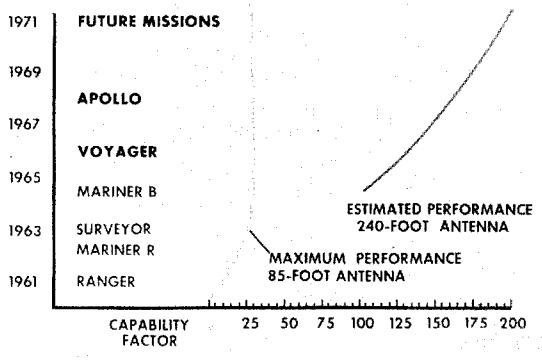


FIGURE 7–13. Deep space antenna system capabilities.

the decade. Note that during the next few years we expect to reach the maximum capability (an increase by a factor of 25 from the present) of the 85-foot antenna system. The 240-foot antenna system, however, should provide a capability adequate to meet the requirements of future spacecraft, including live television from the Moon.

Figure 7-14 is a pictorial representation of this very large instrument. The actual details are, of course, still in the design stage, but we have determined its approximate size (it

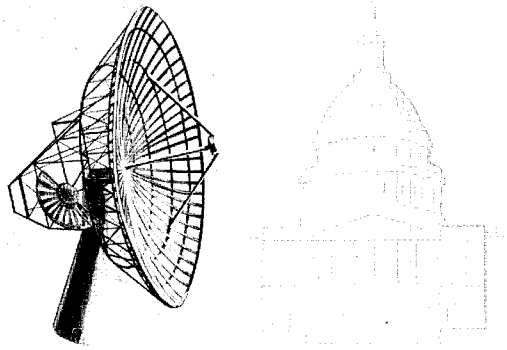


FIGURE 7–14. Advanced antenna, 240-feet in diameter, compared with Capitol building.

will stand about as high as the Capitol building) and its overall configuration. We hope to build this one at Goldstone, California, the master station of the Deep Space Network. You will notice that it is very similar to our existing smaller antennas except in size. Other than size, the real differences are the improvements in the electronics, the surface accuracy, and the servosystems performance expected with this large instrument. In our planning we are drawing heavily in this area on our experience with the existing 250-foot dish in Manchester, England, and the new 210-foot dish in Parkes, Australia.

Figure 7-15 illustrates some secondary or by-product types of information obtained when we attack tracking and data acquisition problems. For example, the Jet Propulsion Laboratry recently conducted system tests of the deep space net. The primary objectives were to test several prototype pieces of equip-

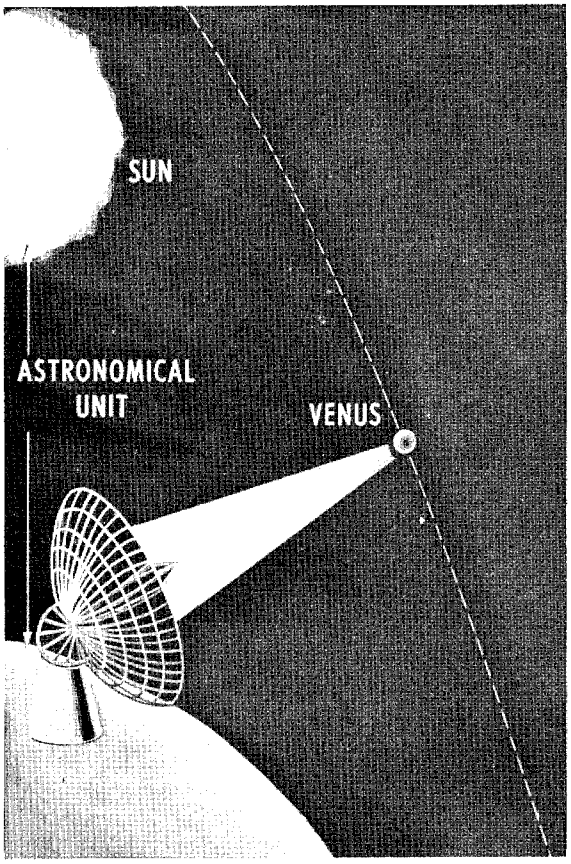


FIGURE 7–15. Deep space net system test. Primary objectives: operational testing of prototype subsystems; reliability and operational problem investigation. Secondary objectives: determination of astronomical unit more accurately; Venus investigation.

ment which had been developed by that Laboratory, and to test the combined system and its reliability. The Jet Propulsion Laboratory did this by setting up an experiment to track the planet Venus for an extended period before, during, and after its closest approach to the Earth in its orbit. The actual distance, when closest, was some 28 million miles. Of course, in tracking one of our spacecraft far out in space, we have some cooperation—the spacecraft is transmitting a signal to us. In the case of Venus, to get such cooperation, we would have to persuade the inhabitants to cooperate and maybe we will someday, or we would have to place a transmitter on Venus. Lacking any such cooperation, we used the planet as a reflector; we had to bounce signals off its

surface. This had been tried by other groups on the two previous closest approaches during the last 3 years, but the results had been questionable. It was felt that the successful use of all these newly developed and very advanced components in the day-after-day, week-after-week tracking of Venus at that distance would be a very rigorous test.

Scientifically, there could be some very important results. A better determination of the distance of Venus from the Earth and a better determination of the characteristics of the orbit of Venus around the Sun would provide a better knowledge of the astronomical unit, which is the mean distance from the Sun to the Earth—a basic yardstick for astronomers in their calculations of the spacing between the Sun, the planets, and other stars. Such a result would be of great importance in helping us come close to small and faraway targets in our planetary missions. Other by-products of such experiments in the future could be knowledge of the reflectivity and rotation of Venus, that is, the length of the Venus day. Since Venus is permanently shrouded in clouds, the astronomers have never seen the surface of the planet.

The experiment was most successful: an engineering success because the advanced systems and components were used to track Venus continuously and successfully day after day for over 2 months; a scientific success because the astronomical unit was established as 92,751,070 miles ±300 miles, which is an accuracy of three parts per mission. This is some 200 times better than it had been known before. To the people involved in the experiment, Venus somehow seemed far closer and more real as they kept in contact with it day after day for 2 months.

Other laboratories, including Soviet laboratories, attempted parallel experiments during this period of closest approach. The Soviets, after announcing a serious disagreement with our results, eventually announced their agreement with our values.

Figure 7-16 shows the network of stations used for Project Mercury, the manned orbital flights. The requirements that led to this network included a specification that there

FIGURE 7–16. Mercury tracking data acquisition net.

be communication with the capsule and reception of telemetering for 5 minutes out of every 15. A vital requirement was the need to provide a clear-cut assurance that the capsule was in an acceptable orbit before it reached Bermuda or else it had to be brought down near the Canary Islands. The number of tracking radars and the quality of tracking stemmed from the specifications as to the size of the recovery area into which the capsule must be brought on its return to Earth; that is, we had to know the orbit well enough to predict just where the capsule would land. Finally, there was the all-important requirement that all data from the tracking and telemetering stations be continously displayed at the Mercury Control Center in Florida. All stations, therefore, had to be tied together with a real-time communication system. This is the first truly global network, providing a belt of stations circling the entire world. Because the plan for the initial series of flights was for only three orbits, it would be only 3 hours from the first pass over a station such as Bermuda to the third pass over the station. In this short time minitrack and Baker-Nunn stations were of no use as the Earth would not turn enough during three orbits to bring them into a usable position. In addition, there are certain interesting policies that affected our procedure. We wanted to avoid endangering the Mercury experiment with an experimental support system; that is, we wanted to

use nonexperimental instrumentation. We wanted to emphasize duplication and reliability because of the *manned* flight aspect far more than we did for our unmanned flights. And, finally, we had the need to checkout this global system of stations, to check out all functions at all stations in a fashion parallel to the meticulous checkout and countdown at the launch site.

The stations are shown as dots in figure 7-16: Bermuda, a ship between Bermuda and Africa, the Canary Islands, Nigeria, Zanzibar, a ship in the Indian Ocean, two stations in Australia, Canton Island in the middle of the Pacific, Mexico, White Stands, Corpus Christi, and Eglin Field tracked the first two orbits; Hawaii and the Pacific Missile Range in California tracked the second and third orbits.

Figure 7-17 gives some idea of the desired and of the emergency recovery areas which placed requirements on the tracking and computing. In the case of the deliberately initiated reentry and recovery, the tracking provides the information for the time for firing of the retrorockets to set the capsule down where desired. In any case, when the capsule starts down X or Y, we track.

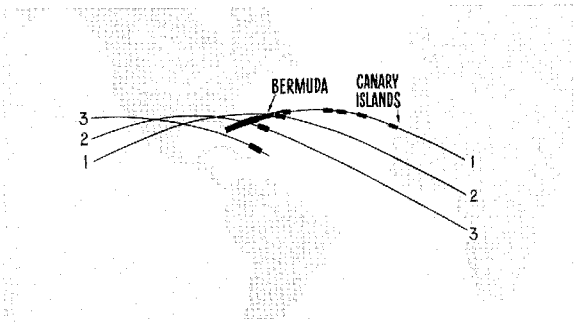


FIGURE 7–17. Project Mercury recovery areas.

Figure 7-18 is a foreshortened representation of the various stages of the Mercury-Atlas 6 flight. The tracking requirement through launching, staging, and injection was most severe—in order to provide the vital "go-no go" information; then there was the continuous tracking, telemetering, and communication during the three orbits, and, finally, the vital tracking during the return to Earth so that the capsule could be quickly picked up by the waiting ships.

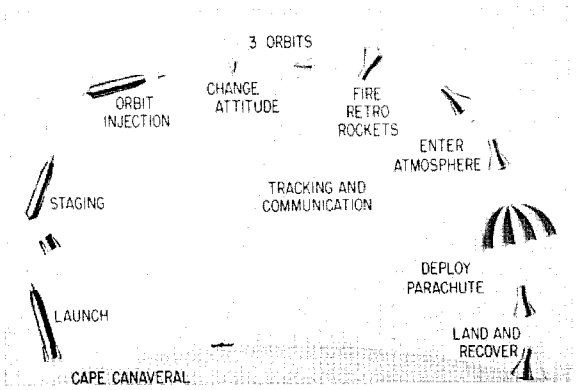


FIGURE 7–18. Project Mercury flight projectory.

Figure 7-19 recalls the intense few minutes during the launch phase: the agonizing wait until we were sure that the astronaut was in orbit and the tremendous thrill as he was picked up by one station after another for the dramatic 5 minutes that each station could talk to him.

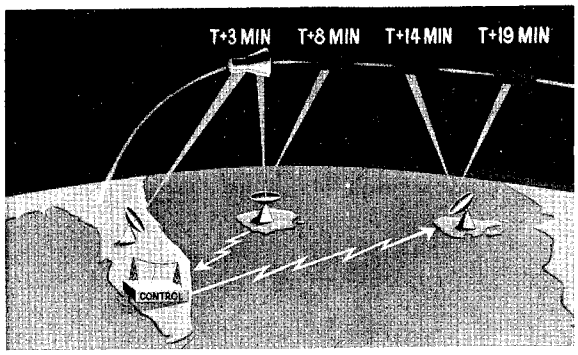


FIGURE 7–19. Initial flight of Mercury spacecraft.

The mission nerve center (fig. 7-20) on the ground was the Mercury Control Center in Florida which knew exactly where the capsule was at all times; the Center had a complete digest of the telemetering as measured at each station and could talk with Astronaut Glenn a fair part of time as easily as we can talk to an airliner between Seattle and San Francisco. The figure is an actual photograph of part of the display at this ground control center.

Finally, figure 7-21 portrays the few minutes during the descent of MA–6. A problem occurred because a small switch malfunctioned and the telemetered information left doubt as to the degree of attachment of the vital heat shield. Also, as is well known,

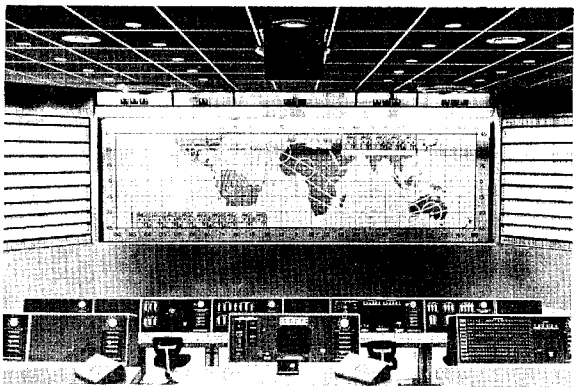


FIGURE 7–20. Mercury control center.

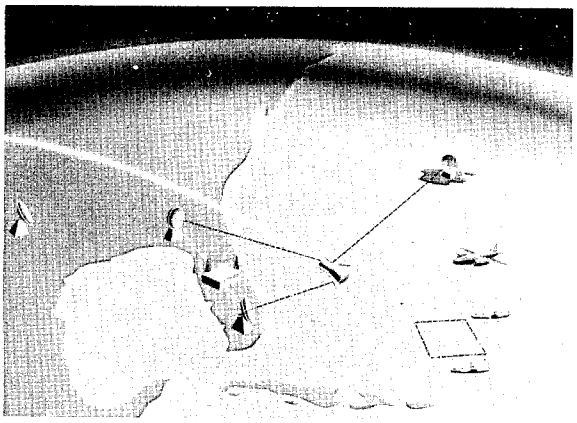


FIGURE 7–21. Descent of MA–6 spacecraft.

upon reentry into the atmosphere, the high speed and tremendous heat results in a blanket of ionized air particles surrounding the capsule which makes communication with the capsule difficult or marginal and we experienced this difficulty in the MA–6 flight.

The strain and suspense was almost unbearable but we had our reward for 3 years of planning as the capsule reported in, one station after another, in its progress around the world. The people at the overseas sites had a tremendous thrill as suddenly all the instruments on their panels came alive as the capsule came over the horizon. As the data from each tracking station were sent back to Goddard Space Flight Center we found we were predicting the path of the vehicle to closer than 1,000 feet. As a result, of course, the predictions of the recovery point, the point of contact with the Earth, were excellent.

Launch-area instrumentation is as follows:

(1) Tracking
(2) Telemetry
(3) Range safety (electronic and optical)
(4) Engineering sequential photography
(5) Frequency monitoring interference control
(6) Timing
(7) Geodetic control
(8) Communications

We use the Department of Defense launch ranges and their extensive instrumentation whenever possible. However, with the advent of the Saturn and the liquid-propelled Nova, and the implementation of the new launch area for the manned lunar landing program at Cape Canaveral, we are increasingly concerned with the requirements for launch-area instrumentation resulting from these programs. This involves some of the same types of radar and telemetering receiving equipment that are used in support of the spacecraft missions previously described. However, we are now introducing several additional terms. Range safety covers the devices, electronic or optical, that maintain a very close surveillance of the launch vehicle in the initial phases of its trajectory—those phases during which some failure or errant signals in the guidance system could return it dangerously to Earth. High-speed photographic monitoring of the various functions and phases of the launch is, of course, of major importance to diagnose troubles. Frequency monitoring and interference control equipment maintain surveillance over the immediate launch area to detect troublesome radio signals which could cause interference even to the extent of causing premature destruction of the rocket during its early flight. Finally, all stations,whether in the launch area or around the world, must be tied together through common timing and geodetic control systems as well as by communications.

Figure 7-22 is a diagram of our communication linkage that ties together our worldwide networks. These are combinations of telephone, teletype, and microwave installations usually rented from commercial common carriers. We use this communications

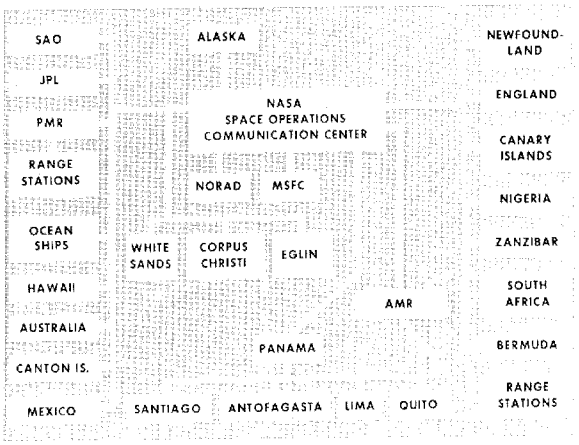


FIGURE 7–22. Communications network.

system to control the networks and for the transmission of data and information. Note that the Space Communications Operations Center, or SPACON, at Goddard, is the focus of the entire system. Owing to the extraordinary requirements of the communications system supporting Project Mercury, a separate explanation of it is worthwhile. Figure 7-23 reveals this special network. The key at the bottom of the two columns indicates that it is composed of radio, landline, and submarine cable circuits with "A" indicating alternate routes. If, because of ionospheric conditions, the normal path is "out of order", the station simply reverses its direction of transmission. For example, communications from Zanzibar normally come to SPACON via repeater circuits through Kano and London. However, if radio conditions are unsatisfactory for this route,

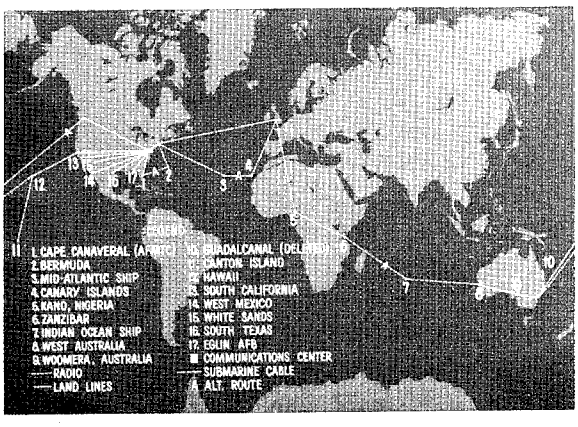


FIGURE 7–23. Mercury ground communications.

Zanzibar will communicate with SPACON via the Indian Ocean ship and Australia.

One other outstanding feature of the system is that nearly all of the stations can communicate with SPACON by voice as well as by teletype for control purposes and emergencies. Many people heard on radio and television the Mercury Mission Control Center in Florida talking with Astronaut Glenn when he was over the Canary Islands, over Australia, or over Hawaii.

Some of the statistics of the international participation in data acquisition are as follows:

Foreign stations located on contributed land	95 percent
Foreign stations managed by foreign nationals	60 percent
Foreign stations having some foreign national staff	100 percent
Foreign governments providing some financial support to the stations	45 percent

Note particularly that one-half of our overseas stations are managed by foreign nationals, and that foreign nationals are employed in some capacity at all our foreign sites.

These cold statistics, however, do not fully describe the wonderful cooperation that exists in those countries in which we have stations. We needed their help to do a more thorough job of collecting data from our scientific satellites; we needed their help if we were going to talk to Astronaut Glenn for 5 minutes out of every 15. So these stations in the clove groves of Zanzibar and in the peanut fields of Nigeria are just as much needed for the experiments as Cape Canaveral. The countries have come to realize the part they play and to take pride in it.

We have built no houses for our technicians; we do not furnish them with any special facilities. Our technicians send their children to local schools and live and work side by side with the local people. As a result we have made many real friends in these countries around the world.

These, then, are the facilities and networks by which we keep track of our spacecraft as they whirl through space; this is how we recover the unique and valuable data recorded by the vehicles, and how we give assistance to our modern explorers.

Session III

Chairman: George S. Schairer

GEORGE S. SCHAIRER, ***Vice President, Research & Development, The Boeing Company***

Born in Wilkinsburg, Pennsylvania, Dr. Schairer graduated with a B.S. degree in general engineering from Swarthmore, and received his M.S. degree from Massachusetts Institute of Technology. He was formerly with the Bendix Products Corporation and Consolidated Aircraft (now Convair). His former positions at Boeing include: Head of the Aerodynamics Unit; Staff Engineer, Aerodynamics and Power Plant; Chief of Technical Staff; Assistant Chief Engineer; and Director of Research.

In 1949 he received the Sylvanus Albert Reed Award of the Institute of the Aeronautical Sciences. In 1951 he was elected a Fellow in the Institute of the Aeronautical Sciences. In 1958 Swarthmore College conferred upon him an honorary doctor of engineering degree. In 1959 the American Society of Mechanical Engineers awarded him the 1958 Spirit of St. Louis medal.

8. Projects Mercury and Gemini

By ROBERT R. GILRUTH, *Director of the Manned Spacecraft Center, NASA*

Mr. Gilruth was formerly head of the NASA Space Task Group. He directs Project Mercury, this nation's initial manned space flight program.

Before his Space Task Group appointment, Mr. Gilruth was assistant director of the Langley Aeronautical Laboratory, National Advisory Committee for Aeronautics.

Mr. Gilruth was born October 8, 1913, in Nashawauk, Minnesota. He was graduated from the University of Minnesota with a B.S. degree in aeronautical engineering in 1935 and was awarded a master's degree in this field the following year.

In the early 1940's, Mr. Gilruth developed the "wing-flow" method of research, a system which uses the high-speed flow of air above the wing of a diving airplane to investigate high-speed phenomena on small research models. This concept provided information in the transonic speed regime for new aircraft and missiles, and it effectively filled the gap before transonic wind tunnels and free flight techniques were developed.

The transonic gap led to another concept by Mr. Gilruth: use of expendable free-flight rocket models which were instrumented to give a wealth of information. This concept was translated into the Pilotless Aircraft Research Division at Langley which he directed and the establishment of Wallops Station, Virginia.

Mr. Gilruth has been author or coauthor of approximately 50 research papers, and has received a number of high awards, including the NASA Distinguished Service Medal.

INTRODUCTION

One year ago this month, President Kennedy in a special address to Congress established manned lunar landing at a national goal. The President's statement followed by only a few weeks the flight of Astronaut Shepard in a Mercury spacecraft. Shepard's flight was repeated a few months later by Astronaut Grissom in a similar Mercury ballistic flight. Then several orbital flights were made—first unmanned then with a chimpanzee named Enos, and most recently by Astronaut Glenn in a three orbit flight February 20, 1962.

These flights of the last 12 months came after an intensive period of research and development which in 3 years produced a manned spacecraft, operational techniques, a world-wide tracking and instrumentation network, trained flight and ground crews, and military rockets adapted to manned space flight.

The management organization for this effort was the NASA Space Task Group at Langley Field, Virginia. In October 1961, it was decided to relocate this group at Houston, Texas, and to establish there the Manned Spacecraft Center for Projects Apollo and Gemini in addition to Mercury. At the present time both Project Gemini and Project Apollo are being managed out of Houston while the Mercury team is still at Langley Field and Cape Canaveral, Florida.

In this presentation I intend to review briefly the Mercury concepts. This is particularly appropriate because of its major influence in the Apollo concepts. Also the role of Project Gemini will be briefly discussed in the same context.

PROJECT MERCURY

Project Mercury is well known as this nation's initial manned space flight effort. It used, as basic concepts:

(1) The Atlas launch vehicle and its guidance
(2) A blunt nonlifting reentry body with retrorockets for recovery from orbit
(3) A parachute landing on water
(4) An automatic escape system (escape tower)
(5) A progressive buildup of tests.

Figure 8–1 illustrates the Atlas launch vehicle as well as the two other primary vehicles used in the progressive buildup of tests. On the left is shown the Little Joe solid-propellant vehicle which was developed for early flight tests of various Mercury systems, including the escape rocket, the parachutes, the environmental system, the structure, and the landing and recovery operations. In the center is shown the Redstone which was used to qualify the spacecraft and its systems further and for introducing man into the total system. This introduction of man into the system covered two areas: (1) the pilot aboard the spacecraft in order to determine and verify man's capabilities in space flight; (2) the crew in the control center in order to determine and verify their ability to exercise real-time control over the progress of the flight. The

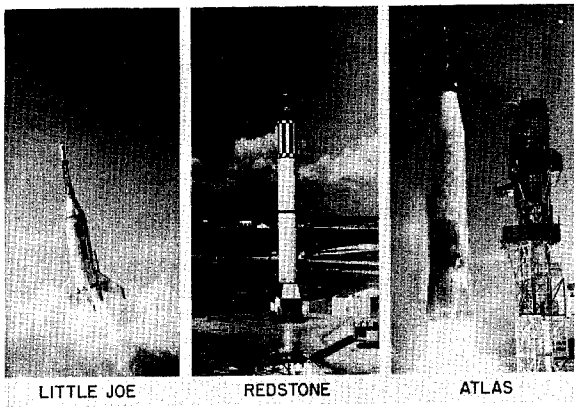


FIGURE 8–1. Project Mercury launch vehicles.

Atlas, on the right, is the vehicle used for orbital flights in which all the flight and ground systems were further qualified and which culminated in our successful manned orbital flight of February 20, 1962.

The parachute landing and the automatic escape systems are both illustrated in figure 8–2 which is a sequence of photographs from the Mercury-Atlas flight of April 25, 1961. The two left-hand photographs show the normal appearance of the flight at an early time. The next panel shows the escape rocket firing when a command destruct signal was sent to the launch vehicle because it was not following the prescribed trajectory. The third photograph shows the spacecraft well away from the exploding

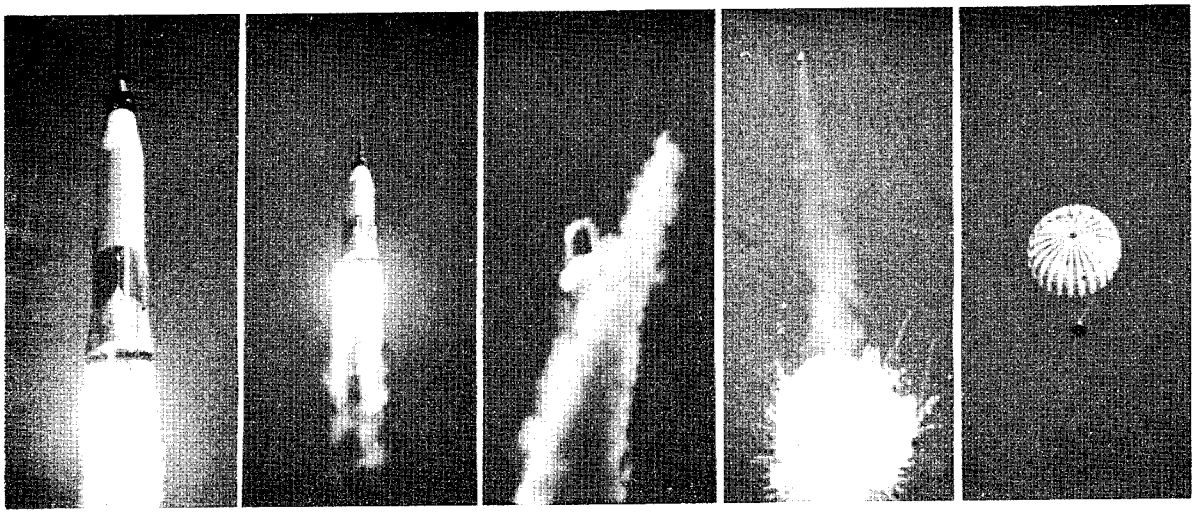


FIGURE 8–2. Escape sequence, Mercury flight 3.

launch vehicle, and the last picture is that of the spacecraft descending unharmed on the parachute. The same spacecraft was recovered and later used for the first Mercury orbital flight, MA–4.

Now, let us examine some of the basic problems encountered in Project Mercury. The basic technical problems were:

(1) Development of the spacecraft and its systems
(2) Pilot selection and training
(3) Flight control in real time
(4) Automatic versus manned control
(5) Procedures
(6) Launch vehicle-spacecraft integration.

Under spacecraft and its systems, we found in our initial research and development flight tests that the distribution and level of afterbody heating as shown by the wind-tunnel tests were not completely accurate and that there was a concentration of heating on the afterbody cylindrical section. To solve this the original thin refractory metal panels on the afterbody were replaced by thicker beryllium panels. This was a change that was necessary after one of our first flight tests. Another additional system that we had to provide for beyond the original concept was land-landing capability. We had to devise an impact bag to absorb the shock loads in certain conditions of abort wherein a land landing could occur.

Part of the problem with the spacecraft and systems lay in the area of maintenance and checkout. As shown in figure 8–3, the Mercury spacecraft is quite compact and the systems are relatively crowded. Generally, only one system could be reached at one time and in order to work on, or check, one systems others had to be moved and later rechecked. This naturally slowed somewhat the preflight preparations of each spacecraft.

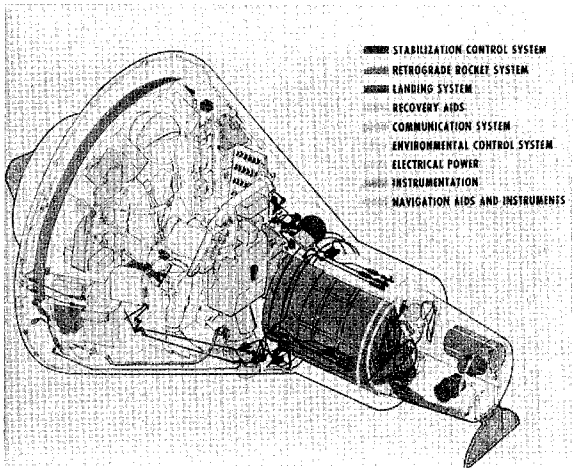


FIGURE 8–3. Interior arrangement.

Pilot selection and training was a problem, but I would say here that the original concept was very good; we are well satisfied with the techniques used and we are well satisfied with the criteria we established. We are using test pilots, experienced test pilots. We feel that this has been wise, and I would say that pilot training is one area in the future work in our space flight programs where we can come close to predicting lead time.

Then next item, flight control, is a whole story in itself. In lanuching a manned satellite the problem is a bit different from launching an unmanned one in that you want to know the orbit parameters and trajectory in real time and whether you are achieving a good orbit. This problem, of course, led to the development of a control center at Cape Canaveral and the world-wide tracking and instrumentation network. Basically, the problem is one of giving the flight director on the ground a picture in real time of the trajectory and also the behavior of the onboard systems. If an abort is indicated, he can so advise the pilot immediately; for example, if during lift up to 60,000 feet the pilot has not recorded that the systems are all good and if the flight director sees a loss of oxygen pressure, the flight director would command an abort. Another problem was that of automatic versus manned control. In Mercury we had to provide a completely automatic system because, of course, we had to fly animals first. At the same time we wanted to use as much of the same hardware as possible for the manned flights and we wanted to give the man as much override as possible to take advantage of the extra reliability he can provide. This gave us a problem of complexity which would not exist if we could have gone with a manned vehicle all the way.

Operating procedures were another problem. We were dealing with a new area of manned flight. For example, we had to develop procedures for use on the launch pad to rescue the man in case of trouble when we did not want to use the automatic escape system or if for some reason that malfunctioned. There are many, many details that must be worked out in a manned flight operation.

The last item is launch-vehicle–spacecraft integration. It would be hard to conceive of a simpler type of spacecraft than Mercury to integrate with a launch vehicle. It is symmetrical, small, and has no lifting surfaces and yet this is an area where we experienced considerable trouble. We had a structural dynamics problem between the spacecraft and the launch vehicle which was not anticipated as being a problem when we started.

To summarize our present position, we have taken Project Mercury from a concept to the actual hardware and trained flight and ground crews. The specification manned orbital flight occurred on February 20, 1962. Another such flight is now imminent. Manned flight in space has become, with President Kennedy's public announcement on May 25, 1961, a national goal. I would say also that acceptance of new concepts by both the public and by the technical community has been largely achieved. Many of these concepts are being used directly in Projects Gemini and Apollo.

PROJECT GEMINI

Project Gemini is an intermediate step between Mercury and Apollo, the manned lunar-landing project. The program is designed to extend our studies of man's capabilities in space to include long-duration missions of days rather than hours, to include studies of man's abilities to rendezvous in space by locating another vehicle, maneuvering it and his spacecraft until they are in close proximity, and then joining the two, to obtain space flight experience.

The Gemini spacecraft and launch vehicle are illustrated in figure 8–4. Basically, the spacecraft is quite similar in shape to the Mercury spacecraft but is enough larger to house a two-man crew in order to permit the long-duration missions. The launch vehicle is a Titan II second-generation ICBM propulsion unit which is being produced for Gemini by the Space Systems Division of the Air Force. The spacecraft will rendezvous and dock with an Agena stage launched by an Atlas similar to that used in Mercury.

In Gemini we are exploring advanced concepts in system engineering for space vehicles based on Mercury experience. Every effort is being made to reduce systems interfaces, to package systems to facilitate their development, access, and checkout, and to minimize problems of final assembly and

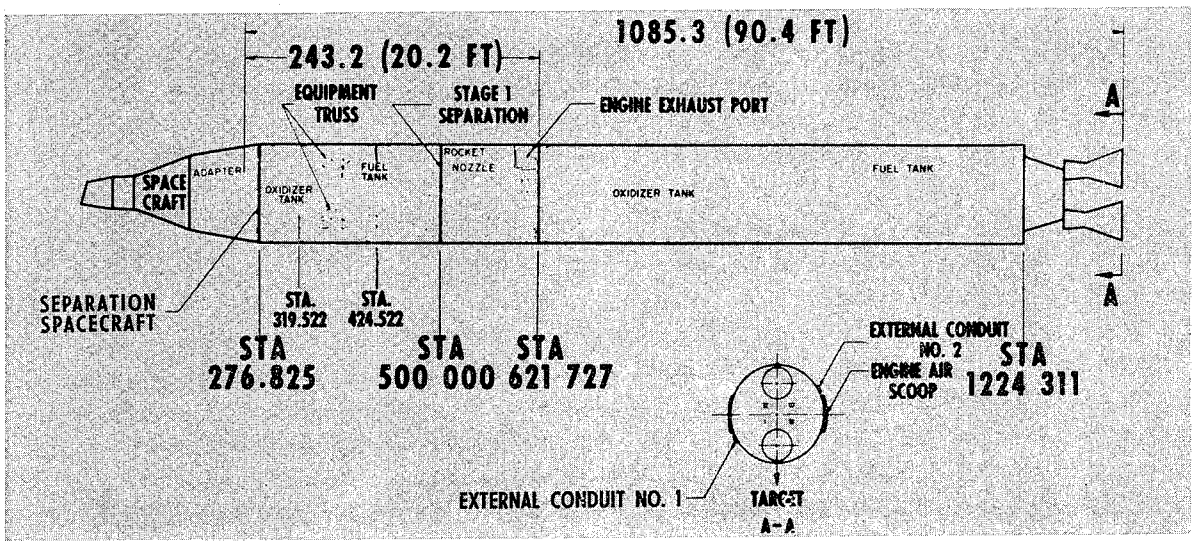


FIGURE 8–4. Gemini launch vehicle and spacecraft.

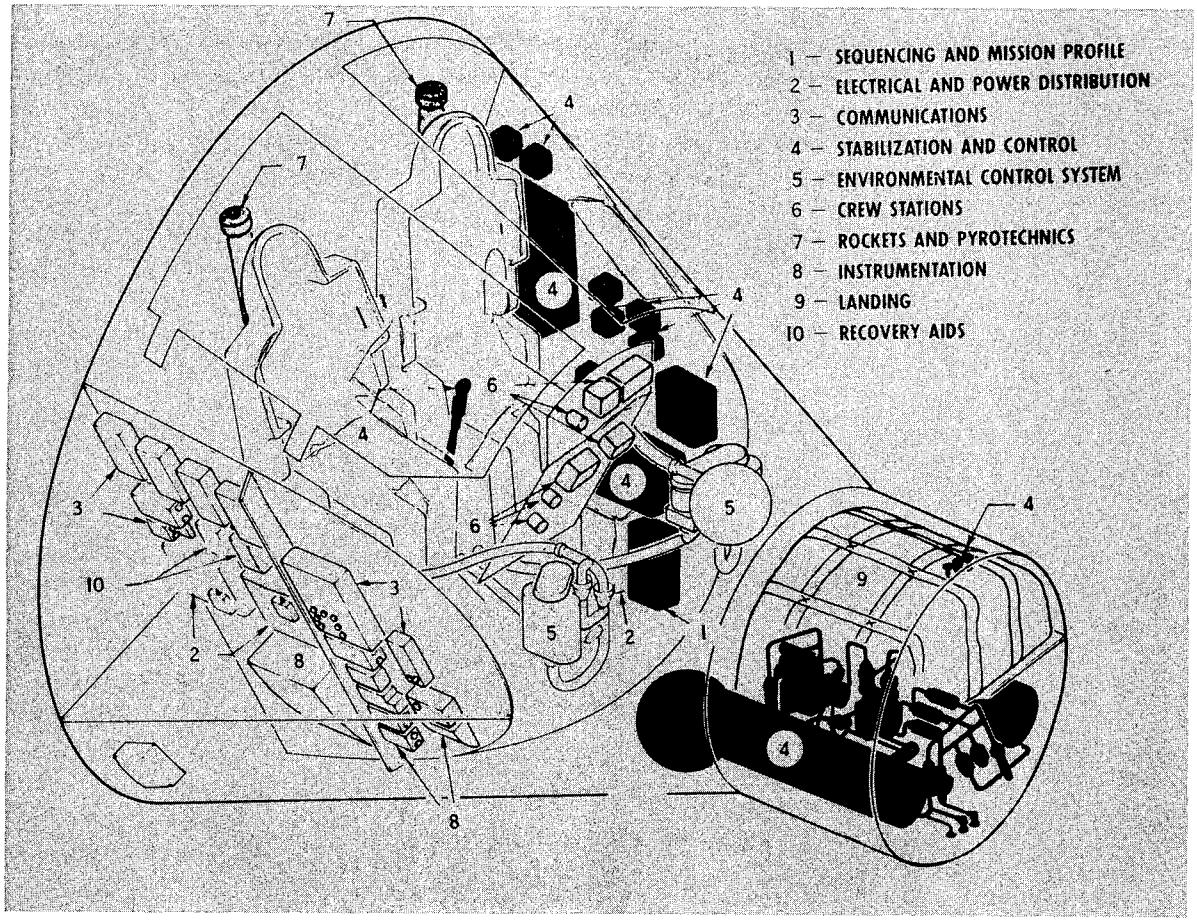


FIGURE 8–5. Interior arrangement of the Gemini spacecraft.

maintenance. The general interior arrangement is shown in figure 8–5. This experience should have a direct influence in Apollo design.

As indicated previously our problems in the area of pilot selection and training have not been great and are felt to be well in hand. No particular problems are anticipated for Gemini and, in fact, the provision for a two-man crew will allow more pilots to acquire actual space flight experience.

The problems of flight control in real time for Gemini should be intermediate in severity between those for Mercury and Apollo. Our experience with Gemini in controlling long-duration missions and in launching two large vehicles at precise time intervals as required for satisfactory rendezvous experiments should contribute both knowledge and actual operational experience that will be valuable to the solution of Apollo flight control problems.

Since our Mercury flights have shown that man can, indeed, operate satisfactorily in a space environment and since the second Gemini crew member will provide backup for the first, it is planned that Gemini will have less automatic sequencing of flight modes than did Mercury. Operations with man in the role of mode selector and acting as sensor operator in the rendezvous missions should again provide experience and knowledge that will increase our confidence in the role to be played by man in Apollo.

In the interim period between Mercury and Apollo the requirements to operate Gemini will do much to improve the development of operational procedures.

The problems of launch-vehicle–spacecraft integration between the Titan II and Gemini should be somewhat less than in the

Atlas-Mercury program. For one thing, we have the Mercury experience to guide our thinking. For another, Gemini will not have a long heavy escape tower on the front to change the structural vibration modes of the combined launch vehicle and spacecraft. This does not mean, incidentally, that we feel we no longer need a launch escape system. On the contrary, we feel we will need some means of escaping from a malfunctioning launch vehicle for at least several more generations of launch vehicles. On Gemini this escape means is provided by ejection seats, much like those used in present-day high-performance aircraft. Our studies to date show that such seats will be suitable for Gemini because of the much lower explosive yield of the storable hypergolic fuels used in Titan II as compared with the yield of the cryogenics used in other launch vehicles.

One last problem to discuss is that of land landing. We must consider both the ability to land the spacecraft safely on land rather than water and the ability to land at a preselected point on the Earth's surface. Both of these ends must be achieved before we can feel that the terminal phases of space flight have been satisfactorily developed. The achievement of point-landing capability requires that throughout the reentry phase of flight the pilot must be able to apply controlled amounts of lift to the vehicle to change its course in order to correct for navigational errors, winds, and so forth. In Mercury we felt that we did not need this capability since for an initial exploratory program we could satisfactorily account for dispersion from the preplanned landing point by disposition of the recovery force aircraft and ships. This course of action assured us of the quickest and simplest means of getting on with the job. In Apollo, however, this control of lift during reentry will be required to permit safe entry into the atmosphere at the very high speeds associated with the return from the lunar trip. In order to gain experience with this type of operation, the Gemini spacecraft will be built with an offset center of gravity so that it will tend to trim at some finite value of lift rather than at zero lift as in Mercury. The direction of this lift vector and thus the direction of the course corrections will be controlled by rolling the spacecraft with small reaction jets. With such control the Gemini pilot should be able to reach any landing point within about 100 miles to either side of the zero-lift line of flight and several hundred miles up or down range from the zero-lift landing point.

Even with controlled lift during reentry, if a parachute is used for the final stages of letdown, one still faces the problems of wind drift in the lower atmosphere, of avoiding local hazards such as rocks, cliffs, or trees, and of attenuating the final landing shock in any except a directly vertical landing. To provide solutions to these problems on Gemini we plan to use the Rogallo wing or paraglider illustrated in figure 8–6. Until

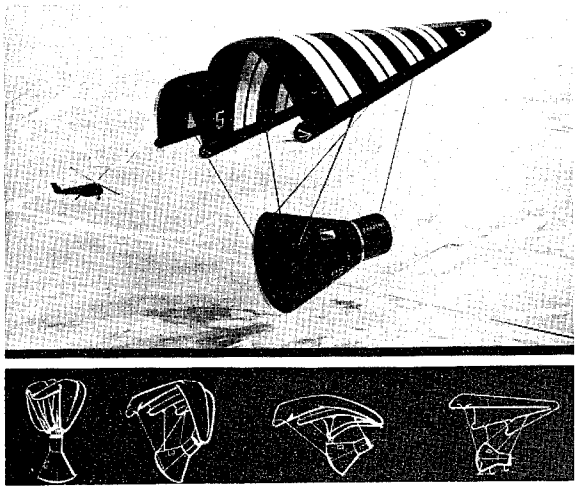


FIGURE 8–6. The Rogallo wing.

ready for use in the lower atmosphere, the wing is carried folded and uninflated in the small neck of the spacecraft. When the spacecraft has completed its entry and slowed to subsonic speed, the paraglider is deployed and inflated as illustrated in the small sketches on the lower part of the figure. The pilot then has the ability to glide to landing strips, counteract rather high winds that would blow a parachute off course, avoid local hazards, and finally flare out to reduce his vertical velocity to zero and land with a reasonable horizontal velocity on the skid-type landing gear shown in the small sketch at the far right.

CONCLUDING REMARKS

In summary, manned space flight has come into its own as a major part of our total space flight program.

Project Mercury has provided the initial step upon which our future program is being built. In bringing Mercury to this stage we have acquired a large fund of both general and detailed knowledge that should do much to help advanced manned flight programs. In particular, we feel that we have adequately demonstrated man's capability and utility in space flight and have given initial solutions to basic space problems.

Project Gemini is in the design and construction phase. It is planned to utilize the lessons learned in Mercury and to provide significant increases over Mercury in space flight duration and maneuverability. Gemini will provide flight experience and technical knowledge that will be applied to Apollo and to more advanced space flight missions.

9. Project Apollo

By GEORGE M. LOW, *Director of Spacecraft and Flight Missions, Office of Manned Space Flight, NASA*

Mr. Low was born in Vienna, Austria, in 1926. He came to the United States in 1940, and became a naturalized citizen 5 years later. He earned a bachelor of aeronautical engineering degree in 1948, and a master of science in aeronautical engineering degree in 1950, both from Rensselaer Polytechnic Institute.

Mr. Low joined the National Advisory Committee for Aeronautics, predecessor of NASA, at the Lewis Research Center in Cleveland, Ohio, in 1949. There he specialized in research in the fields of aerodynamic heating; boundary-layer theory and transition; and internal flow in supersonic and hypersonic aircraft. During his years at the Lewis facility, he was Head of the Fluid Mechanics Section and later Chief of the Special Projects Branch. He was formerly Chief of Manned Space Flight, and later Assistant Director for Manned Space Flight Programs, NASA Headquarters.

The author of numerous technical papers and articles, Mr. Low is an Associate Fellow of he Institute of the Aerospace Sciences, and a Senior Member of the American Rocket Society.

Slightly less than a year ago I addressed the First National Conference on the Peaceful Uses of Space on the subject of Manned Space Flight. As I recall, my talk was delivered the day after President Kennedy established the manned lunar landing program as a national objective. At that time he stated, "I believe that the Nation should commit itself to achieving the goal, before the decade is out, of landing a man on the moon and returning him safely to earth."

Before I give a report on the current status of Project Apollo, let me briefly outline the specific accomplishments since last year's Conference:

We have acquired a 1,600 acre site in Houston, Texas, and have started construction of a major new NASA Center, the Manned Spacecraft Center. Personnel from this Center are responsible for Project Mercury and will carry out the development of all future manned spacecraft and flight missions.

Under the direction of the Manned Spacecraft Center, we have initiated the Gemini program as a prelude to Apollo and have awarded a contract for the two-man Gemini spacecraft to McDonnell Aircraft Corporation; detailed arrangements for the Gemini launch vehicles, the Titan II and the Atlas-Agena, have been worked out with the Air Force.

Manned Spacecraft Center also has contracted with North American Aviation, Inc., to design, develop and construct the three-man Apollo spacecraft which is to land men on the Moon. The launch vehicles for Apollo will not be discussed in this paper, since these will be the subject of paper 10. Suffice it to say that all stages for both the Saturn and the Advanced Saturn are under contract to the Marshall Space Flight Center, and that the engines for the giant Nova are being developed.

Along the Florida Coast, we are acquiring 73,000 acres of land for the launching sites for Project Apollo; this area is five times the present size of Cape Canaveral.

In Washington, we have established the Office of Manned Space Flight, the focal

point of a hard-hitting organization which includes the Manned Spacecraft Center in Houston, the Marshall Space Flight Center in Huntsville, and the Launch Operations Center at Cape Canaveral.

Project Apollo's goal can be stated rather simply: "To accomplish a manned lunar landing and return at the earliest practicable date." (See fig. 9–1.)

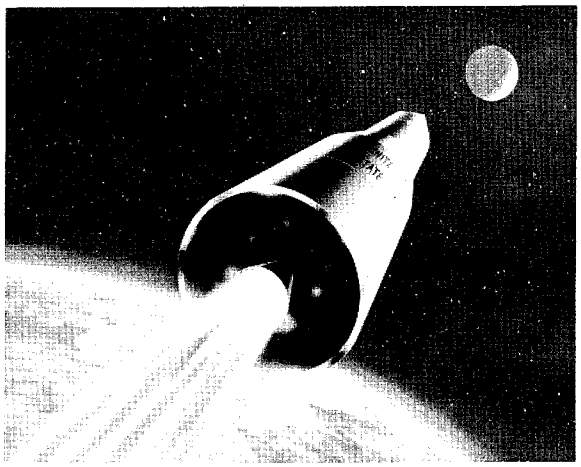


FIGURE 9–1. Manned lunar landing, Project Apollo.

This goal, of course, is not an end unto itself. Rather, the Apollo program will focus our scientific and technical talents on a task that is exceedingly broad in scope and high in complexity. By its very nature, it will lead to a general advancement in technology that has heretofore seldom been equaled.

There are several methods of accomplishing a manned lunar landing. Three of these —the three that are most plausible—are illustrated in figure 9–2. On the left of the figure is the so-called direct approach. Here, the spacecraft is launched from the surface of the Earth, and is accelerated to escape velocity by successive stages of a single launch vehicle. Near the Moon, the entire craft is decelerated by its own onboard propulsion system, and is thereby landed on the Moon's surface. The second approach makes use of rendezvous in Earth orbit. In this approach, two or more pieces of the space vehicle are brought together in Earth orbit, are either assembled in Earth orbit or refueled, and then accelerate the spacecraft from orbital speed to escape speed. The lunar landing and take-off phase of this mission would be the same as in the direct-approach mission. A third possible approach is lunar-orbit rendezvous. In this mission, a single launch vehicle is used on the surface of the Earth in order to inject the spacecraft to escape speed, just as in the case of the direct approach. Spacecraft propulsion is applied to establish an orbit around the Moon. A smaller lunar landing vehicle is then sent from lunar orbit to the surface of the Moon and, later on, returned to lunar orbit. In lunar orbit, it will rendezvous with the mother ship. The crew will then return to Earth in their spacecraft.

Let me describe each of these three missions in greater detail. In figure 9–3, the launch vehicle and spacecraft for the direct approach are illustrated. The Nova launch vehicle is required for this mission. This vehicle, which develops 12 million pounds of

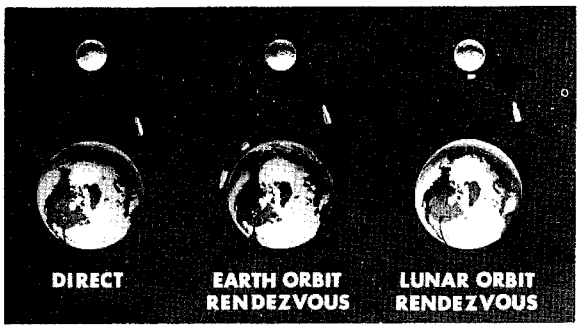


FIGURE 9–2. Project Apollo, lunar landing flight techniques.

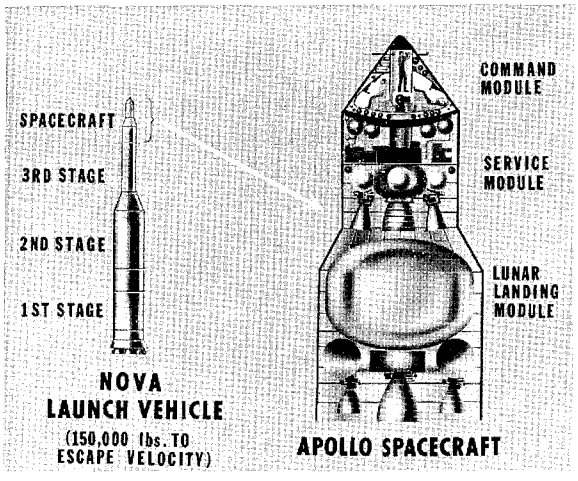


FIGURE 9–3. Launch vehicle and spacecraft for direct approach.

thrust, or more, on take-off, has the capability of accelerating a 150,000-pound spacecraft to escape velocity.

The Apollo spacecraft, as used for the direct mission, is illustrated in this figure. The craft consists of three basic components, or modules: the command module, the service module, and the lunar landing module.

The command module is the flight control center for this mission. It will house the three-man crew, together with the equipment for life support, communications, guidance, and navigation. The command module is the only component of the Apollo spacecraft that will reenter the Earth's atmosphere.

The service module is essentially a propulsion stage. Its propulsion system will provide for mission abort capability and will also be used to execute the take-off from the Moon. A smaller secondary propulsion system in the service module will be used for midcourse corrections on the way back from the Moon, and for attitude control. This module will also contain some of the spacecraft components that are not needed directly within the pressurized cabin of the command module; for example, the electrical power supplies will be in this unit.

The lunar landing module is a propulsion stage; its function is to decelerate the spacecraft as it approaces the Moon in order to execute a soft lunar landing. A secondary propulsion system within this module will be provided for midcourse corrections on the way to the Moon, and for attitude stabilization and control.

Although the lunar landing module is shown as a single unit, our recent studies have indicated that a two-stage lunar landing system offers some advantages. The first stage of this module would decelerate the craft to a small velocity relative to the Moon's surface and would then be jettisoned at a low altitude. The remaining stage, equipped with a landing gear, would provide the final touchdown deceleration.

Four major steps in the direct mission are illustrated in figure 9–4. First, the launching from Cape Canaveral, with the three-stage Nova; the last stage boosts the 150,000 pound spacecraft to a speed of 25,000 miles

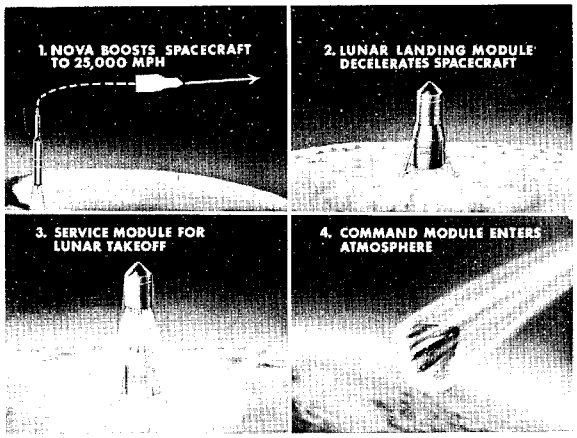


FIGURE 9–4. Direct mission.

per hour—a speed nearly 1½ times the velocity of an orbiting Earth satellite. The spacecraft arrives at the Moon 2½ days later. After perhaps one or two passes around the Moon, the lunar landing module is guided to a soft landing.

While on the Moon, two of the crew members will leave their craft and explore the surface of the Moon in the vicinity of the landing site. Then, at a predetermined time, service module propulsion will be used for the lunar take-off. By the time the craft enters its return trajectory, the various propulsion systems will have imparted a total velocity change of 41,000 miles per hour: 25,000 miles per hour to escape the Earth's gravity, 8,000 miles per hour to land on the Moon, and 8,000 miles per hour for lunar take-off.

The last part of this figure shows the command module reentering the Earth's atmosphere 2½ days after lunar take-off. On the way from the Moon, service module propulsion will have been used to guide the spacecraft to a point within a rather narrow reentry corridor; this feat requires an accuracy equivalent to hitting a target the size of a nickel at the far end of a football field. Within the Earth's atmosphere, the pilot will be able to fly his spacecraft toward a preselected landing site. Then, at a relatively low altitude, three large parachutes or a paraglider, will be deployed to reduce the impact velocity.

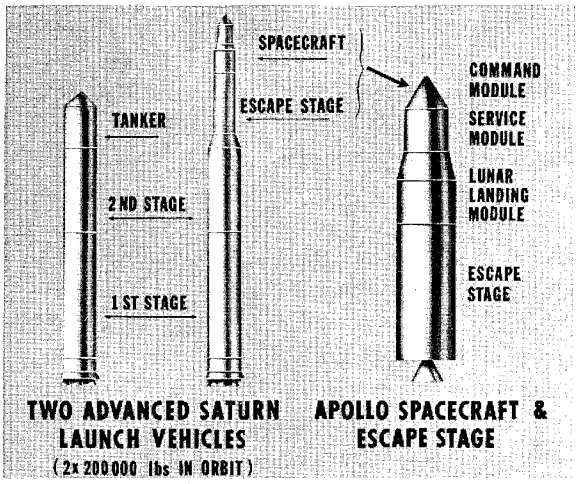


FIGURE 9–5. Earth orbit rendezvous technique.

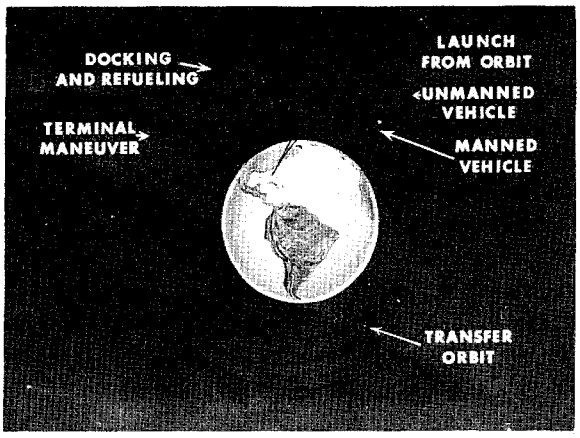


FIGURE 9–6. Earth orbit rendezvous.

The launch vehicles and spacecraft for the Earth orbit rendezvous technique are shown in figure 9–5. Two Advanced Saturns are required for this mission. One places the Apollo spacecraft, together with an escape stage, into Earth orbit. The spacecraft would be identical to the one illustrated in figure 9–3; it includes the command module, the service module, and the lunar landing module. The escape stage, when fully loaded with propellants, has the capability of accelerating the spacecraft from orbital velocity, 18,000 miles per hour, to escape speed, 25,000 miles per hour. However, when this stage is first placed into orbit, it is only partially loaded with propellants. The remaining propellants are carried into orbit in a tanker stage on the other Advanced Saturn. Once both vehicles are in orbit, they are brought together in a rendezvous maneuver. Propellants are then transferred to the escape stage, and the spacecraft is launched toward the Moon.

The rendezvous itself is shown in more detail in figure 9–6. The unmanned tanker will be launched first and will be placed into Earth orbit. After this orbit has been precisely determined by ground tracking, the manned spacecraft will be launched into a lower orbit. It would, of course, be desirable to launch the second vehicle at an exact moment of time so that it will arrive in orbit in a position for early rendezvous with the tanker. However, we do not believe that it will always be possible to launch a booster as complex as the Advanced Saturn exactly on schedule. This, indeed, is why the two vehicles, the spacecraft and the tanker, will be launched into orbits of different altitude. The manned craft, in the lower orbit, will have a shorter period and thus catch up with the one in the higher orbit. Once the two vehicles are in proper phase, the manned craft will transfer to the higher orbit so that it reaches that orbit in close proximity to the tanker. In the terminal maneuver, the two vehicles will be brought still closer together, so that the rendezvous, docking, and fuel-transfer maneuver can be made. After the escape stage is fully loaded with propellants, the spacecraft will be launched from Earth orbit toward the Moon. From this point on, the flight is identical to that previously described for the direct approach.

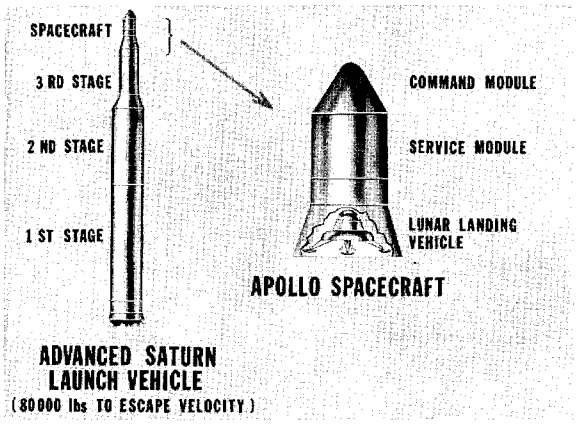


FIGURE 9–7. Lunar orbit rendezvous technique.

The launch vehicle and spacecraft for the lunar orbit rendezvous mode are shown in figure 9–7. In this approach, the heavy command and service modules are not landed on the Moon. Instead, they remain in lunar orbit, and a much lighter lunar landing vehicle is sent to the lunar surface and then returned to lunar orbit. By this method, the performance requirements for the launch vehicle are greatly reduced, so that a single Advanced Saturn is adequate for this mission.

This launch vehicle can send the command and service modules, together with the lunar landing vehicle, on a trajectory toward the Moon. Near the Moon, service module propulsion will be used to place the entire craft into lunar orbit (fig. 9–8). After the lunar

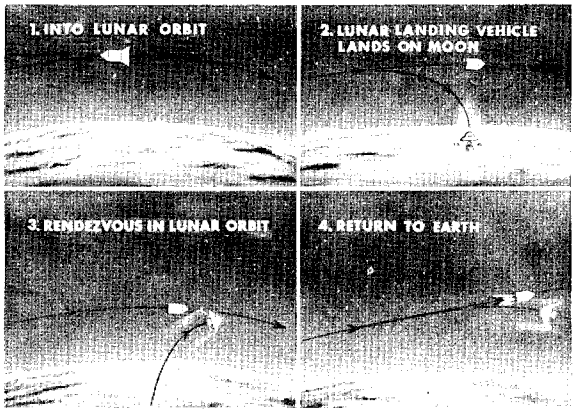


FIGURE 9–8. Lunar orbit rendezvous.

orbit has been established, two of the men will enter the lunar landing vehicle and descend to the Moon's surface. After the desired time on the Moon, the same vehicle will be launched back into lunar orbit. There it will rendezvous with the command and service modules. Service-module propulsion will then send the spacecraft on a trajectory toward Earth. The Earth reentry and recovery phases of the mission are the same as for the direct and Earth orbit rendezvous approaches.

These, then, are the three possible missions: direct, Earth orbit rendezvous, and lunar orbit rendezvous. Each has its advantages and its disadvantages. We have selected, on a temporary basis, the Earth orbit rendezvous mode as the primary approach to the manned lunar landing mission.

In the meantime, our studies of all three approaches are continuing. These studies have confirmed that all three techniques are feasible. The final selection of a mode is based on a detailed technical and operational analysis of all modes. The development risk will be assessed, so that the mission that has the highest probability of early achievement can be selected.

Once this selection has been made, it would be most desirable to pick a single path, without a scheduled alternate mission on a competitive time scale. By selecting a single mode, it will be possible to devote all our resources, all the required funds, and all the required technical and managerial talent to this one task. This, we believe, is essential in a program as complex as Project Apollo.

It is certainly clear that in order to accomplish the Apollo mission, we will have to achieve a standard of reliability that heretofore has never been approached in space vehicles. We have all heard statements to the effect that a launch vehicle for manned flight need not be more reliable than a launch vehicle for a missile or an unmanned spacecraft because we can always provide an escape system to save the pilot's life, even though the mission might not be completed. I can not accept such a premise. I believe that we have a reasonable probability of mission completion—a reasonable chance of carrying out the entire mission from Earth takeoff to lunar landing and back to Earth—before we can attempt the first lunar landing expedition.

Of course we must have, for all manned space flight missions, the highest probability of pilot safety; but we must also have a very high probability of mission completion.

An illustration of just how difficult it will be to achieve this high probability of mission completion is shown in figure 9–9 in which the probability of mission completion is plotted as a function of the number of stages, or modules, in the space vehicle system. For the Apollo mission, we will have at least five stages and perhaps as many as ten. For example, using the direct mode, we

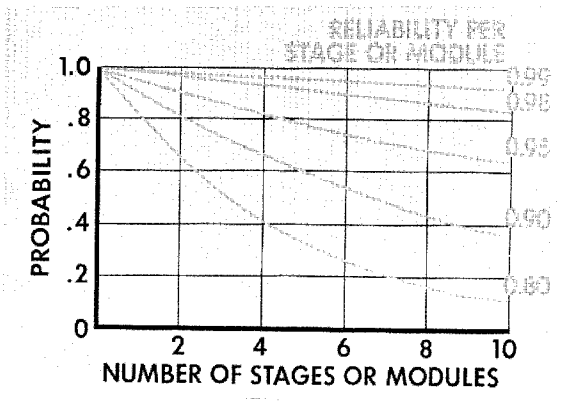


FIGURE 9–9. Probability of mission completion.

will have five propulsion stages; three of them on the launch vehicle carrying the spacecraft to escape velocity, one for lunar landing and another for lunar take-off. Using the Earth orbit rendezvous mode, on the other hand, we could have as many as 10 hardware stages. If we assume a mission reliability of 90 percent, and I do not believe that such a goal is too high, then each stage, or module, must have a reliability of between 98 and 99 percent. Of course those stages without backup, such as the lunar take-off module, must have a reliability consonant with pilot safety requirements, far in excess of 99 percent.

Look at this curve in another way. During the early development of our current launch vehicles we generally achieve a reliability of between 50 and 80 percent per stage. If we assume the higher of these two numbers, that is, 80 percent, for the Apollo vehicles, then our probability of mission completion will only be of the order of 10 to 20 percent for each flight. Such low numbers would be entirely unacceptable.

Another factor that should be considered, is the time or duration of each mission. It will be much more difficult to achieve the high reliabilities required for the mission when flight times become much longer than they are today. In figure 9–10, mission times for Mercury and for Apollo are compared. On the left-hand side is a major breakdown of the Mercury orbital mission including launch, orbit injection, retrofire, reentry, and recovery. A similar breakdown for the Apollo Earth orbit rendezvous mission is shown on the right-hand side of the figure. The total Mercury mission, Astronaut Glenn's flight, lasted only about 5 hours. The lunar landing mission, with approximately

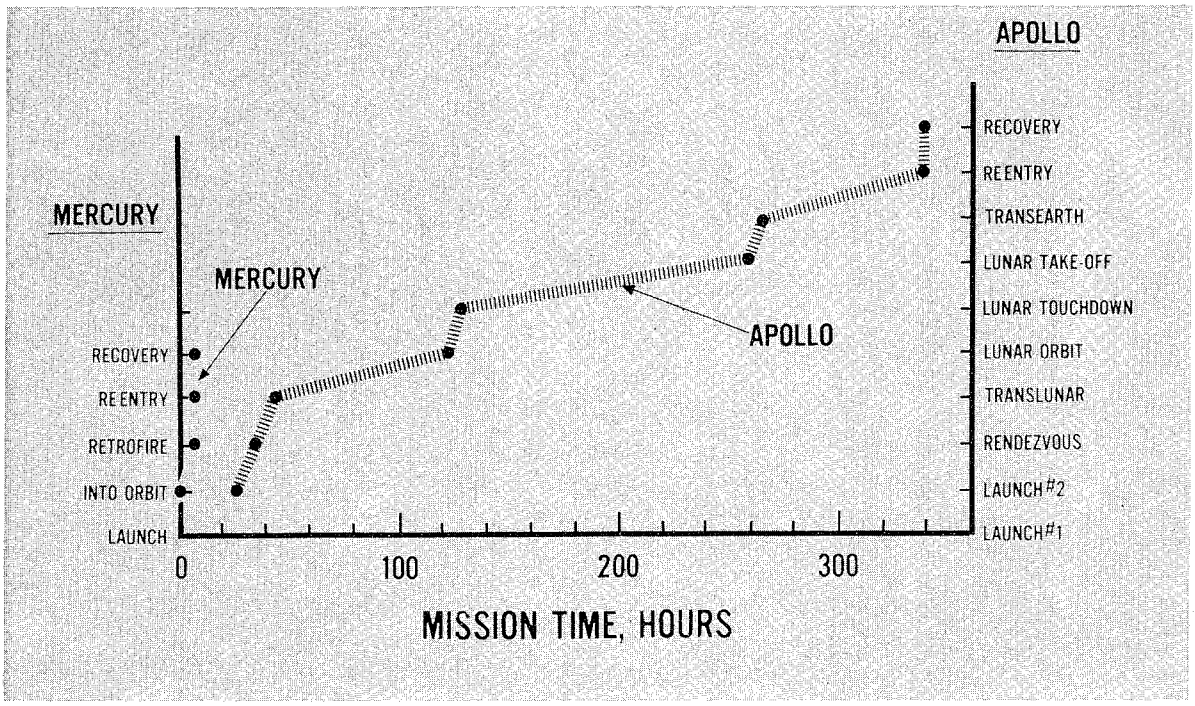


FIGURE 9–10. Comparison of Apollo and Mercury missions.

a 1-week stay time on the Moon, will last more than 60 times as long. In the Mercury flight, the launch vehicle, the Atlas, had to operate for only about 5 minutes after its last complete ground checkout; the spacecraft systems, for only 5 hours. In Apollo, propulsion stages would work 250 hours after Earth take-off; the spacecraft, longer than that.

I have tried to illustrate that it will be difficult indeed to achieve the mission reliability and pilot safety goals that we must establish for Project Apollo. Yet, I believe that these levels of reliability can be achieved, and will be achieved, by methods that are really not very much different from those applied in other complex manned systems. Although there are many examples of highly reliable systems, perhaps the design philosophy employed in today's high-performance aircraft is most closely related to the requirements for the Apollo mission.

Some of the most important reliability factors include soundness and simplicity of design; an excellent quality in all components, subsystems, and systems; intensive ground and flight test programs; adequate training and mission simulation for all involved in the operation; and most important of all, the use of man to enhance reliability wherever he can do so.

Disregard, for the moment, the first item on this list, and consider the next item: quality control. Most of the failures in today's launch vehicles and spacecraft can be traced directly to the failure of a single part or component. In general, these are not design failures in the sense that the part was overstressed or overloaded. Rather, they are failures of a particular part, caused by poor materials or poor workmanship. A typical example of this type of failure occurred during the Mercury-Atlas 5 mission, the two-orbit flight of the chimpanzee, Enos. The flight had to be terminated at the end of two orbits because of a control-system malfunction. An examination of the small-reaction control-system jets after the flight showed that a small piece of metal thread had plugged one of the orifices. This failure might have been avoided through stricter quality control.

A major step toward achieving a quality of excellence can be obtained by instilling a pride of workmanship in all associated with the project. There is no better incentive for quality control than the knowledge that a man's life depends on one's work. Equally important is inspection and reinspection of every part and component, of every system and subsystem, in order to assure that no mistakes are made.

The next item on the list is a thorough ground and flight test program. I believe that the need for such a program is obvious. There is no way of assuring that all the hardware will meet its design criteria without testing prototypes in an environment that is generally more severe than the actual flight environment. No amount of analysis is sufficient to identify all problem areas; in a test program problems are usually discovered that were not even thought of before the test was made. In project Apollo, therefore, we have developed rigorous specifications for qualification and reliability testing of every item that goes to make up a spacecraft. Complete prototype spacecraft will then be subjected to the actual flight environment, both in large thermal-vacuum facilities and in actual flight tests.

In Project Mercury we have learned that simulation and training are an absolute requirement. The training of the pilots has, of course, received a great deal of attention. But equally important is the extensive simulation of flights carried out by all persons involved in an actual operation. All the flight controllers, and the network, computer, and communications experts, will have to perform literally hundreds of practice missions wherein every conceivable emergency is simulated. Through such exercises they will learn to work together as a well-functioning team, a team that supports the pilot throughout his mission.

Now return to the first item on the list of reliability factors: soundness and simplicity of design. This item may be broken into three categories.

The first of these is the provision of adequate design margins. Obviously, if all systems operate at a stress level considerably

below their design limit, then the likelihood of failure will be minimized.

The use of redundant systems cannot be overemphasized. In general, such systems do not exist in our missiles and unmanned spacecraft; a single failure, therefore, often causes the loss of an entire mission. Yet, no one would even consider building an airplane without complete redundancy in all critical components required for control. In Project Mercury, the redunant reaction control system permitted Astronaut Glenn to complete his planned mission; without this redundancy he would have had to terminate the flight early. Our design philosophy in the Apollo spacecraft is to utilize redundant systems so that no single failure will jeopardize the mission. I believe that similar redundancies should be examined for the Apollo launch vehicles. It may well be that critical launch-vehicle systems—the guidance system and the hydraulic system, for example—should be duplicated.

A third important design consideration is the independence of various systems and subsystems.

Consider the attempted launch of the first Mercury-Redstone, where a faulty signal caused momentary ignition, lift-off to about 1 inch above the ground, and then engine shutdown. In rapid sequence then, the Mercury escape tower jettisoned, the drogue and main parachutes ejected, and the hydrogen peroxide was jettisoned, while the launch vehicle settled back on its launch pad. This was a dramatic example of what can happen when several complex systems are closely integrated. In Apollo, we are striving to segregate all subsystems insofar as practicable. This should greatly simplify the design, checkout, and operation of the craft.

The last item on the list of reliability factors is crew participation.

There are those who believe that the entire Apollo mission could best be performed automatically and that the crew should merely go along for the ride; there are also those who feel that the pilot should himself take every action onboard and that there is no place for any automatic system.

Of course, neither of these two extremes is proper. In Apollo, the basic guideline is to assume that active crew members are available at all times to perform tasks as complex as men normally perform here on Earth, or in the Earth's atmosphere. With this guideline, one can then determine which tasks are best performed manually and which should be performed automatically. Certainly the pilot will always be in control of his spacecraft, either directly or through an autopilot. The crew will monitor all the complex systems and control or adjust these as required. In most instances, man will be better able to select between redundant modes than an automatic mode selector would. Insofar as practicable, the ability for in-flight maintenance will exist. Automatic systems will be employed whenever they are required for added precision, for increased speed of response, or to relieve the crew from tedious tasks.

I believe also that consideration must be given to using the flight crew in enhancing the launch-vehicle reliability. Here I do not necessarily advocate that the pilot should guide and steer his launch vehicle—although this, too, has been suggested and proved to be feasible. But there is no reason why at least one of the Apollo crew members should not be a flight engineer during powered flight. Certainly, with proper displays, he can select the redundant systems just as he would in an aircraft. He should be able to monitor and adjust many of the primary systems, and initiate manually many of the launch-vehicle sequences. Even with all these functions the flight engineer's panel in the Apollo spacecraft would be simpler by far than the flight engineer's display in a modern airplane.

There is good statistical evidence available that active crew members can greatly enhance mission reliability. For example, in 43 out of the first 44 X–15 flights, the desired mission objectives were achieved. Yet, without an active pilot, 17 of these missions would have failed.

I am confident that if we pay proper attention to all of the reliability factors that I have listed—to reliability through design, quality control, test, training, and manned

input—we can acieve the required reliability goals for this program.

In the Apollo program we have accepted a tremendous challenge. To meet this challenge we will have to surpass all our efforts of the past—in design, in engineering, in manufacturing, and in testing. If we do this—if we accept the philosophy that our launch vehicles and our spacecraft must be designed to work not just some of the time but all of the time—then we will be able to carry out our responsibility to our country to be second to none in man's conquest of space.

10. Launch Vehicles and Launch Operations

By **WERNHER VON BRAUN**, *Director, George C. Marshall Space Flight Center, NASA*

Dr. Von Braun was born in Wirsitz, Germany, on March 23, 1912. He was awarded a bachelor's degree by the University of Berlin. Two years later, in 1934, he received his doctorate in physics at the same institution.

In 1930 he joined a group of inventors who constituted the German Society for Space Travel. In 1932 he was employed by the Ordnance Department of the German Government. From 1932 until 1937 he was chief of a small rocket development station near Berlin. The liquid-fueled rockets identified as A–1, A–2, and A–3, forerunners of the V–2, were developed there.

He became technical director of the Peenemünde Rocket Center in 1937. The V–2 was developed there.

Dr. Von Braun came to the U.S. in September, 1945, under contract to the U.S. Army. He directed high-altitude firings of captured V–2 rockets at White Sands Missile Range, New Mexico. Later he became project director of a guided missile development unit at Ft. Bliss, Texas, which employed some 120 of his Peenemünde colleagues. In 1950 the entire group was transferred to Huntsville, Alabama, where the Army centered its rocketry activity.

The Army Ballistic Missile Agency development team which Dr. Von Braun headed was transferred to the National Aeronautics and Space Administration in 1960 at the direction of the President. The group was made responsible for developing and launching NASA's space vehicles. The major current project is the Saturn heavy space rocket.

At the Huntsville installation, Dr. Von Braun directed the development of the 200-mile Redstone rocket, the Jupiter IRBM, and the Pershing rocket.

Special versions of the Redstone and Jupiter were used by the Von Braun team in launching the Free World's first satellites of the Earth and Sun, Explorer I and Pioneer IV, respectively and in the first successful space flight and recovery of animal life.

Dr. Von Braun has received many professional and scholastic honors for his leading role in rocketry and space research activity. In 1959 he was presented the Distinguished Federal Civilian Service Award by the President of the United States.

Our smaller—but all-important—space carrier vehicles such as the Thor-based series and the solid-propellant Scout, an economical and versatile workhorse, have been discussed in preceding papers. Their capabilities and missions are for the most part concerned with scientific experiments in near-space physics, often relating directly to the outer atmosphere and its interactions with space phenomena.

This paper will concern our large space carrier vehicles—the ones we are now using and will use in the future to undertake interplanetary investigations and to accomplish the manned space flight programs discussed in the preceding papers. This review of our large space carrier vehicles will be limited to descriptions and capabilities and will not include operational employment.

Our mission at the George C. Marshall Space Flight Center is to develop NASA's

space launch vehicles; other centers are responsible for their payloads.

Closely tied to the development of large carriers is the task of manufacturing, testing, and launching them. I shall also touch on these important facets of the space program. NASA's Launch Operations Directorate at the Atlantic Missile Range is the organization that handles the firing of the carriers we develop.

Large space carrier vehicles means those at least based on the military's ICBM first stages, producing in excess of 350,000 pounds of thrust, and the still larger vehicles being developed by the Marshall Center.

The Atlas ICBM has been used, in a suitably modified form, to launch many artificial Earth satellites and space probes. Of the six configurations created—Atlas-Score, Atlas-Able, Atlas-Agena A, Atlas-Agena B, Mercury-Atlas, and Atlas-Centaur—only the latter three are still in service (fig. 10–1.).

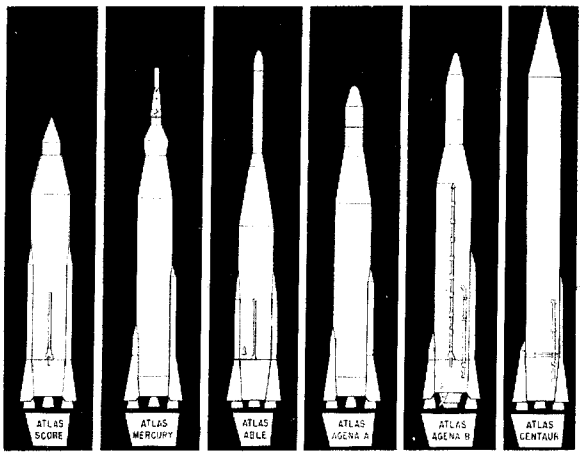


FIGURE 10–1. Third group systems.

To convert the Atlas from its military to space role, a number of modifications are necessary. These include removal of the warhead, strengthening of the upper neck section, and incorporation of interstage adapting structures. NASA is using the Mercury-Atlas, Atlas-Agena B, and the Atlas-Centaur for manned and unmanned satellite missions, for lunar hard- and soft-landing craft, and to project probes into deep space and to the nearer planets of the solar system.

The Mercury-Atlas that boosted Astronaut Glenn into orbit February 20, 1962, is shown in figure 10–2. The Mercury-Atlas is a one-stage vehicle propelled only by its Atlas D engines. The 362,000-pound thrust of these engines is sufficient, however, to place the 3,000-pound Mercury capsule and the empty Atlas D into a low Earth orbit (approximately 100 miles).

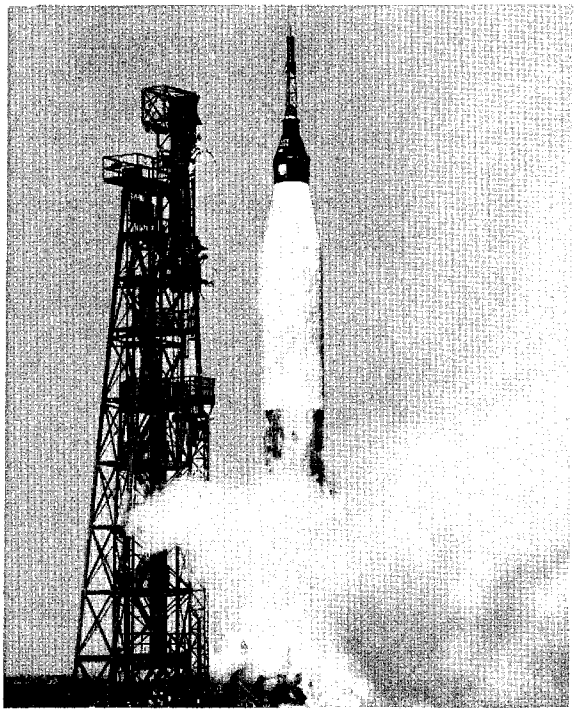


FIGURE 10–2. Mercury-Atlas 6 launch.

All three engines are ignited at launch. The outer two are jettisoned at the end of their burning period. The main engine continues to burn until orbital velocity is obtained. (See fig. 10–3.)

The Atlas is constructed of thin-gage stainless steel, and its structural rigidity is maintained through internal pressurization. Heavier gage skin is required at the forward end of the liquid-oxygen tank to provide for increased aerodynamic stresses imposed by the payload. Also, to undertake the Mercury mission, the payload adapter section is modified and an abort-sensing and implementation system is incorporated. If it senses any malfunction in the performance of the Atlas, it triggers the Mercury's emergence escape system, and the capsule is blasted free of the launch vehicle. In the Mercury application the Atlas is 67.34 feet

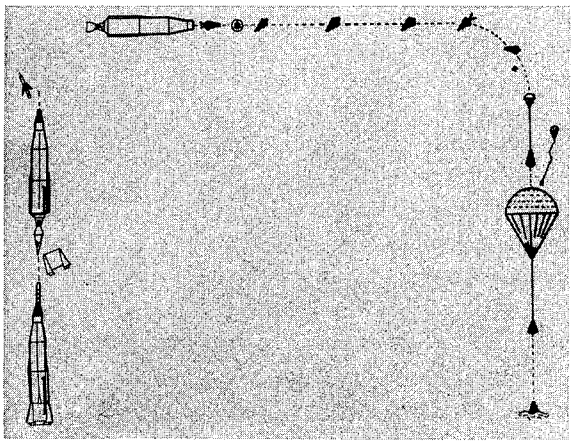


FIGURE 10–3. Diagram of sequence of Mercury-Atlas orbit.

long from its engines to the capsule adapter section. With the Mercury and its escape tower installed, the carrier is 95.25 feet in length.

The two-stage Atlas-Agena B (fig. 10–4) is used to launch a variety of military, military support, and scientific payloads. It can orbit large Earth satellites and place in departure trajectories lunar probes and interplantary and planetary exploration craft. When employed as the launching vehicle for a satellite, the entire Agena B stage becomes, in fact, the satellite. For lunar and interplanetary missions it will supply the final boost velocity to its payload, which detaches and continues toward its destination separately. The Atlas-Agena B was used in April 1962 to propel our Ranger IV spacecraft with exacting accuracy along a translunar trajectory that resulted in an impact on the far side of the moon—without benefit of the planned midcourse correction in flight. It is being readied for Mariner R probes that we hope to launch towards the planet Venus later this year. (See fig. 10–5)

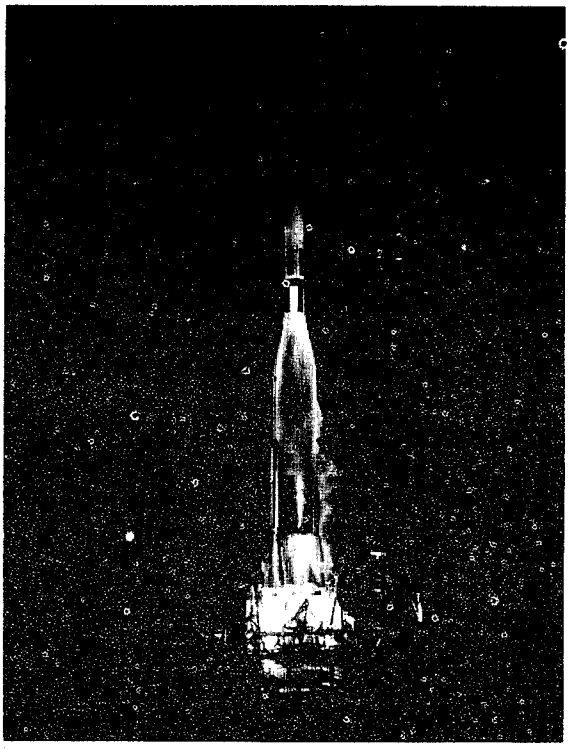


FIGURE 10–4. Atlas-Agena B launched.

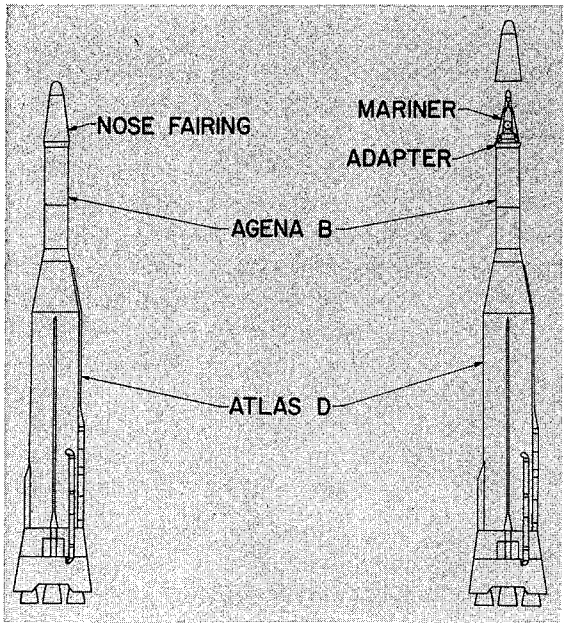


FIGURE 10–5. Mariner launch vehicle.

The Atlas-Agena B consists of a Convair Atlas D first stage and a Lockheed Agena B second stage. When modified for the Agena B mission it weighs about 260,000 pounds. With the adapter for the second stage it stands 78 feet high.

The second, or Agena B, stage is powered by a single-chamber Bell Aerosystems rocket engine operating on inhibited red fuming nitric acid and unsymmetrical dimethylhydrazine. The 15,000-pound-thrust engine is capable of being shut off and restarted in

space. After coast and prior to reignition, ullage rockets provide enough acceleration to seat the propellants at the bottoms of their respective tanks. Including the Ranger adapter, the stage is 22 feet long and 5 feet in diameter. It has integral, load-carrying propellant tanks.

Components of the guidance system are the inertial reference system, timing devices, velocity meter, and infrared horizon sensor. During powered flight pitch and yaw control is maintained by gimbaling the rocket motor; during periods of coast high-pressure gas jets are used.

In a lunar application the Atlas D outer engines burn for about 2½ minutes before cutting off and dropping away. The smaller center engine continues firing for another 2 minutes, bringing the carrier to an 80-mile altitude. The two small 1,000-pound-thrust vernier engines fire for a period of time to trim velocity and shut off in accordance with guidance commands. An onboard computer commands the Atlas airborne guidance system to start the timer on the Agena B stage.

Upon vernier cutoff the Atlas-Agena B coasts for about 30 seconds. Then the spring-loaded aerodynamic shroud protecting the Ranger payload is discarded. Explosive charges separate the Agena B from the Atlas first stage, and retrorockets on the latter slow it down to assure that it does not interfere with the second stage. The Agena B goes through a pitch maneuver to bring it in horizontal alinement to the Earth's surface. When this is accomplished, the timer sends a signal to the propulsion system and ignition occurs.

During the 2½ minutes of powered flight, the stage is controlled by the hydraulic control system, with corrections being supplied by an infrared horizon-sensing device. When the Agena B engine cuts off, the Ranger payload is in a circular parking orbit approximately 100 miles above Earth. After a 14-minute coasting period, the Agena B engine relights and powers the payload for another 1½ minutes, placing it in the lunar trajectory. Some 2½ minutes after engine cutoff the Agena B and the payload are separated and the Ranger continues alone toward the Moon.

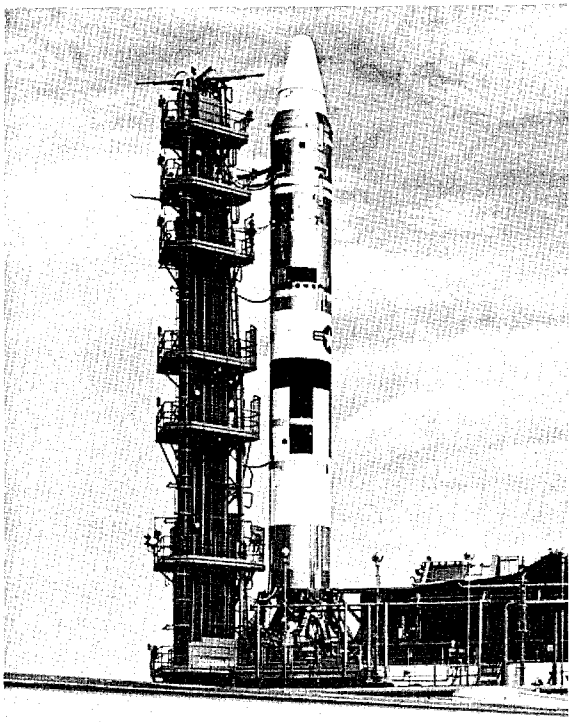


FIGURE 10–6. Atlas-Centaur on launch pad.

The mating of the Centaur second stage to the Atlas first stage results in the most advanced of the Atlas-based series of space carrier vehicles, the Atlas-Centaur, shown in figure 10–6 on its launcher. Still in the development stage, the carrier will continue to be flight tested throughout 1962 and 1963. When it becomes operational, the 105-foot-tall 300,000-pound Atlas-Centaur will be capable of placing approximately 8,500 pounds in a low Earth orbit, 2,300 pounds to the Moon, and 1,300 pounds to Venus and Mars.

Atlas-Centaur is the first known carrier to use the high-energy propellant combination of liquid oxygen and liquid hydrogen. While its first stage is powered by conventional liquid oxygen and kerosene engines, the twin-engine second stage employs this potent, frigid, new fuel combination. I do not mean to imply that its RL-10-A3 engines have not been thoroughly tested on the ground—they have been fired over 700 times since 1958—but rather emphasize that they have not been subjected to actual flight conditions integrated with a carrier vehicle. The

RL-10-A3 engine is introducing a new technology that will soon play a major role in the unmanned and manned exploration of space.

The explanation of why we are so excited about the hydrogen/oxygen combination is simply this: It is a new rocket propellant which develops over 40 percent more thrust from each pound of propellant consumed per second than the conventional kerosene/oxygen combination. Because of this extra energy, a carrier powered by liquid-hydrogen-burning engines can carry heavier payloads longer distances than previous carriers. One of our major objectives is to do just this, and do it reliably.

Three views of the Atlas-Centaur system are shown in figure 10–7. Atlas-Centaur is unique not only because of its second-stage propulsion system but because of the construction of the stage. Earlier Atlas-based carriers had relatively narrow upper stages compared with the Atlas first stage. The Centaur stage (fig. 10–8), like the Atlas, has a diameter of 10 feet. In order to accommodate the stage the forward conical section of the Atlas liquid-oxygen tank is enlarged and a 13-foot aluminum interstage adapter and separation system added. The stage uses a stainless-steel, pressure-supported, monocoque structure much like that of the Atlas.

Figure 10–9 shows the Centaur stage in position in the service structure. The 42-foot-long second stage weighs approximately 32,000 pounds not including the jettisonable nose cone and several hundred pounds of insulation discarded during the early phases of flight. Because liquid hydrogen boils off rapidly after being loaded, the tank must be adequately insulated during the loading period, as well as during the time the carrier is passing through the lower atmosphere. Four ½-inch-thick fiber-glass quarter panels of insulation extend from the nose fairing

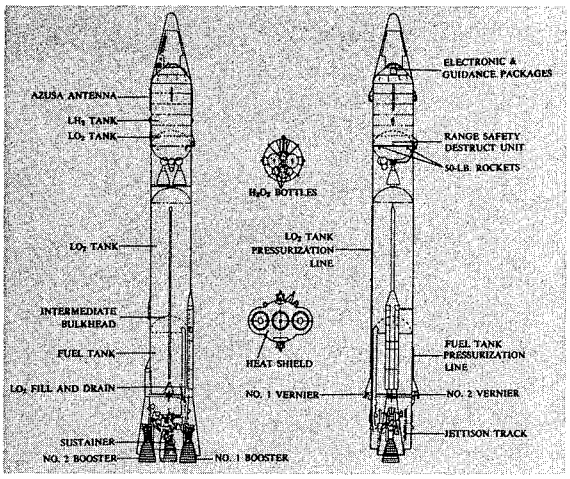


FIGURE 10–7. Major Atlas-Centaur system.

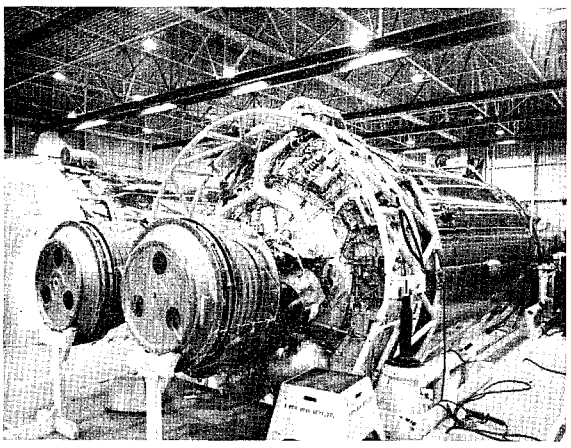


FIGURE 10–8. Centaur.

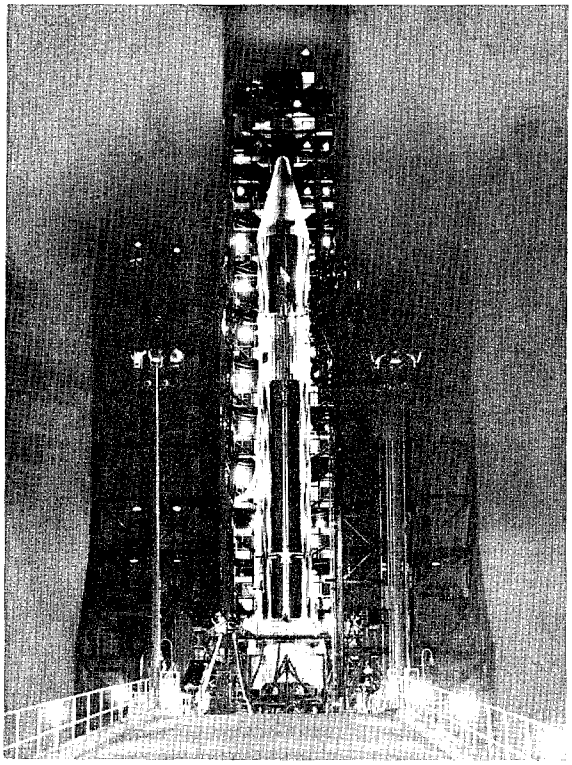


FIGURE 10–9. Centaur stage in service structure.

to the point of interstage separation. They are emplaced by spring-loaded tension straps and explosive bolts. When the carrier leaves the region of high aerodynamic heating the programer commands the bolts to explode and the panels are removed.

Such difficult missions as placing a satellite in synchronous 22,300-mile orbits around the Earth require the second stage to fire, turn off and coast, refire, coast again, and refire at a later time. After entering into its initial circular orbit the Centaur stage coasts for approximately 55 minutes. Then it is fired into a transfer ellipse in which it coasts for about 5 hours, after which final thrust is applied to inject it into a synchronous, circular 24-hour orbit over the equator. Some two-thirds of the propellants are expended during the first burning period, a quarter during the second, and a tenth during the third.

An extremely accurate, all-inertial guidance system is used to perform such maneuvers. During the coast period the guidance system becomes inactive, with only a timer operating. However, before this occurs the second stage's forward section is pointed away from the Sun to reduce hydrogen boil off. Added protection is given by a fiberglass radiation shield. Since the forward end is pointed away from the Sun, the rear engine section is consequently pointed toward it. This helps to keep engines warm during the coast periods, which is necessary at the beginning of the start sequence.

Figure 10–10 shows the 15,000-pound-thrust RL–10 engine. Four small 50-pound-thrust hydrogen peroxide motors are fired before main engine ignition to seat the propellants at the base of the tanks. One of the main objectives of the first Centaur launch is to learn more about liquid hydrogen under zero-gravity conditions.

The liquid hydrogen enters the cooling jackets around the thrust chamber. This not only cools the chamber, but heats the liquid hydrogen and expands it through the two-stage centrifugal pump. From there it is injected into the combustion chamber where it is burned in the presence of atomized liquid oxygen. The heat absorbed by the

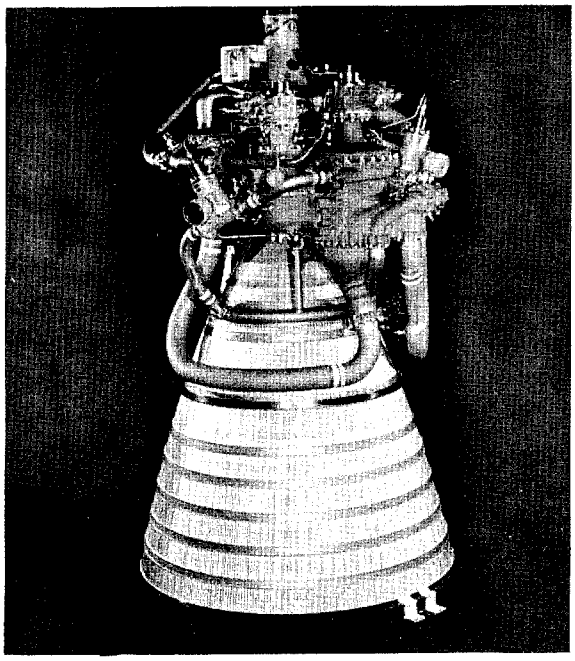


FIGURE 10–10. RL–10 engine prior to preliminary flight rating test.

liquid hydrogen in the cooling jacket gives enough energy for turbopump drive. The chamber operates under 300-psi pressure conditions at 6,000° F temperatures.

The Centaur is earmarked to launch communication satellites and environmental research satellites into 24-hour orbits, Surveyor probes softly onto the Moon, and Mariner craft along Venus and Mars flyby trajectories. It may also be employed to orbit meteorological satellites into 24-hour orbits.

There are two versions of the Titan ICBM. Titan I, the smaller and less powerful of the two, is operational, while the brand-new Titan II is just entering the flight-test stage. This latter carrier, shown in figure 10–11 has been selected by NASA to boost into orbit our Gemini satellites now under development. There is also the still larger and more powerful Titan III, now being developed, but it is not scheduled to handle any NASA missions.

The Titan II ICBM has not been used as a space carrier vehicle, but we are going to call on its capabilities in the NASA manned space flight program. It was captive test fired for the first time in Denver, on December

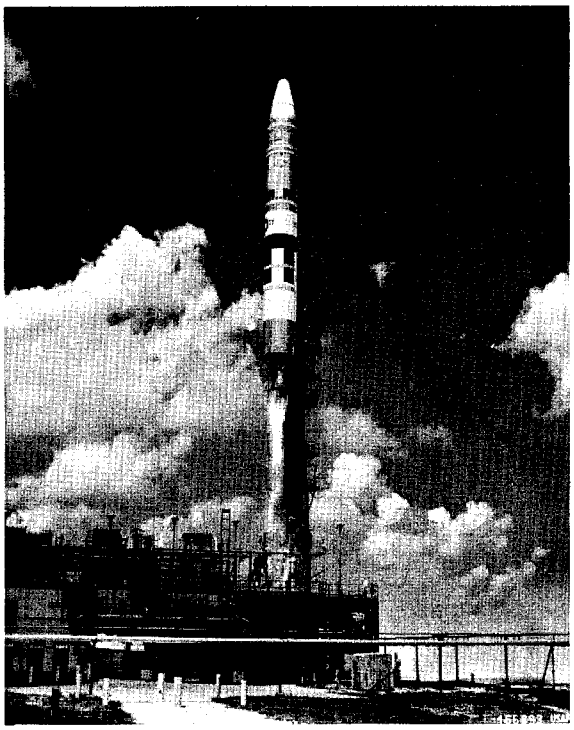


FIGURE 10–11. Titan II.

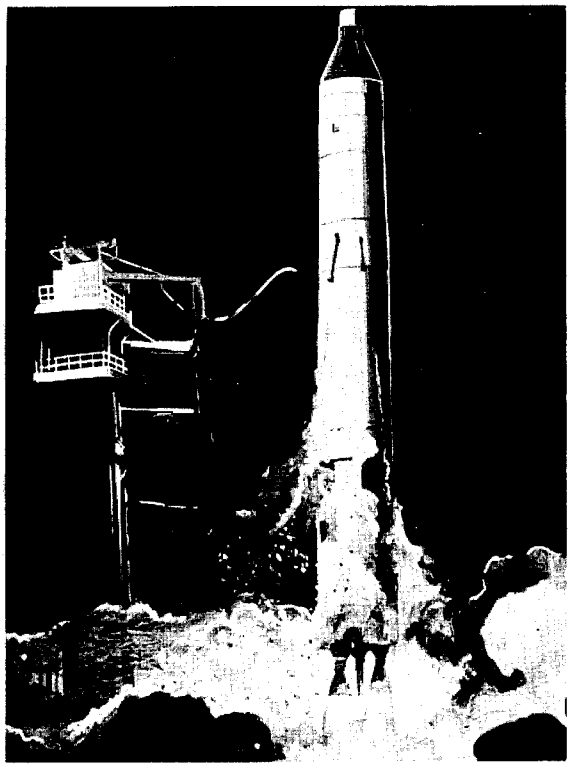


FIGURE 10–12. Artist's conception of Titan II launching.

28, 1961, and on March 8, 1962, underwent a similar test at the Atlantic Missile Range.

Then, on March 16, 1962, Titan II successfully made its maiden flight, carrying a payload of instruments 5,000 miles over the Atlantic Ocean. Figure 10–12 shows an artist's concept of the launching of the Gemini spacecraft. In its standard military version, the Titan II is 103 feet long, 10 feet in diameter, and weighs 300,000 pounds, when fully fueled. It consists of two tandem-mounted stages, the first powered by two 215,000-pound-thrust rocket engines and the second, by a single 100,000-pound-thrust rocket engine. All engines operate on a storable hypergolic mixture of nitrogen tetroxide and a combination of unsymmetrical dimethylhydrazine and hydrazine. Titan II is a rigidly constructed carrier with conventional-type tanks. Copper-rich aluminum alloy is extensively employed.

When the Titan II becomes operational, we plan to use it to orbit our 6,000-pound Gemini two-man satellites now under development. In the Gemini project we will be able to practice rendezvous maneuvers in orbit to help pave the way towards successful completion of the Apollo program.

Much larger than the Atlas- and Titan-based carriers are two space vehicles being developed by NASA under the Saturn program. Saturn vehicles will be capable of sending payloads of many tons into Earth orbit, to the Moon, and into deep space. The main purpose of the project is manned space exploration, including the landing of men and equipment on the Moon within this decade. Several versions of the Saturn have been studied. Only the principal ones are mentioned here.

The Saturn C-1 configuration consists of three stages, S–I, S–IV, and S–V. There are two so-called Block I and Block II designs. In the Block I design (fig. 10–13) the first stage clusters eight Rocketdyne H–1 engines, each capable of generating 165,000 pounds of thrust at sea level. The four inboard engines are mounted at a fixed 3° cant from the vertical. The outboard engines cant 6° from the vertical, and each

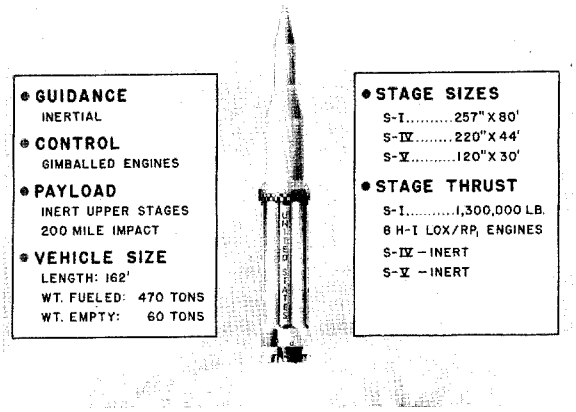


FIGURE 10–13. Saturn C–1 (block I) characteristics.

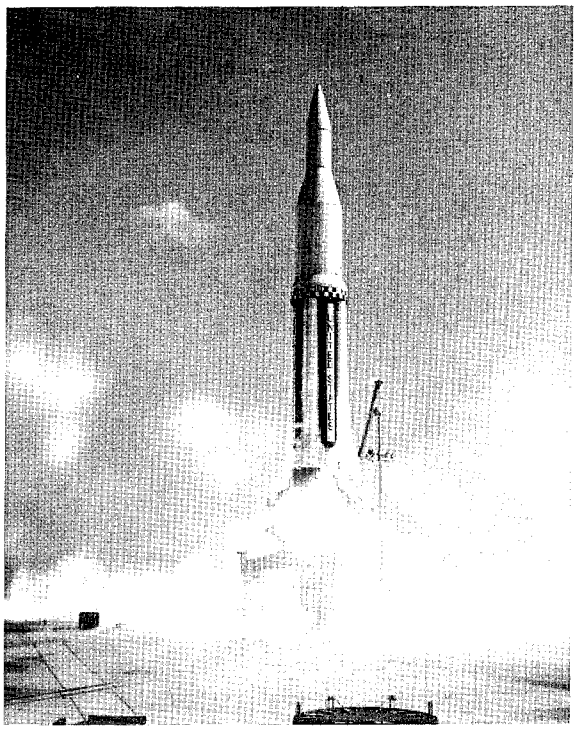


FIGURE 10–14. First launch of a Saturn C–1.

can be gimbaled for booster control. They burn RP–1 fuel, kerosene with liquid oxygen as the oxidizer.

The second and third (S–IV and S–V) stages will be flown as dummy stages in the first four of the programed 10-vehicle flight test program.

Figure 10–14 shows the first launch of a Saturn C–1 launch vehicle with inert upper stages, at Cape Canaveral October 27, 1961, less than 3 years from the beginning of the Saturn program. During the 8-minute flight, the rocket reached a peak velocity of 3,600 miles per hour, and an altitude of 85 miles before impacting some 215 miles out in the Atlantic. Another 100-percent-successful launch was accomplished from the Cape April 25, 1962. The cluster of eight engines generated 1.3 million pounds of thrust.

The inert upper stages were filled with water as ballast to simulate weight of a complete vehicle. A bonus scientific experiment was performed during the second launch. The 95 tons of water carried as ballast were deliberately exploded at 65 miles altitude to find out what would happen to the water were it in the cold vacuum of space. The Project High Water experiments will probably be repeated in the third and fourth launchings.

In the Block II design the S–I stages will have eight H–1 engines each capable of generating 188,000 pounds of thrust at sea level (fig. 10–15). Figure 10–16 is an artist's concept of the Block II design of the Saturn C–1 Apollo at lift-off.

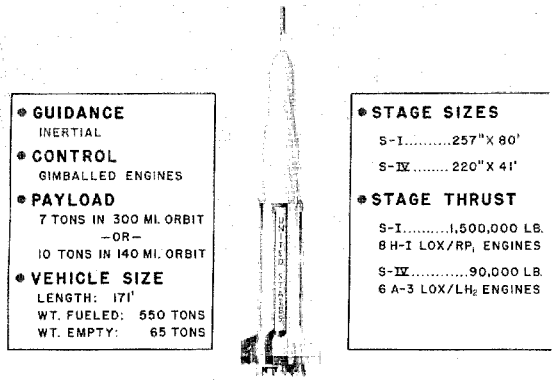


FIGURE 10–15. Saturn C–1 (block II) characteristics.

After the Saturn C–1 will come Saturn C–5, or as it is sometimes called, the Advanced Saturn. In figure 10–17 it is shown in its two-stage version, with the Apollo spacecraft. The Saturn C–5 will be 33 feet in diameter, and have a take-off weight of more than 6 million pounds. First stage of the Saturn C–5 will be powered by five F–1 kerosene–liquid-oxygen engines which yield

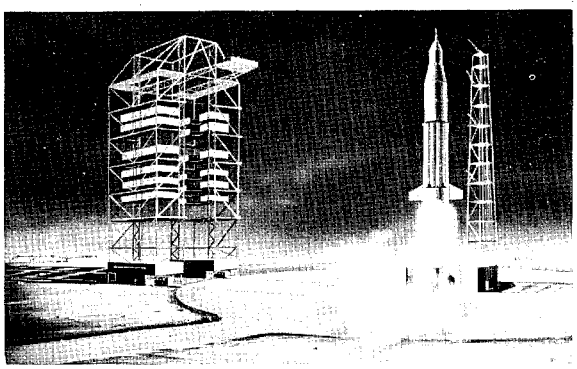


FIGURE 10–16. Saturn C–1/Apollo at lift-off.

a total thrust of 7.5 million pounds. This is five times the thrust of the first-stage booster of Saturn C–1. The second stage of Saturn C–5 will be powered by five J–2 liquid-hydrogen–liquid-oxygen engines each one of which will provide 200,000 pounds of thrust.

With the addition of a third stage, consisting of a single J–2 engine, the Saturn C–5 will be capable of placing 200,000-pound payloads into low Earth orbit, or speeding 90,000 pounds out into deep space. (See fig. 10–18.)

The secret of the Saturn C–5's tremendous lift-off strength is the F–1 engine, shown in the background in figure 10–19. Eight of the H–1 engines, shown in the foreground, are clustered in the first stage of the Saturn C–1. At one jump we move forward to a "single-barrel" engine that will have the same thrust as all eight H–1 engines, 1½ million pounds.

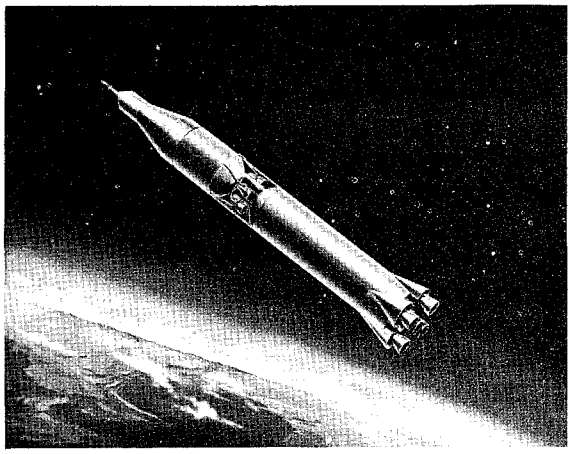


FIGURE 10–17. Saturn C–5 Apollo, two stages.

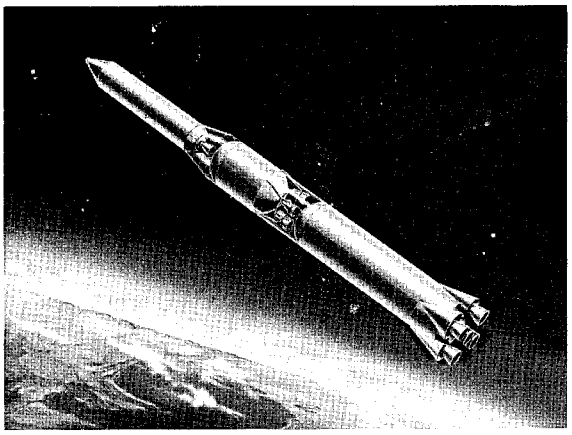


FIGURE 10–18. Saturn C–5, three stages.

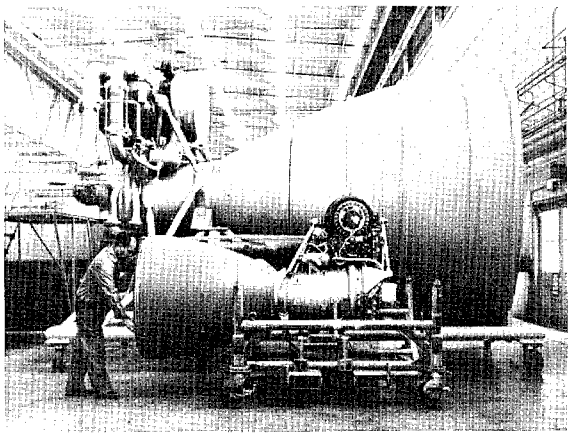


FIGURE 10–19. F–1 engine and H–1 engine.

Like the H–1, the big F–1 engine burns RP–1 fuel and liquid oxygen.

The F–1 engine is not just a drawing-board dream. It has been static fired by Rocketdyne at Edwards Air Force Base in full duration tests at maximum proficiency. (See fig. 10–20.)

The S–IC will be the first stage of the Advanced Saturn vehicle, C–5 (fig. 10–21). Powering the new booster will be a cluster of five F–1 engines, each generating 1.5 million pounds thrust. Preliminary planning for the booster is underway at the Marshall Center, and a contract for its development and fabrication has been signed with The Boeing Company. Twenty-four flight boosters and several ground test versions are to be produced at the Michoud Plant in New

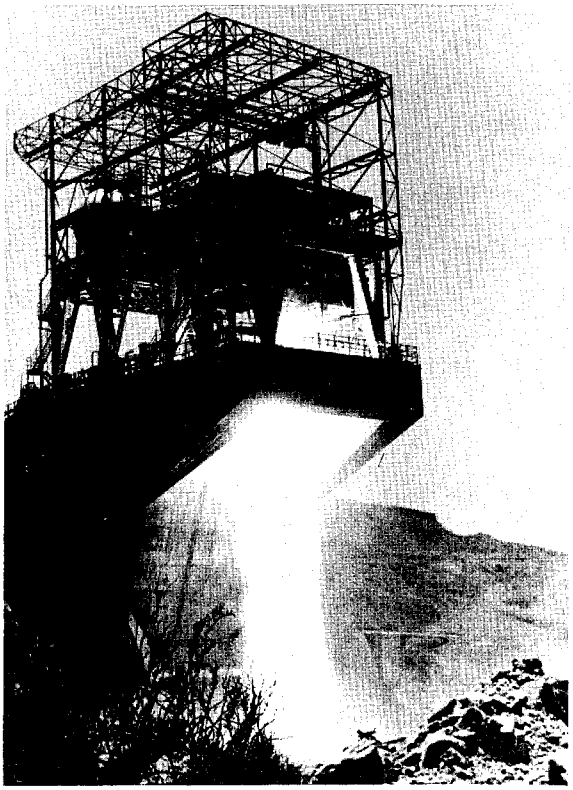


FIGURE 10–20. Static firing of F–1 engine.

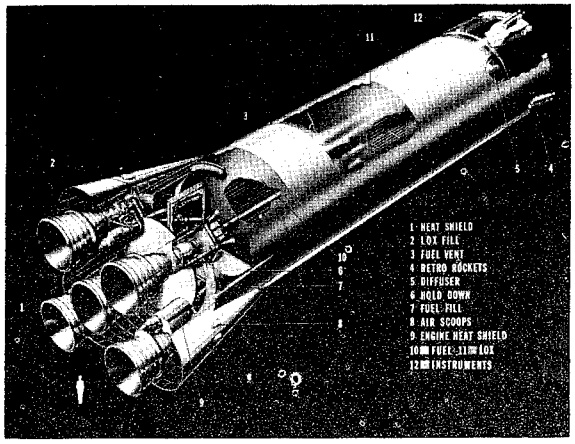


FIGURE 10–21. C–5 booster.

Orleans. Static testing will be at the MSFC Mississippi Test Facility, 35 miles east of New Orleans.

The S–II will be the second stage of the Advanced Saturn vehicle (fig. 10–22). A contract for its development and production has been signed with the Space and Information Systems Division of North American

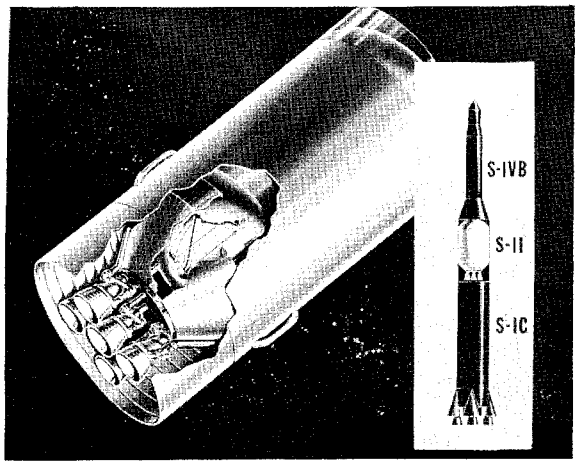


FIGURE 10–22. S–II cutaway view.

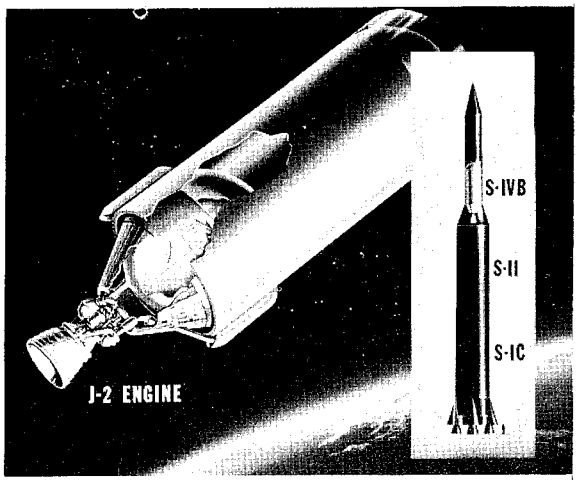


FIGURE 10–23. S–IVB cutaway view.

Aviation, Inc., and early work is in progress. The S–II, like the S–IC, will be 33 feet in diameter. It will be powered by five J–2 liquid-hydrogen–liquid-oxygen engines, for a total stage thrust of a million pounds. The engine is under development by the Rocketdyne Division of North American, with first delivery to NASA expected in 1963.

The third stage of the Saturn C–5 vehicle will be known as the S–IVB, a modification of the S–IV stage which is used on the Saturn C–1 (fig. 10–23). A contract for the modification and production of the unit is being negotiated with Douglas Aircraft Company.

The length of the new stage will be increased to some 70 feet. The power plant

will be changed from six RL–10 engines in the S–IV to a single J–2 engine in the S–IVB. Thus the new stage will have a thrust of 200,000 pounds compared with 90,000 in the S–IV.

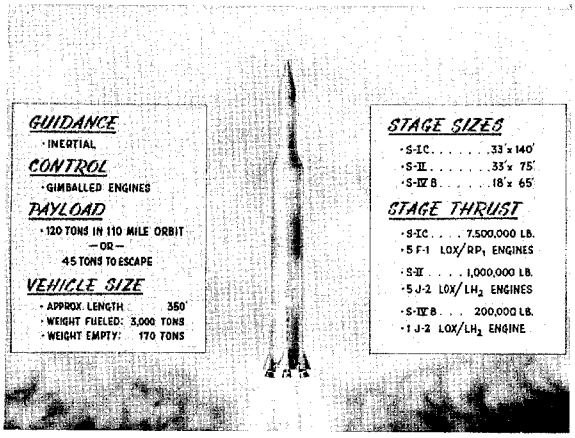


FIGURE 10–24. Saturn C–5 characteristics.

Figure 10–24 summarizes the characteristics of the Saturn C–5. The Saturn C–1 will be used to place Apollo spacecraft carrying three men into Earth orbit for up to 2 weeks. The C–5 will be used for sending the three-man spacecraft around the Moon. It may also be used for manned lunar landings, using the rendezvous technique.

Finally, we come to the Nova. Figure 10–25 shows a comparison of the Saturn C–1 and C–5 with the Nova. Nova, another three stage vehicle, will be able to lift about 400,000 pounds into low Earth orbit or speed 150,000 pounds out into deep space. Nova will stand about 280 feet in height, exclusive of payload, with the first stage about 50 feet in diameter. The first stage will consist of a cluster of eight F–1 liquid-propellant engines, generating a total thrust of 12 million pounds. Development has already begun on the M–1 engine for the second stage.

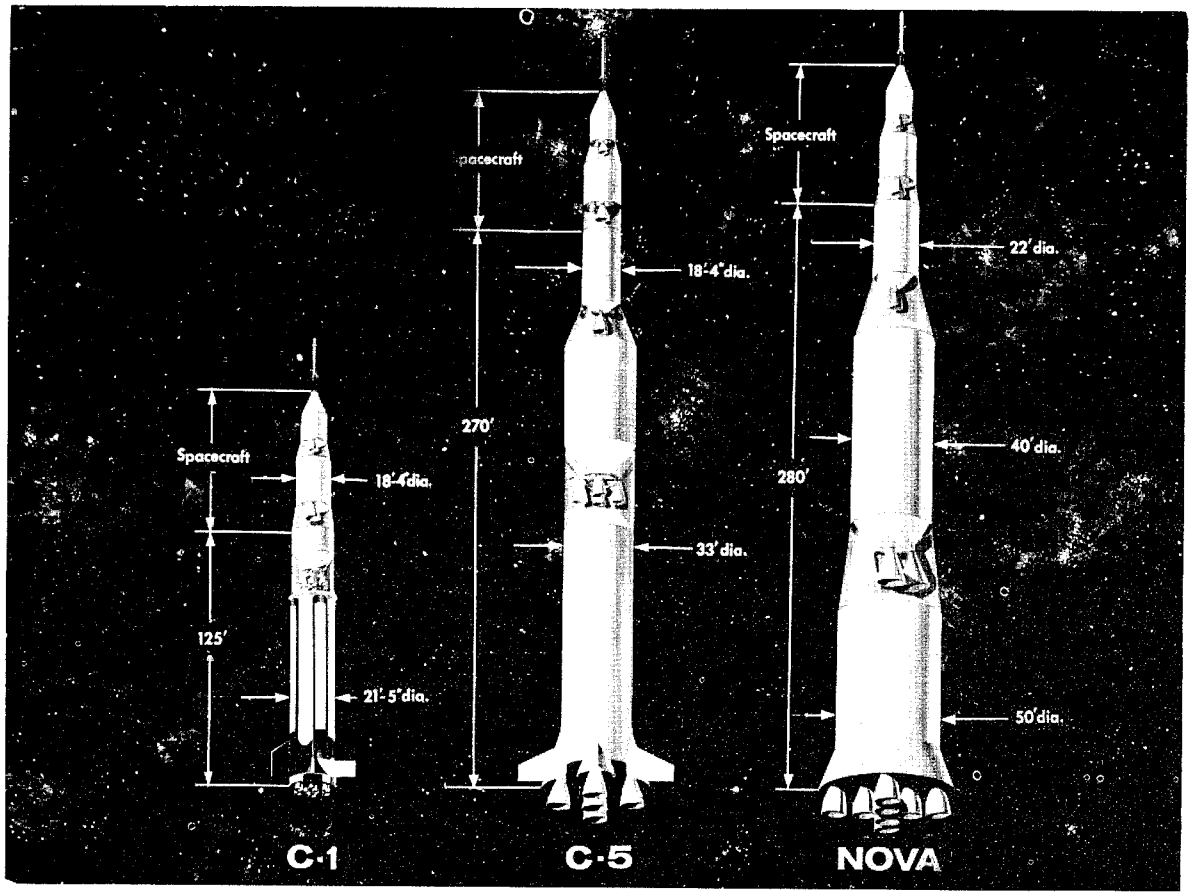


FIGURE 10–25. Saturn-Nova comparison.

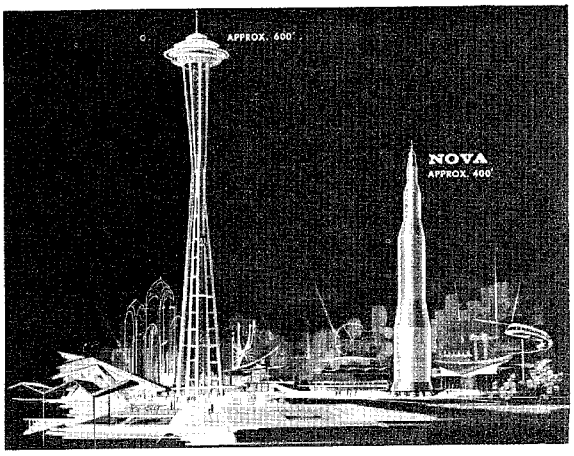


FIGURE 10–26. Comparison of Nova and Seattle space needle.

While the Advanced Saturn will enable the lifting of a specially prepared Apollo spacecraft for a flight around the Moon, the Nova will have power enough to send a fully equipped Apollo spacecraft on a direct flight to a landing on the Moon, with the power to return to Earth. Figure 10–26 is an artist's comparison of the Nova with the Seattle space needle.

Most of NASA's large space carrier vehicles are launched from the Atlantic Missile Range at Cape Canaveral. We have quite a large investment there in real estate and facilities and we are planning more. The two Saturn vehicles which have already been successfully launched were flight tested from the NASA Vertical Launch Facility 34, shown in figure 10–27. VLF 34 occupies 45 acres of 20,000 acres of the Atlantic Missile Range and was completed in June, 1961. The word *complex* is a very good one to describe this facility, for the Saturn launch site is rather complex. The major elements of VLF 34 represent a multimillion dollar investment and include the tallest structure in the state of Florida and the largest self-propelled, movable structure in the world.

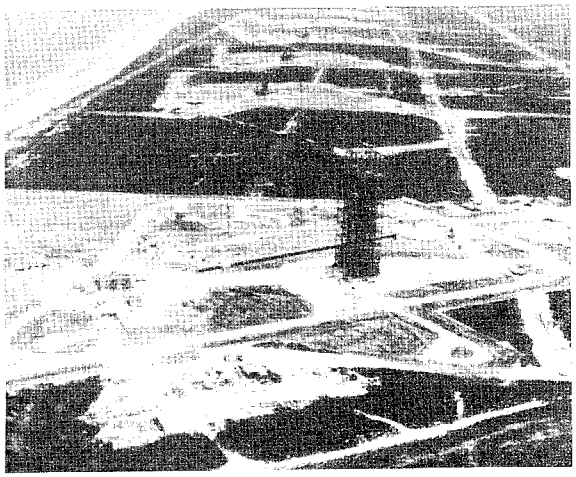


FIGURE 10–27. Vertical launch complex 34.

Starting with the launch control center, the nerve center of the complex, we have a reinforced concrete blockhouse 156 feet in diameter at the base and 26 feet tall (fig. 10–28). The blockhouse is designed to withstand blast pressure of 315,000 pounds per square foot the equivalent of 50,000 pounds of TNT detonating at a distance of 50 feet.

The lower level of this structure (fig. 10–29) is the electrical terminal area and contains the telemetry equipment, and other communications. The upper level has the instrumentation controlling the actual servicing and launching of the vehicle.

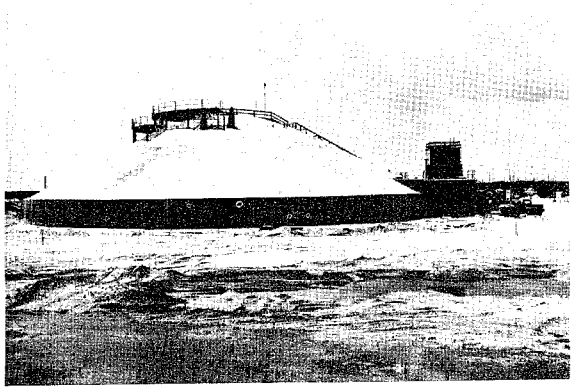


FIGURE 10–28. Blockhouse.

The service structure, used to erect the Saturn on its launcher and to check out the assembled vehicle, is 310 feet high (fig. 10–30). Each of its two supporting legs contains a two-floor building that houses the structure's operating equipment and vehicle checkout apparatus. The structure is mounted on standard gage railroad tracks and can travel at a top speed of 40 feet per minute.

The launching pad, 438 feet in diameter and 8 feet thick, is equipped with launching pedestal, launcher, and flame deflector.

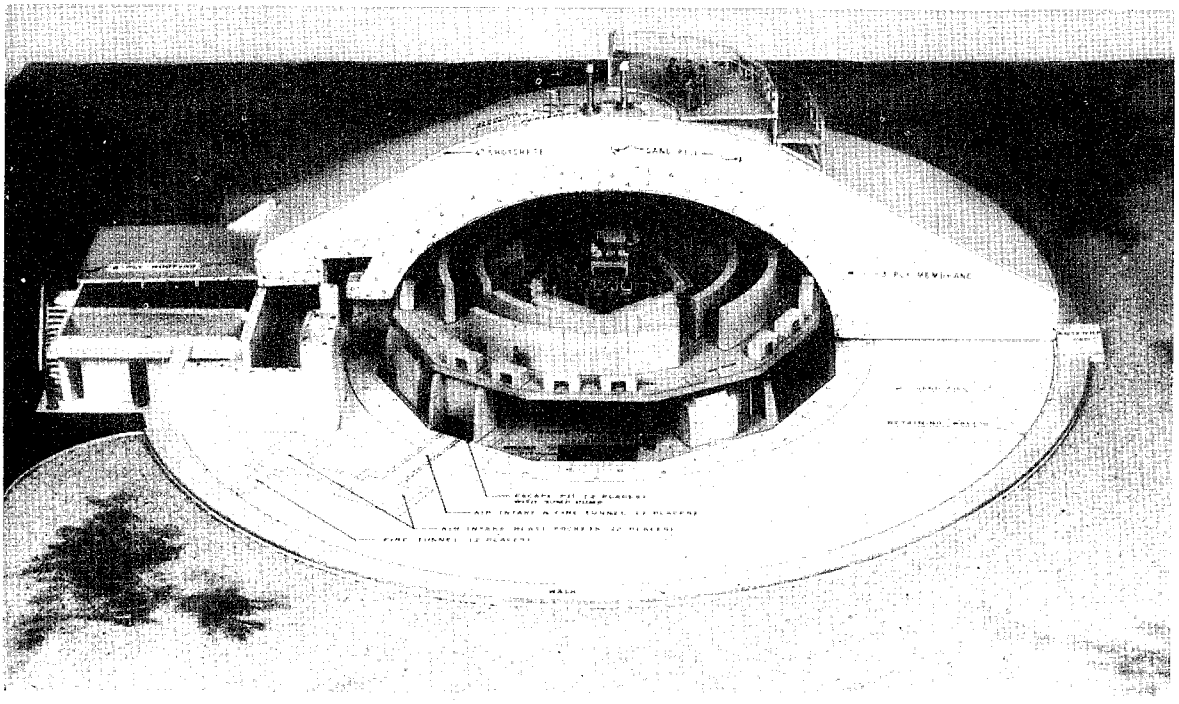


FIGURE 10–29. Blockhouse instrumentation.

An aerial view of Launch Pad 34 is shown in figure 10–31. The pedestal is made of reinforced concrete and is 40 square feet and 27 feet high.

Atop this structure is the eight-arm Saturn launcher. Below the launcher is the rail-mounted flame deflector that splits the 5,000° F flames of the Saturn's exhaust into two horizontal components.

The other major item of equipment on the pad is the umbilical tower adjacent to the launcher pedestal, which contains the electric, hydraulic, and pneumatic lines for supplying each stage. It is at present only 27 feet tall, since we are now firing only inert upper stages. By the time we flight test our first complete Saturn, it will be extended to a height of 240 feet.

Storage facilities associated with VLF 34 include a 125,000-gallon liquid-oxygen storage tank and a 13,500-gallon tank and transfer equipment, a 60,000-gallon PR–1 fuel storage facility and pumping equipment, and a high-pressure gas storage facility for nitrogen and helium. A skimming basin, located on the edge of the launch pad, collects any fuel spilled during fueling operations. Figure 10–32 shows a Saturn on the launch pad.

Vertical Launch Complex 37 is located about a mile north of Complex 34, but unlike Complex 34, it will have two pads served by the same support facilities (fig. 10–33). This arrangement will permit us to launch six vehicles a year rather than four, which is the maximum number of launches permitted by Complex 34.

The major difference between the two launch complexes is in the service structure employed. The structure for Complex 37 will be an open-truss tower with a trape-

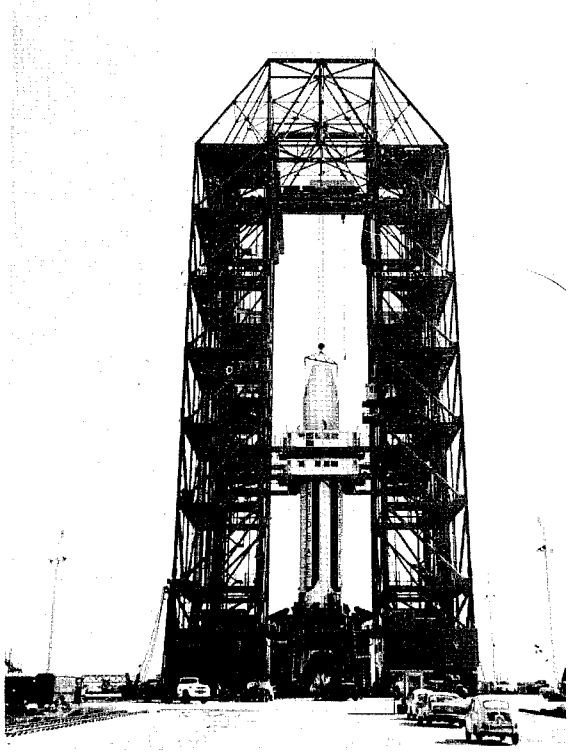


FIGURE 10–30. Service structure.

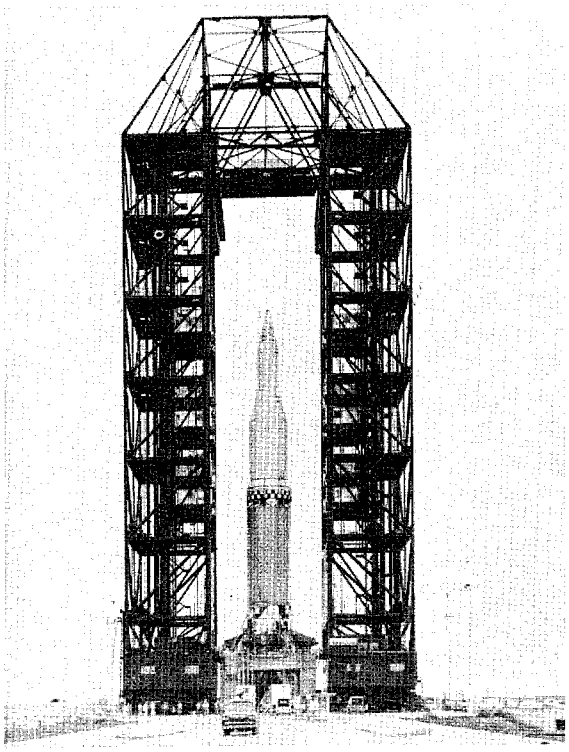


FIGURE 10–32. Saturn on launch pad.

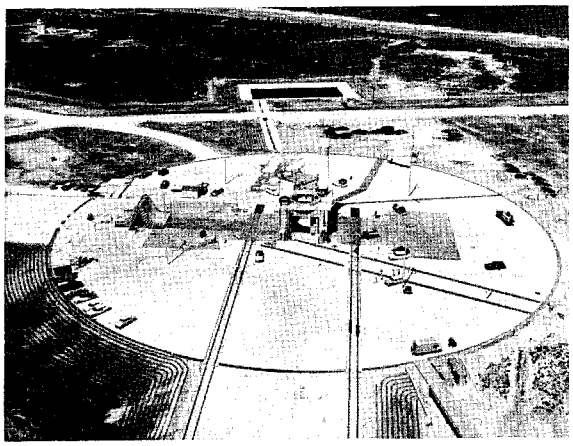


FIGURE 10–31. Aerial view of launch pad 34.

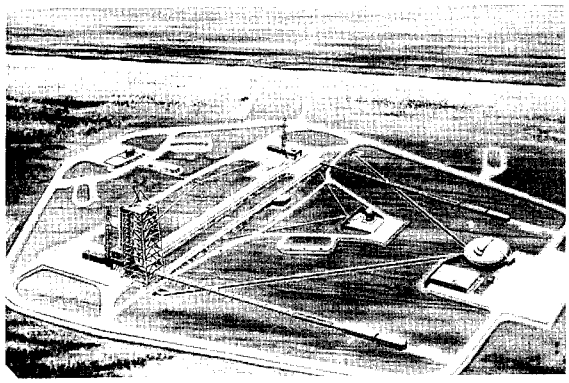


FIGURE 10–33. Vertical launch complex 37.

zoidal shape, the vertical face next to the launcher. A stiff-leg crane atop the structure will be used to erect the vehicle. Platform levels will swing out from the structure to enclose the various stages of the assembled Saturn. This structure, like the one at VLF 34, will be rail mounted and travel on tracks connecting the two launching pads of the new facility. Construction is already underway on Complex 37, and one pad should be completed this year. The first launch is scheduled for next year.

Only slightly less complex than VLF 34 and VLF 37 is VLF 36—our launch facility at Cape Canaveral for the Centaur space carrier vehicle. The blockhouse (fig. 10–34) used with this complex served as a model for those later constructed at the two Saturn launch-

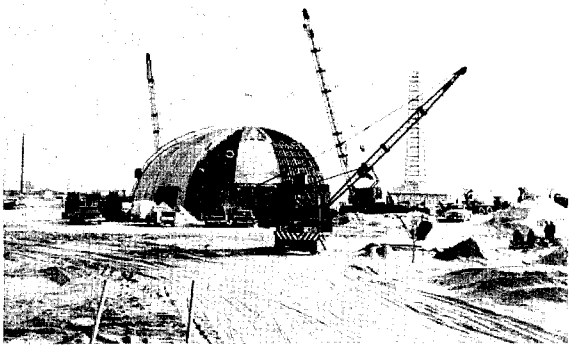


FIGURE 10–34. Construction at complex 37.

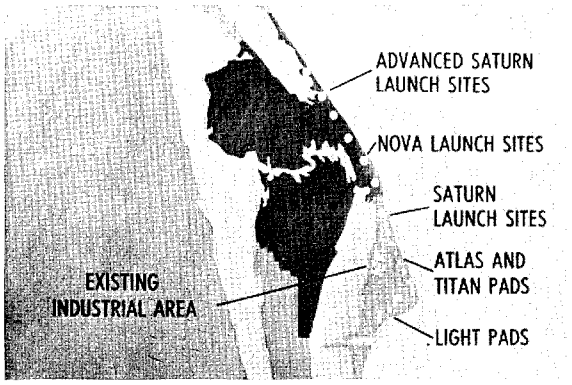


FIGURE 10–35. Land acquisition map at Cape Canaveral.

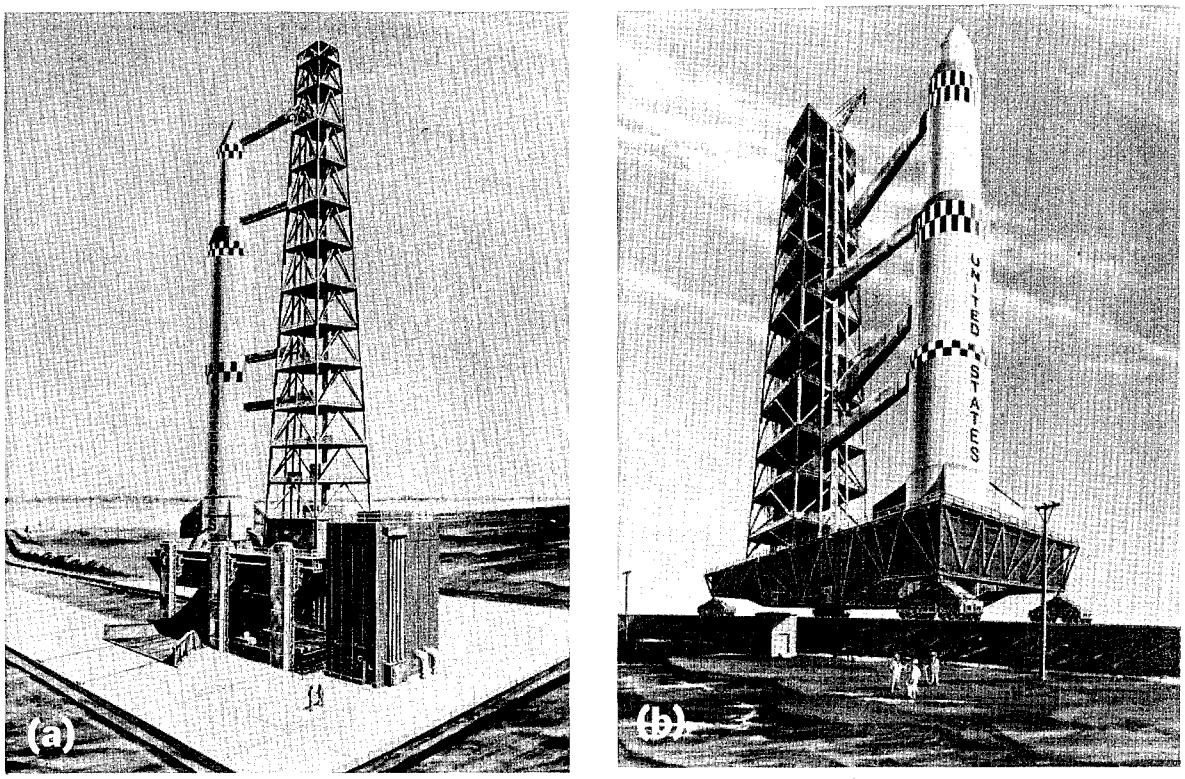


FIGURE 10–36. Concepts of future launching sites.

ing sites. The Centaur launcher and servicing tower are similar to those used with the Atlas–Agena B.

In the future, to handle and launch Nova and the other large space carrier vehicles that will follow Saturn, other launching sites will be built in an area to the north and west of the present sites (fig. 10–35). These new installations will require bold new means of handling extremely large and heavy vehicles. But already we are beginning to plan for the time when we must construct these sites, and a few concepts have emerged. (See figs. 36(a) and 36(b).)

I do not mean to underrate or slight the Pacific Missile Range and its activities in

space carrier vehicle launchings, but NASA has only a very small portion of the space activity at PMR. Through 1964, only 11 NASA launchings are scheduled from this facility and these are primarily Scout and Thor-Agena B launchings. The major NASA installations at PMR are tracking stations for the Tiros weather satellite and tracking and command stations for the Mercury program.

Although the NASA's own launching facility at Wallops Island, Virginia, is comprised of only 100 acres, some very important space-vehicle launches take place there. Generally speaking, the Scout is the largest vehicle that is launched from Wallops. But the Little Joe vehicle tested the Mercury capsule in launches from this site, and atmospheric probes are regularly launched from five special pads there.

In conclusion, I would like to say a few words about the manufacture and testing of large space carrier vehicles. As we were developing Saturn at MSFC, it became obvious that we would need a large fabrication and assembly building when the vehicle went into production. We found such a plant in September of last year: the Michoud Plant, shown in figure 10–37, is located some 15 miles east of New Orleans. This one-story building encloses almost 43 acres and has 1,869,020 square feet of usable floor space. During World War II, Michoud produced aircraft; and during the Korean War, it manufactured engines for tanks.

Within this huge industrial facility the Chrysler Corporation will manufacture the S–1 first stage for the Saturn C–1, producing 20 of them during the length of its contract. Also at Michoud, the Boeing Company will produce more than 25 S–1C stages, the first stage for the Advanced Saturn.

Closely associated with the Michoud operations will be a huge new static test facility to be constructed at Logtown, Mississippi only 35 miles from the Michoud plant. This site will encompass some 142,000 acres, and as many as six static test stands such as the one shown in figure 10–38 will be constructed; these will be capable of testing boosters with thrusts up to 20,000,000 pounds.

Some sociologists and historians have hopefully speculated that space exploration will in time become a substitute for war. They feel that the attempts to explore space may be the idealistic "moral equivalent of war," absorbing man's overexuberant energies, aggressiveness, and imagination, and taxing his resources.

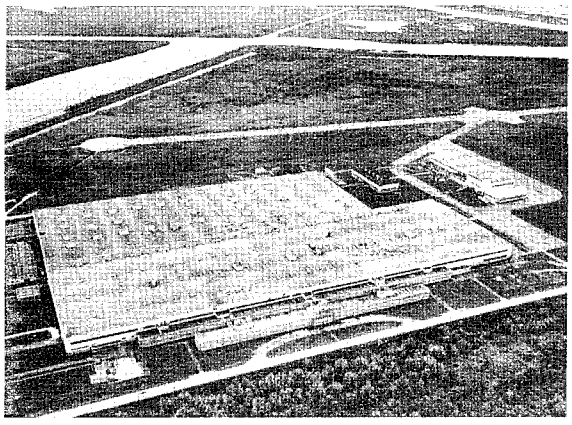


FIGURE 10–37. Michoud ordnance plant.

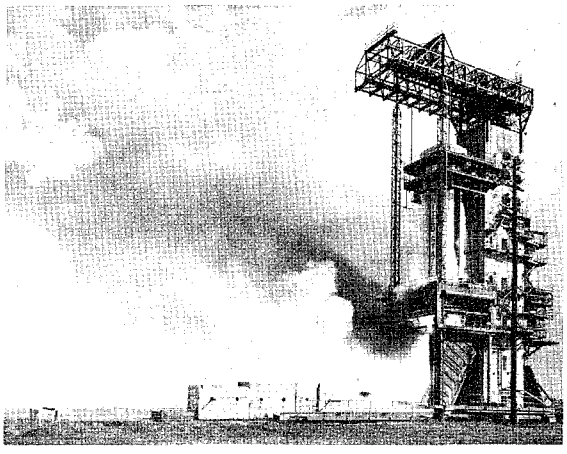


FIGURE 10–38. Static test tower.

Session IV

APPLICATIONS OF SPACE TECHNOLOGY

Chairman: Frank W. Godsey, Jr.

FRANK W. GODSEY, JR., *Consultant to the Administrator of NASA*

Born in Beaumont, Texas, Dr. Godsey has a B.S. degree from Rice University and M.S. and E.E. degrees from Yale University. Formerly president of Electronic Communications, Inc., and a vice president of Westinghouse Electric Corporation; currently, he is sharing time between NASA as a consultant to the Administrator and his duties as President of Space Capital Corporation and as Board Chairman of Dev Tek, Inc. Dr. Godsey has been active for 33 years in scientific engineering and business management, and principally concerned with electronics and aircraft activities.

In Sessions I and II papers and discussions on the space sciences, nuclear and electric systems research, space vehicle research, and also meteorological and communications satellites, with their tracking and data acquisition problems, were presented.

Session III concerned Projects Mercury, Gemini, and Apollo, and a general discussion of launch vehicles and operations.

In this Session, Session IV, still another group of distinguished panelists will present papers about the payloads of the meteorological and communications satellites, what we expect to do with them, and some of their operating and management problems. One of these problems is the Communication Satellite Corporation that will provide worldwide telephone service via the orbiting satellites, as well as global television and high-speed wide-band data and facsimile transmission for everything from weather maps to fast news coverage and instant mail. There are about as many ideas as there are people as to how this company should be organized and operated, who should own it, and a great many other equally difficult questions. The nature of this organization is to be resolved in the Congress, and I am hopeful that out of this session of Congress an objective and realistic bill will issue that will adequately represent the broad interests of the public while at the same time allow the management group to operate with great effectiveness. This will pose a number of tasks. Several of these tasks are familiar: the man-in-space program, meteorological and communication satellites, space probes, and all the associated research and hardware projects.

Still another task arises out of the interesting difference between the space program and every other major program in existence today. Although the space program is far from the largest in the national budget, it is probable that a greater percentage of money is being spent by NASA in space research and development work, as distinguished from the relatively straightforward design and manufacturing and other activities, than in any other effort of the Government. Almost every small or large space project must have new materials, new processes, new engineering and design techniques, and constant improvement, invention, and innovation before achievement is possible. These innovations, new technologies, and new materials are not to be used and then left behind in the fast-moving space program, perhaps only through fortunate circumstance to reappear in nonspace applications. The NASA is charged by Congress with searching out these extra dividends in the form of technological by-products and making them available to industry, agriculture, medicine, the professions, the arts and trades, and for general public use as effectively and as promptly as can be done. None of us is so naive as to believe that the first interplanetary space ship will return from its maiden voyage laden with a cargo of rare spices from the Indies. But the indirect benefits of the space program will add much to the lives of each of us through the search for and the application of these by-products. Work has started on this task and progress is being made, although it is much too early to estimate the total end result.

11. Satellites and Weather Forcasting

By DAVID S. JOHNSON, *Deputy Director of Meteorological Satellite Activities, U.S. Department of Commerce, Weather Bureau*

Mr. Johnson was born in Porterville, California, on June 29, 1924. He attended Reed College and Harvard University and received his A.B. degree in meteorology in 1948 and his master's degree in 1949 from the University of California.

He was formerly employed as Associate Meteorologist with the Pineapple Research Institute of Hawaii and the Hawaiian Sugar Planters Association Experiment Station. During this period he was active in research in the fields of cloud physics and agricultural meteorology, again specializing in instrument development and field experiments.

In 1956 Mr. Johnson came to the U.S. Weather Bureau in Washington, D.C. Until 1958 he served as Chief of the Bureau's Observational Test and Development Center. He has served as Chief of the Instruments and Observations Section, and Assistant Chief and Chief of the Meteorological Satellite Laboratory.

In his capacity as Deputy Director of Meteorological Satellite Activities of the Weather Bureau, he is concerned with the Bureau's programs in satellite research and operations, system development, and management of the National Operational Meterological Satellite System.

Just 2 years ago the first Tiros weather satellite gave meteorologists powerful new eyes with which to view their atmospheric domain. Since that time developments have been rapid. Techniques have been developed for using the satellite observations in day-to-day weather analysis and forecasting. Communications have been improved to increase the availability of the satellite observations throughout the world. Research using the Tiros data is increasing our understanding of the atmosphere and will lead to improved weather observing satellites and application of the resulting data.

The importance of meteorological satellites in weather analysis and forecasting can be appreciated by considering the global nature of weather. The Earth's atmosphere, upon which man's existence and activities are so dependent, is a giant and complex heat engine. Heated by the Sun and cooled by radiation into space, the atmosphere is set into motion in a constant effort to equalize the resulting energy unbalances. To forecast these motions and associated weather, adequately, the meteorologist requires measurements over an area comparable with the scale of motion and with a frequency in space and time compatible with the physics which dictate the forecasting techniques to be used.

Meteorologists have long been handicapped by inadequate measurements of the Earth's atmosphere at any one time. The last century saw the start of the establishment of national weather services to provide forecasts to the public. At that time, the value and scope of the forecasts were severely limited by lack of adequate communications, observing stations, and understanding of atmospheric processes.

Improvements have resulted in weather forecasting as observing networks were expanded geographically and in altitude, and as associated communication systems were developed. Nevertheless, even today, ex-

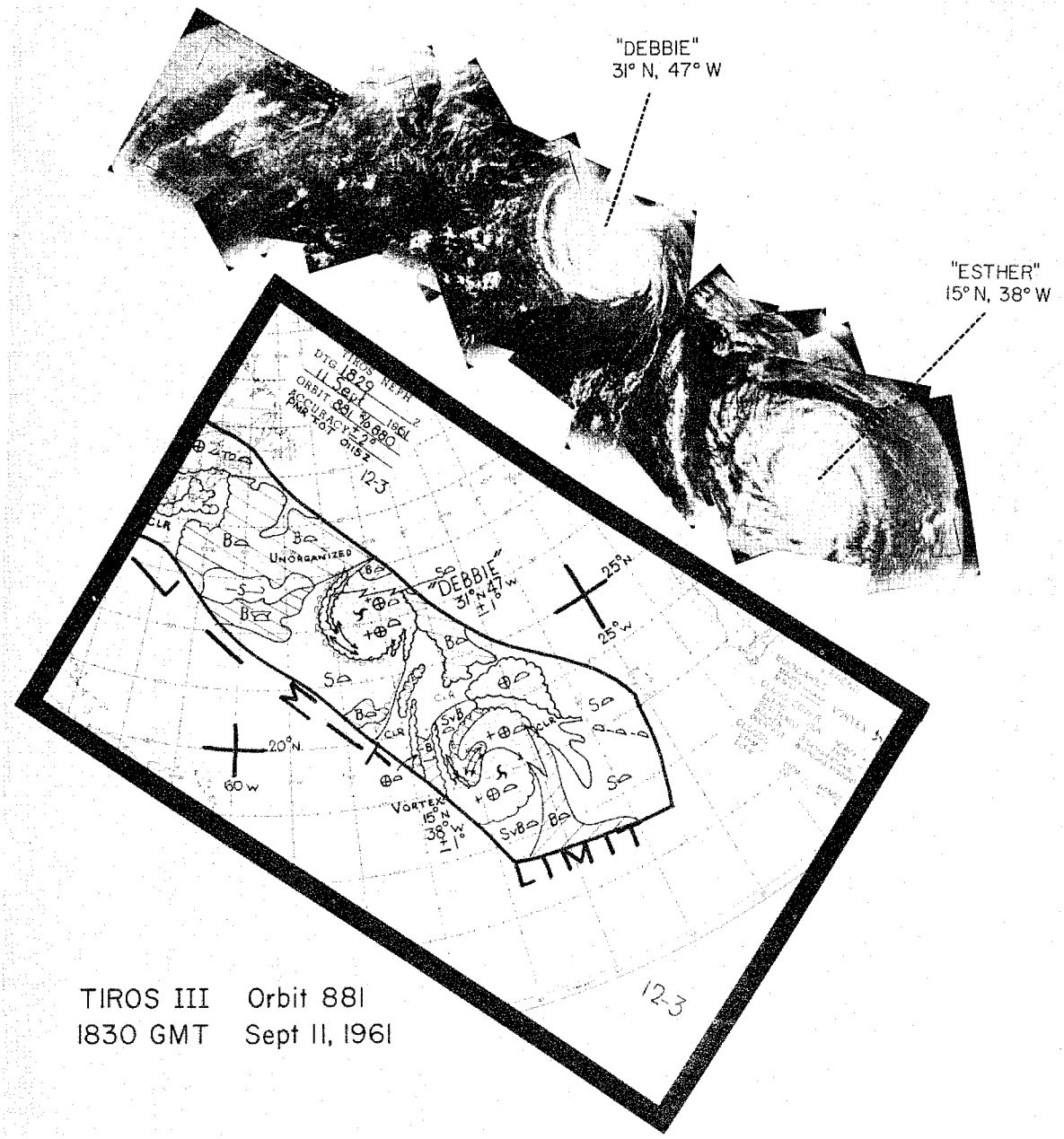


FIGURE 11–1. Tiros pictures and nephanalysis.

clusive of satellite observations, less than 20 percent of the Earth's atmosphere is adequately observed and our communications are becoming overloaded. Weather observations are particularly sparse over the vast oceanic and polar regions of the Earth. Unknown weather disturbances in these regions can have a significant influence on the future weather in distant populated areas. Thus, the accuracy of forecasts of the weather for more than a day or two in advance is quite limited unless these disturbances are observed. Earth-orbiting satellites provide meteorologists with a global observation platform from which measurements can be obtained to fill in these large voids between land-based observing stations and make measurements not obtainable by any other means.

The facilities and techniques for processing the Tiros observations for operational use in weather analysis and forecasting have

been continuously improved since the launch of Tiros I.

Meteorologists stationed at each of the satellite data receiving stations rapidly process the cloud pictures received from the satellite and prepare cloud analyses in which the distribution, structure, and form of the clouds viewed by the satellite are depicted schematically on a map. Such a map and the associated Tiros pictures upon which the analysis is based are shown in figure 11–1. These maps, called nephanalyses, are transmitted by facsimilie circuits to the Weather Bureau's National Meteorological Center in Washington, D.C., where they are utilized in the preparation of current weather maps and forecast charts.

Equipment recently has been installed which also permits the transmission of selected Tiros pictures from the receiving stations to the National Meteorological Center. The actual satellite pictures convey much more detail than it is possible to include in the cloud analyses. Additional equipment is now being installed to permit the transmission of these pictures to certain principal forecast centers also. Cloud mosaics also are being prepared on an experimental operational basis for transmission over this photofacsimilie system.

In addition to their use in the National Meteorological Center, the cloud analyses are relayed by other facsimile circuits to many weather stations in North America for use in pilot briefing and local and regional forecasting.

Until the present time most of the weather services of the world have been unable to receive the satellite cloud analyses by facsimile. However, many of the services can receive weather data from the United States through a cooperative international meteorological radio teletypewriter network. To make use of this means of communication, the satellite cloud analyses are converted to coded form for transmission over this network. Although the information content is reduced considerably in the coding process, this has provided a means whereby many additional countries could obtain the observations in time to be of operational value.

To provide for more adequate international distribution of the satellite observations, the Department of Commerce, Weather Bureau, initiated a few weeks ago a series of experimental international radio facsimile broadcasts beamed to Europe, Africa, Latin America, Hawaii, the western Pacific, and Australasia. Thus, it is now possible for any country within range of these broadcasts and having the proper receiving equipment to obtain the same analyses presently available to weather stations in the United States.

On numerous occasions the Tiros cloud observations have resulted in significant improvements in weather analysis and subsequent forecasts. For example, the Australian weather service used observations from Tiros II to forecast accurately a break in an extended heat wave.

Tiros III photographed tropical storms in all stages of development on more than 50 separate occasions. Five hurricanes were seen in the Atlantic, two in the eastern pacific, and nine in the central and western Pacific. Hurricane Esther was discovered by Tiros III on September 10, 1961. Hurricanes Esther and Debbie as seen by Tiros III on September 11, 1961 are shown in figure 11–1. Many special advisories based on Tiros pictures of these destructive storms were sent to the major United States and foreign centers concerned.

The National Meteorological Center in Washington prepares maps showing the current and forecast weather systems over the Northern Hemisphere. These maps are distributed to U.S. weather stations for their use in preparing specific forecasts. The day-to-day observations by Tiros have provided material assistance to the National Meteorological Center in preparing these maps. Typical examples of such observations from Tiros IV are shown in figures 11–2 and 11–3. A double vortex (storm) system photographed on April 1, 1962, in the western Gulf of Alaska is shown in figure 11–2. A mature storm in the Gulf of Alaska on April 10, 1962, is illustrated in figure 11–3. Satellite pictures of storms, cloud bands, and other large cloud formations have been used for relocation on the weather maps of fronts

FIGURE 11–2. Storm system, western Gulf of Alaska, April 1, 1962.

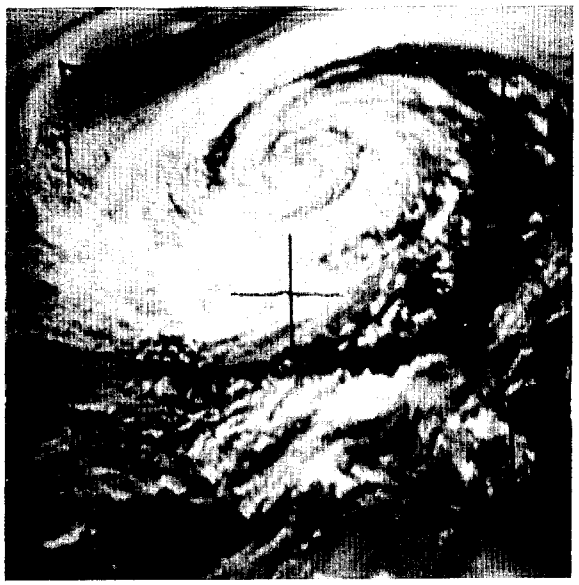


FIGURE 11–3. Mature storm, Gulf of Alaska, April 10, 1962.

and pressure centers, reanalysis of pressure fields, and filling in or confirming analyses in areas having few or doubtful data. However, in one case, on September 6, 1961, a squall line (a long line of thunderstorms) extending from Lake Huron to western Texas was discovered in Tiros photographs. This was a case where conventional observations from a dense network of weather stations failed to indicate an organized severe weather situation.

Satellite observations show considerable potential for application to aviation. A forecaster at the New York International Airport Weather Bureau office writes: "A copy of the [Tiros cloud analysis] depiction was used in lieu of any weather depiction field normally prepared [for the air route between New York and Dakar, Africa] . . . The response from [the airplane] crew members . . . has been enthusiastic . . . There is absolutely no question that the Tiros [analyses] are an invaluable aid in our daily activities."

A significant portion of this conference is concerned with manned space flight. Meteorological satellites are playing their part in this exciting field. Cloud pictures from the Tiros IV satellite assisted the Project Mercury Weather Support Group in preparing forecasts, particularly in areas beneath the spacecraft flightpath where few conventional observations were available. Tiros IV provided pictures of a secondary recovery area as well as a photograph of Astronaut Glenn's actual impact point (the circled cross in fig. 11–4).

While discussing manned space flight, I would like to mention the desirability of considering the inclusion of a scientist on missions of multimanned spacecraft. This scientist should be a keen observer and experimentalist with a strong background in

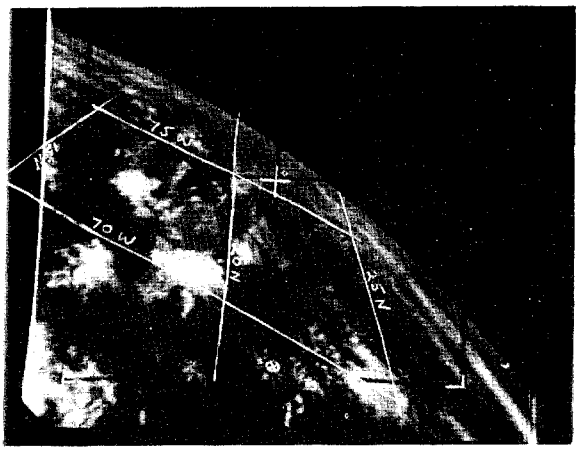


FIGURE 11–4. Tiros IV pictures of recovery area. Circled cross indicates Astronaut Glenn's actual impact point.

meteorology and physics. Aided by carefully selected instrument such a person could contribute substantially to our knowledge of the Earth's atmosphere, high-altitude physics, and, ultimately, the atmospheres of other planets. His experience and intellectual ability, which cannot presently be built into an unmanned spacecraft, would contribute to the design and development of future satellite instrument systems

Severe local storms such as those producing thunder, hail, and tornadoes have been seen on many occasions in Tiros pictures. Such storms frequently are indicated by very bright, discrete cloud images. Such a cloud image is depicted on the northeast shore of Lake Victoria in the Tiros IV picture (fig. 11–5). When frequent observations from weather satellites are available on a regular basis, such as would be provided by the Aeros synchronous satellite now in the planning state, it appears possible that warning of these severe local storms can be effectively improved.

Applications of meteorological satellite observations to other than weather forecasting are developing. For example, with the proper viewing angle the image of the sun reflected off water surfaces is seen in the satellite pictures. The variation in the nature of this image shows promise of indicating sea conditions. Figure 11–5 shows the Sun's reflection from Lake Victoria. The brightest portion of the image is in the southern part of the lake.

Ice fields have been seen in the Tiros pictures. During Tiros IV a joint U.S.-Canadian project called Tirec has obtained simultaneous observations from land, aircraft, and satellite of ice in the Gulf of St. Lawrence and the Great Lakes areas. Figure 11–6 shows two pictures of the Gulf of St.

FIGURE 11–5. Sun's reflection from Lake Victoria.

FIGURE 11–6. Pictures of the Gulf of St. Lawrence area taken on April 3 (left) and April 4 (right), 1962.

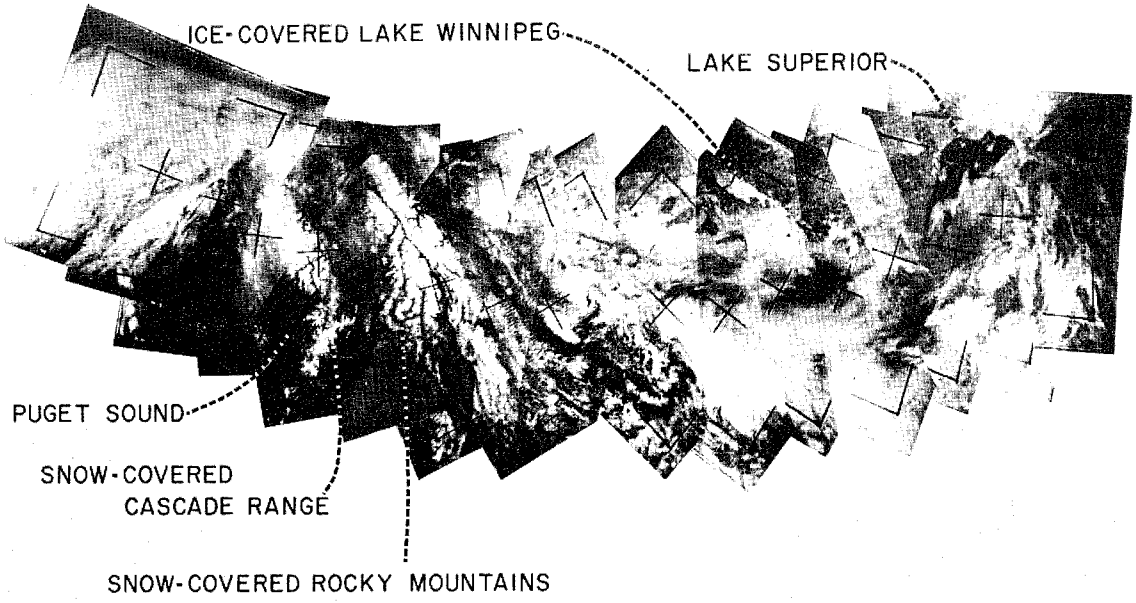


FIGURE 11–7. Tiros IV mosaic, April 11, 1962.

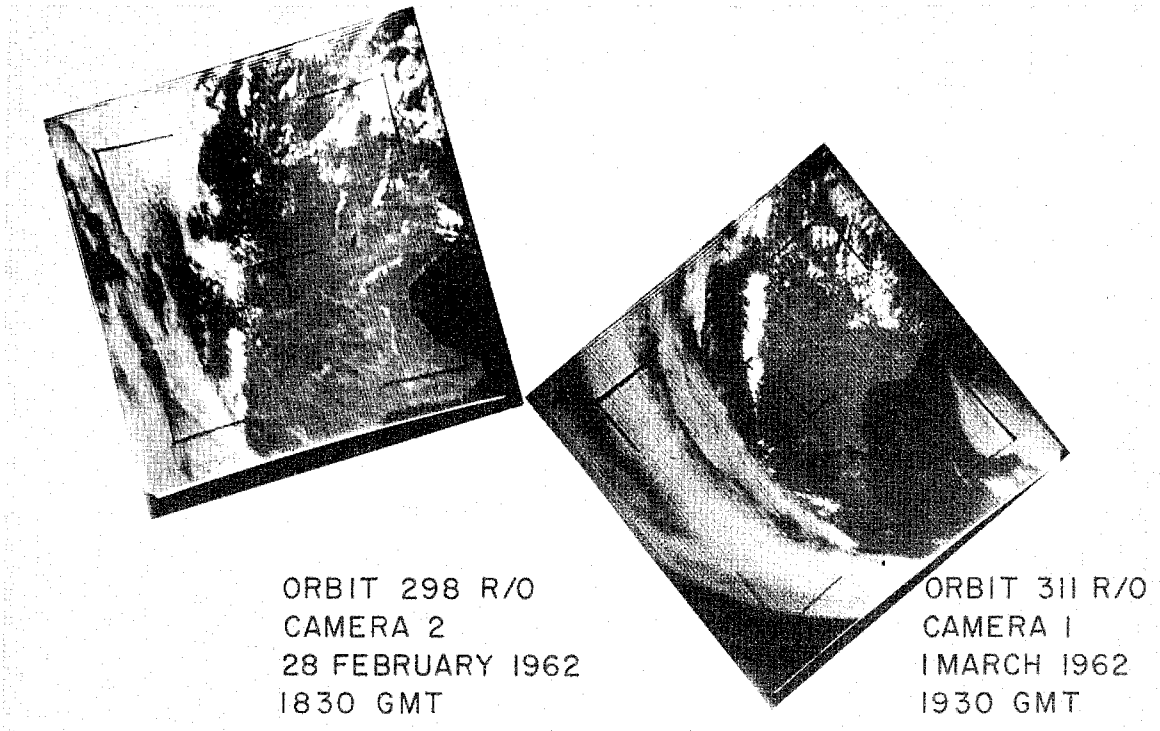


FIGURE 11–8. Tiros IV pictures of southern South America.

Lawrence area taken on April 3 (left) and April 4, 1962. The ice surrounding Prince Edward Island appears the same on both days. The remaining white areas on April 3 are clouds. This project is developing techniques for operational ice reconnaissance by weather satellites which would be of inestimable value to the safety and efficiency of shipping and would reduce the present cost of conventional ice reconnaissance. The satellite pictures also show snow fields which are of value to hydrologists in estimating the snow pack available for hydroelectric generation and irrigation and in forecasting snow melt and runoff. Snow on the Rocky Mountains and the Cascade Range is shown in the Tiros IV mosaic, figure 11–7. Lake Winnipeg is ice covered whereas Lake Superior is generally ice free. Figure 11–8 dramatically depicts southern South America and the Strait of Magellan; snow on the Andes is discernible by examining the two pictures taken 1 day apart.

Figure 11–9 is a particularly good Tiros IV picture of the Middle East showing the Nile River and Delta, Red Sea, Gulf of Suez and Aqaba, and the Dead Sea. Considerable interest has been shown in meteorological satellite pictures of the Earth's surface in geology and mapping.

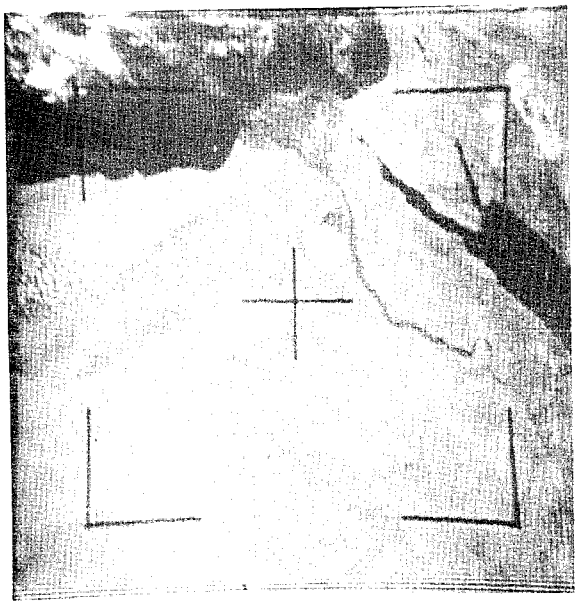


FIGURE 11–9. Tiros IV picture of Middle East.

Study of the solar and terrestrial radiation data obtained by the Tiros satellites already indicates the potential of this class of observation in weather analysis and forecasting. One of the sensors responds to terrestrial radiation in the 8- to 12-micron-wavelength region. The atmosphere is essentially transparent to radiation in this portion of the spectrum so that the measurements obtained are proportional to the temperature of either the Earth's surface or the tops of clouds. Clouds are recognizable as they are generally colder than the Earth's surface. Thus, this sensor in many cases depicts the gross cloud distribution at night when it is not possible to obtain television pictures. It is also possible to obtain a measure of cloud-top height from the readings of this sensor. Such observations contribute to weather analysis and forecasting in the determination of cloud type and the vertical structure and severity of weather systems.

Other radiation measurements permit the evaluation of the Earth's heat budget. The relationship between the time and space variations in the heat budget and the large-scale motions of the Earth's atmosphere is now being studied. This work offers promise of a potential improvement in extended forecasting.

Based on the success of the Tiros program and the potential benefits to mankind of a global weather observing system, the Congress last summer appropriated initial funds to the Department of Commerce, Weather

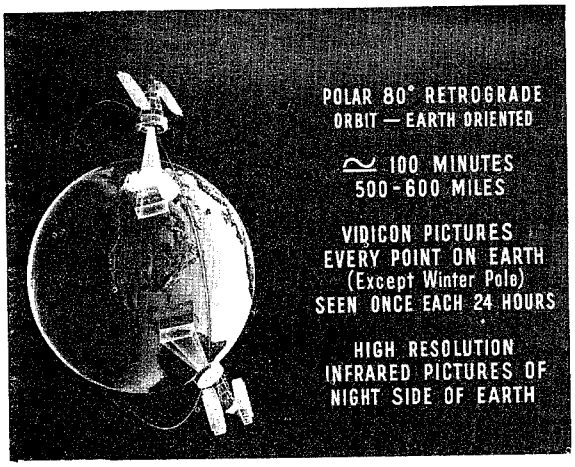


FIGURE 11–10. Nimbus meteorological satellite.

Bureau, for the establishment of a National Operational Meteorological Satellite System. In conjunction with the NASA, additional launches of the Nimbus meteorological satellite (see fig. 11–10) are planned under this program to provide for continuous observational coverage of the entire Earth's weather at the earliest possible time. Additional ground receiving stations, communication facilities, and data processing and analysis facilities are being constructed to provide at least two observations a day of every point on the Earth's surface, to rapidly process these observations, and to disseminate them to forecast centers for immediate operational use.

It is planned that only limited processing and monitoring of the satellite data will be performed at the Nimbus operational satellite receiving stations. More than one-quarter of a billion bits of data will be received from the satellite every 2 hours. The flow of data in the Nimbus meteorological data processing system is shown in figure 11–11.

Wide-bandwidth communications will be used to transmit rapidly all the data from these receiving stations to the Weather Bureau's Meteorological Satellite Activities organization located in Washington, D.C. There meteorologists assisted by high-speed data processing equipment will process the satellite observations in conjunction with conventional weather data and prepare analyses and prognostic charts for both national and international use. The analyzed satellite observations will be distributed by high-quality facsimile equipment.

Improvement of the National Operational Meteorological Satellite System is contingent on the development of new types of satellite measuring techniques as well as on the results of meteorological research from which will evolve new techniques of weather analysis and forecasting.

It is obvious that the advent of meteoro-

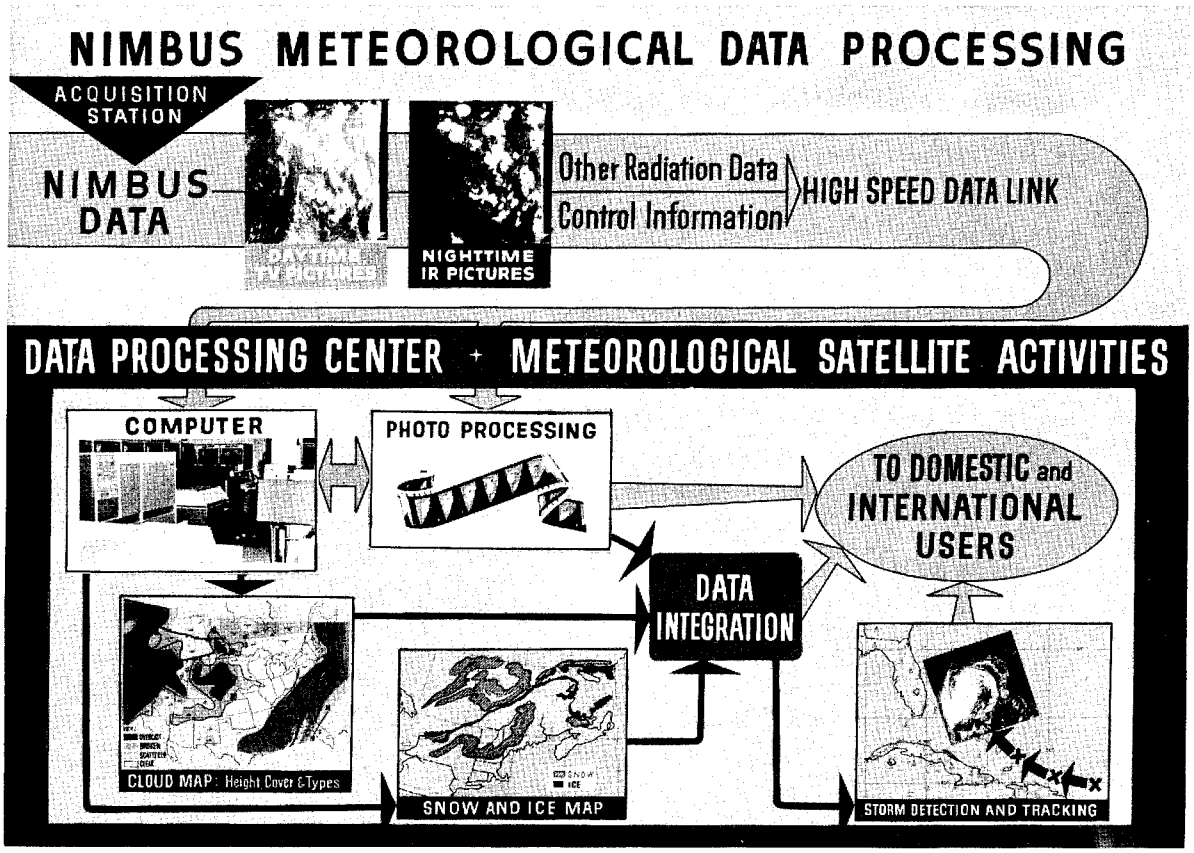


FIGURE 11–11. Nimbus meteorological data processing system.

logical satellites has a strong impact on meteorology throughout the world. This is recognized in the United Nations Resolution Number 1721 and the discussions between the United States and the Soviet Union on cooperation in space activities, both of which include prominent mention of meteorology and weather satellites

In considering international cooperation and use of meteorological satellites, international data communications are of great importance. It is fitting that at this session of the conference both weather and communication satellites, and their international implications, are being discussed. The large volume of data expected from the National Operational Meteorological Satellite System, when added to the ever increasing number of conventional meteorological observations throughout the world, suggests that communication satellites offer the only promise of providing an adequate means for the worldwide exchange and dissemination of weather data and analyses.

12. Low-Altitude Repeater Satellites

By BARTON KREUZER, *Vice President and General Manager of the Astro-Electronics Division, Defense Electronics Products, Radio Corporation of America*

Mr. Kreuzer received his E.E. degree in 1928 from the Polytechnic Institute of Brooklyn and continued in graduate study. He joined RCA in 1928, where he was assigned the responsibility for performing research and development, product design engineering, field engineering, and technical license liaison.

In 1950, after serving the company in various other capacities, Mr. Kreuzer was appointed General Product Manager of the Engineering Products Division, which was involved with a broad variety of defense, broadcast, and industrial electronic systems.

Mr. Kreuzer has participated in a number of programs, including Project Score ("the talking Atlas satellite"), the four successive Tiros meteorological satellites, and Echo I, among others.

He is a Fellow, and former president, of the Society of Motion Picture and Television Engineers; he is a member of Tau Beta Pi, the Armed Forces Communications and Electronics Association, the Air Force Association, the Armed Forces Management Association, the American Astronautical Society, the American Rocket Society, and the Institute of Radio Engineers.

The new perspective that is forced upon us by the Space Age is oddly evident in the title of this paper. The key adjective is "low-altitude," evoking, perhaps, a picture of objects flying just above the rooftops. In the strange new realm of space, however, we are using a different order of measurement. The low-altitude satellites that I shall discuss will be moving in orbits anywhere from a few hundred to more than ten thousand miles above the Earth.

Our ability to boost artificial satellites into orbit around the globe at those altitudes has presented a glittering array of opportunities for entirely new scientific studies and practical services. Among these prospective services, none is more promising in terms of practical application than the use of satellites as communication relays to span the oceans with high-capacity microwave services, including live television, voice, and data transmission.

From the standpoint of telecommunications, space technology has arrived in the nick of time. The present growth rate of international telephone and data communications indicates that we shall be up against a shortage of available channels in another 5 or 6 years unless new high-capacity facilities are provided.

We have kept abreast of the growing demand in our national overland services by moving up to microwave frequencies and employing wide bands that accommodate thousands of voice or data channels as well as the wide-band signals of television. But these services have required chains of repeater stations on towers 20 to 30 miles apart to maintain the strength of the signals and to bend them over the curve of the Earth. Until now there has been no practical way of carrying wide-band microwave signals in similar fashion across the oceans.

Space technology is about to put the key into our hands. High-capacity microwave repeater equipment is small enough and light enough to be carried in satellites that can be launched by presently available rockets.

Such repeaters, moving in orbits a thousand or so miles up, can be "seen" directly and simultaneously by receiving and transmitting antennas on opposite sides of the ocean. As long as one of the satellites remains within direct line of sight of both stations, communications may be made through it in a single hop just as effectively as though there were a chain of relay stations extending across the ocean at ground level.

So far, this principle remains in the realm of highly developed theory for which there is no experimental proof. But the proof is now in the making, with test programs that will begin this summer with low-altitude experiments, including transatlantic television and other microwave transmissions. One of these experiments is Telstar, the subject of a subsequent paper. The other is NASA's Project Relay, for which the Radio Corporation of America is designing and building the experimental satellites.

The Relay satellite is an interesting example of the present state of the art in electronic communications as applied to the special requirements of launching and operation in the harsh environment of space. Its mission is two-fold: first, to demonstrate the feasibility of transoceanic wide-band microwave relay through a satellite repeater, and, second, to collect data that are badly needed by systems and design engineers for the development of any practical operating communications satellite system.

The intended orbit of the Relay satellite will range in altitude from about 800 to 3,000 miles. For communications experiments, this orbit will permit wide-band television, voice, and data transmission between points in a broad area of coverage, as indicated in figure 12–1. The initial experiments during the summer of 1962 involve ground stations in the northeastern United States, England, France, and Brazil. In subsequent Relay experiments in 1963, additional stations in Germany and Italy also are expected to participate.

The orbit also has been planned to collect vital data. It will carry the Relay satellite through the Van Allen radiation belt, permitting the study of radiation effects upon the electronic equipment and especially upon the solar-cell power supplies which cover its outer surface (fig. 12–2).

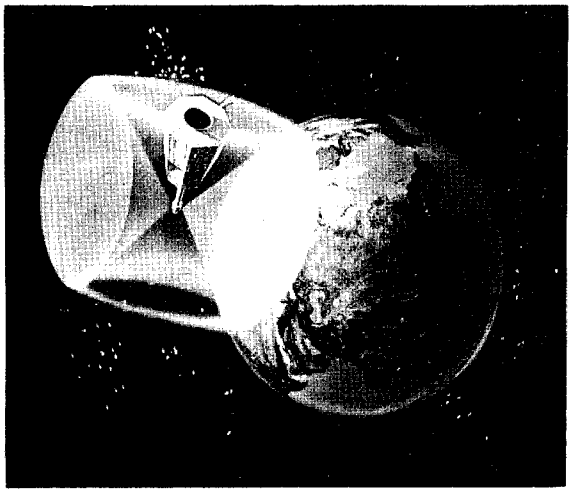


FIGURE 12–1. Relay spacecraft communications coverage.

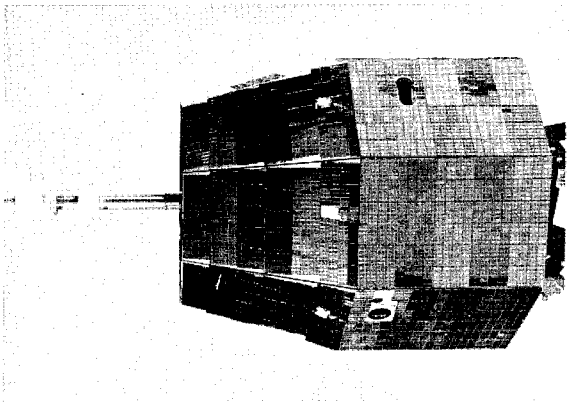


FIGURE 12–2. Project Relay communications spacecraft.

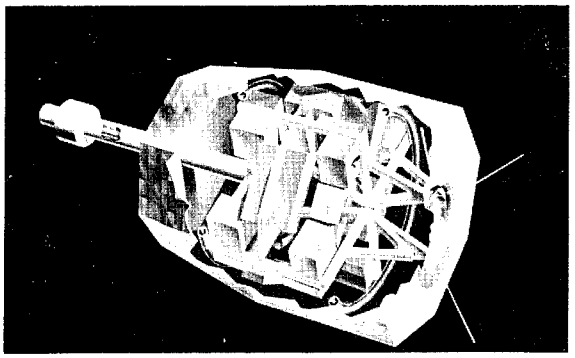


FIGURE 12–3. Relay satellite assembly.

The design of the Relay satellite, shown in figure 12–3, demonstrates the relative ease

with which repeater equipment can be packaged for launching into space. Actually, there is a considerable amount of ingenuity in this design, as will appear in a moment. The important point here is that the complete package is only 27 inches in diameter and 51 inches long, including the pipelike wide-band antenna protruding from one end. Yet the satellite contains complete duplicate repeater systems to provide assurance of maximum reliability. Each is capable of receiving, amplifying, and retransmitting a television channel or 24 voice or data channels. These signals are transmitted with 10 watts of radiated power—a strength which permits reception with an 85-foot dish antenna. The entire satellite, even with its redundant systems, weighs only about 155 pounds.

One of the more interesting aspects of the project has been the decision to avoid new and untried equipment: in other words, to design the satellite repeater to the greatest extent possible with proven components in order to focus the experiment upon questions of space technology without adding uncertainties that would arise with electronic innovations. As a consequence, the principal problems of design have been those of adapting familiar electronic techniques to a new environment.

An illustration is the wide-band transmitting and receiving antenna—the pipelike structure extending from one end of the cylindrical package. A closeup of the antenna is shown in figure 12–4. The problem here was to fit an antenna of suitable power and radiation characteristics into the limited space available in the fairing of the Thor-Delta booster. The result was this design, radiating in a circularly polarized, doughnut-

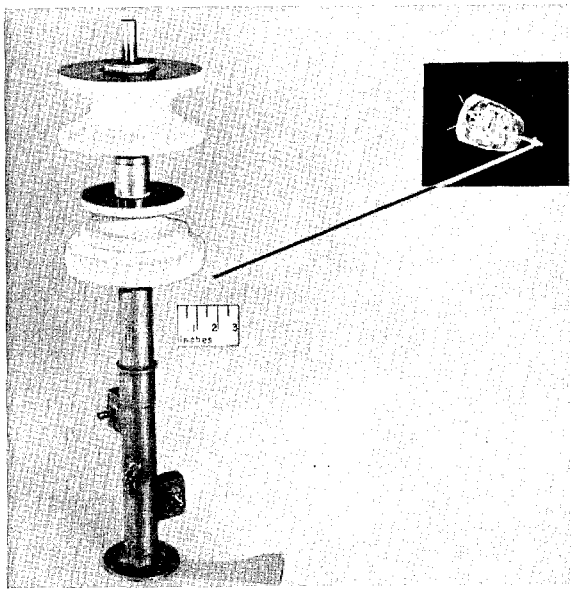


FIGURE 12–4. Project Relay wide-band antenna.

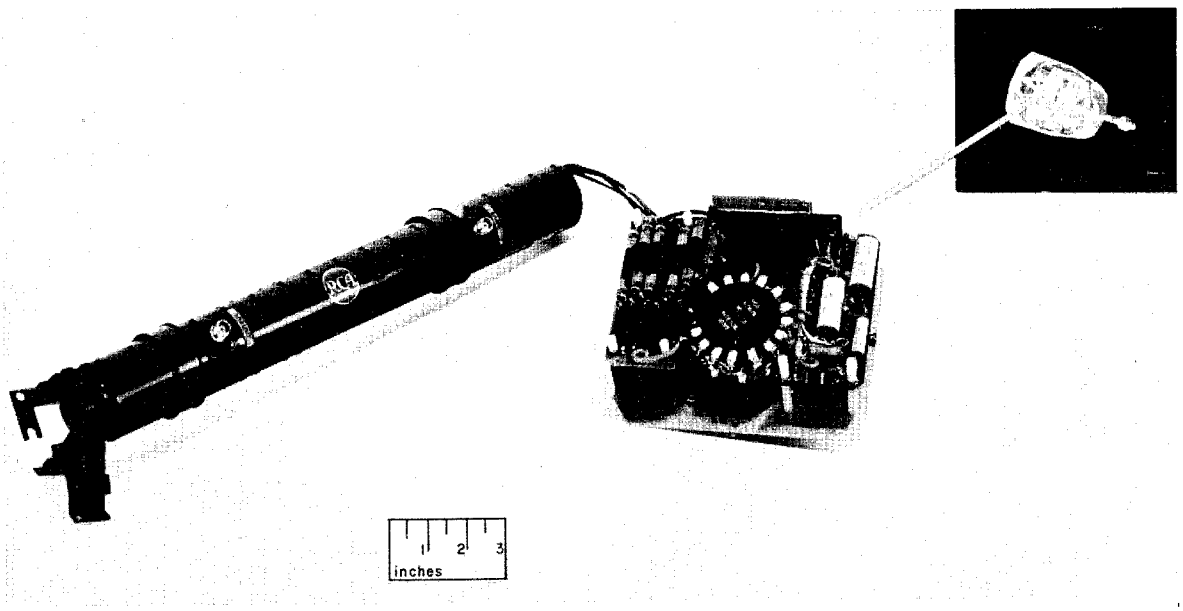


FIGURE 12–5. Project Relay traveling wave tube and power supply.

shaped pattern that is symmetrical about the spin axis of the satellite itself, yet extending only 19 inches beyond the main body of the satellite.

Another adaptation of known techniques is the traveling-wave tube amplifier (fig. 12–5). The desired performance required 10 watts—and there was only one tube available to provide this output in the particular frequency range of the Relay experiment. This was an RCA tube which was scaled for this specific purpose—and when the adaptation was completed, the result was a device with the extremely low weight of 2¾ pounds with a long-life reliable design.

One of the purposes of the Relay experiment, as previously mentioned, is to gather data on radiation effects. This is an area of major uncertainty—particularly in relation to the solar-cell power supply. In the face of this uncertainty, the Relay satellite has been designed to accommodate the greatest possible area of solar cells. The result is an array of 8,215 cells capable of initially producing some 50 percent more power than is required to run the equipment in the satellite—an output of 68 watts, as against an average requirement of 45 watts. Furthermore, the cells are covered with a 60-mil thickness of quartz for added protection against damage from high-velocity electrons in space. There is no present solution to the damage caused by high-velocity protons.

A detailed examination of many of the satellite electronic subsystems, important as they may be to the correct functioning of the mission, does not seem justified since in external appearance they are rather conventional. However, the specially designed thermal controller shown in figure 12–6, which is operated by an expanding liquid system, may be of interest. This controller is used to supplement the passive thermal control elements in keeping the temperature within the satellite suitable for proper operation.

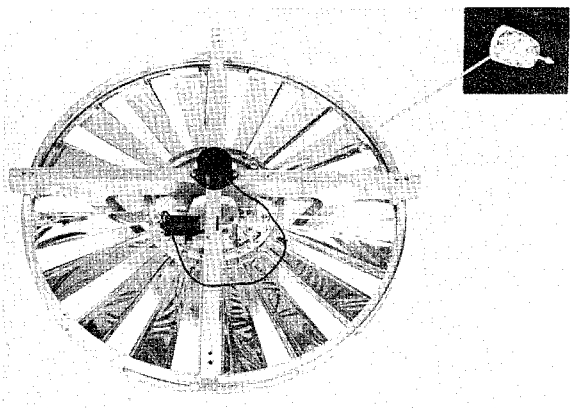


FIGURE 12–6. Project Relay thermal controller.

The physical specifications of the system are as follows:

Weight, lb	150
Duplicated equipment	Wide-band receiver
	Wide-band transmitter plus power supply
	Telemetry transmitter
	Command receiver
	Command decoder
	Beacon
Attitude contol	Provided
Thermal control	Passive plus one controller
Access to subassemblies	Full
Wide-band antenna weight, lb	2

The operational characteristics are given in the following table:

Frequency, kmc:	
Up	2
Down	4
Bandwidth, mc	3
Dynamic range, db	40
Voice channels:	
Capability	24
Actual	12
Television ground reciver:	
Required: type	Cooled parametric
Noise temperature, °K	150
Traveling wave tube:	
Power, w	11
Weight, lb	3
Power radiated, w	10

The Relay ground-station parameters are given in the following table:

	Wide band	Narrow band
Antenna gain:		
Transmitting, db	50	42
Receiving, db	58	51
System noise temperature, °K	50 to 175	420
Receiving-system sensitivity:		
TV, dbm	—95	
Voice, dbm	—94	—104
Transmitter modulation:		
Power output, kw	10	10
Bandwidth at ±1 db, mc	14	1.0
Preemphasis	C.C.I.R.	C.C.I.R.

These stations will be located in the following countries:

Worldwide	NASA minitrack network
United States	Mojave, Calif. (control station)
	Wallops Island, Va. (control station)
	Andover, Me.
	Nutley, N.J.
England	Goonhilly, Cornwall
France	Pleumeur-Bodau, Brittany
Germany	Weilheim, Bavaria
Italy	Fucino
South America	Rio De Janeiro, Brazil

The orbital characteristics are shown in the following table:

Orbit:	
Perigee, nautical miles	800
Apogee, nautical miles	3,000
Orbit plane inclination, deg	54
Average daily contact time:	
(Minimum antenna elevation 7.5°)	
First 30 days, min	97
First 90 days, min	122
First 180 days, min	124
One year, min	76

It is significant to note that the satellite is spin stabilized with its spin axis in the plane of the orbit.

Once the satellite is in orbit, the usefulness of the experiment is greatly related to its operating life. Careful estimates, which we believe have been conservatively made, provide the reliability figures displayed in the following table:

System	Probability of survival	
	1 month	1 year
Wide-band transmission subsystem	0.933	0.792
Telemetry transmission subsystem	0.952	0.434
Overall communications	0.950	0.427

The figures for the overall system include the encoder with its 5,100 parts.

The Relay satellite, like the other experiments scheduled during 1962 and 1963, represents a vital first step toward future operational communications satellite systems. It is yet too early to predict the ultimate nature of our worldwide relay services. Aside from experimental systems, when one considers a global operational satellite communications system, both the requirements of economy and of integration with domestic and international communication carriers must be examined. Such an examination produces arguments today in favor of a synchronous system employing satellites in 24-hour orbits over the equator. At the same time, we are continuing to study possible variations of the low-altitude approach in order to achieve a practical solution of its principal problems.

An elementary version of such a concept is shown in figure 12–7, indicating a possible manner of multiple launch of active-repeater satellites. Without further sophistication, such an arrangement would result in random distribution of the satellites as shown in figure 12–8.

An improved concept is represented in figure 12–9 in a multiple-phased system which seems to offer several attractions. In this concept, we would employ twelve satellites, launched into orbits 12,000 miles above the Earth and spaced precisely from one another to assure continuous service between

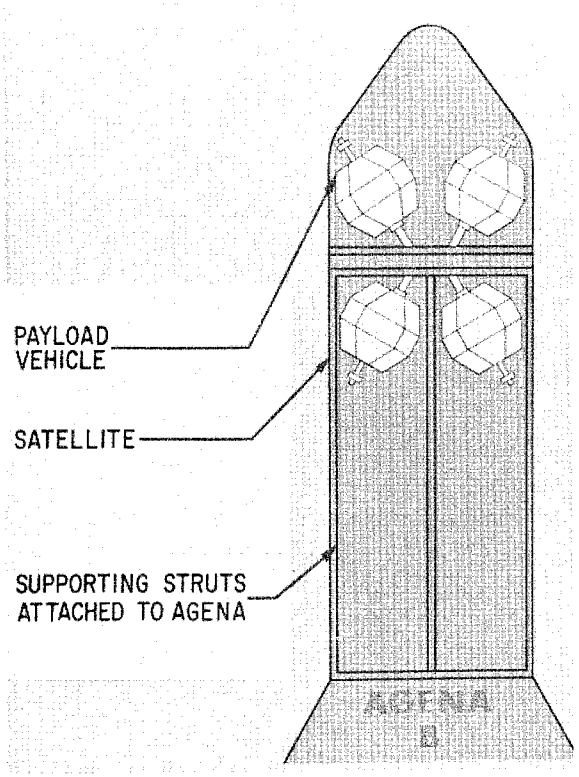


FIGURE 12–7. Multiple launch.

any two points. This is potentially a far more economical approach than the random placement of a larger number of satellites to assure continuous service.

Looking to the long-range future, it seems likely today that world requirements for communications will grow to such an extent that several satellite systems will be needed to satisfy the demand. Thus, at this present very early stage of development, we shall be well advised to pursue a variety of programs, both with low-altitude and with synchronous techniques. We may very possibly have need for multiple systems incorporating both of these principles and others as yet unexplored.

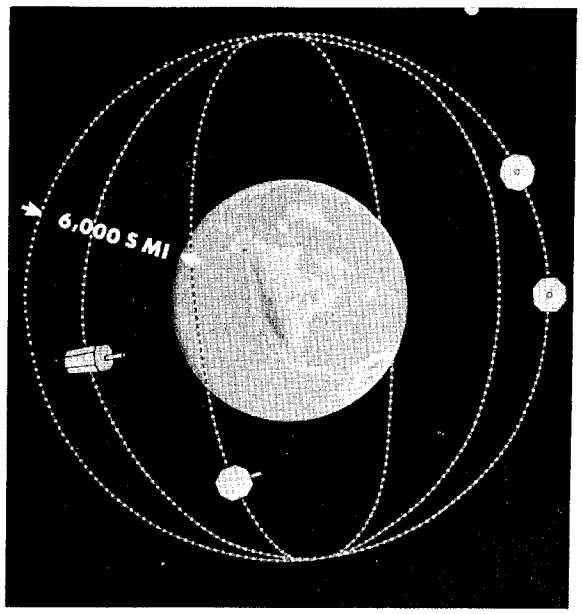


FIGURE 12–8. Satellite orbital system.

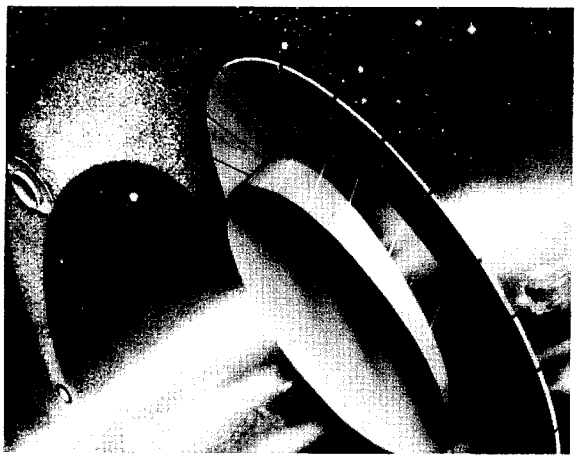


FIGURE 12–9. Multiple-phase stabilized communications satellites.

13. Telstar Project

By JEAN H. FELKER, *Assistant Chief Engineer of the American Telephone & Telegraph Company*

Mr. Felker was born in Centralia, Illinois, March 14, 1919. He received a B.S. degree in electrical engineering from Washington University in St. Louis, Missouri, in 1941. After his discharge from the Army Signal Corps, he joined the Bell Telephone Laboratories in 1945.

He was in charge of the group at Bell Telephone Laboratories that developed TRADIC the first transistor digital computer. At Bell, he has served as Director of Special Systems Engineering and Transmission Engineer.

Mr. Felker has served as Chairman of the IRE Professional Group on Electronic Computers. In 1960, he was elected a Fellow of the Institute of Radio Engineers.

Telstar is the project of the American Telephone and Telegraph Company to demonstrate the relaying of transoceanic telephone service and live television via satellites. It is really much more than that. It will be a calibration of the space environment. We expect that it will tell us a great deal about how to achieve long-life reliable operations in space. This information should be of value to the designers of other kinds of satellites as well as communcation satellites. Most of all, we hope that through our cooperative efforts with NASA the Telstar experiment will be a significant step towards the creation of a commercially operable satellite communication system.

The first Telstar satellite is of necessity a low-altitude satellite. This fact should not be taken to indicate that the Bell System prefers low-altitude to medium-, high-, or other-altitude satellites. We believe that a medium-altitude satellite system could be engineered with reasonable confidence at this time. Whether the first commercial system will be medium-altitude, high-altitude, or a combination of both will depend upon the outcome of a number of experimental programs of which Telstar is only one. This first Telstar satellite is shown in figure 13–1. Telstar is roughly spherical with a diameter of 34½ inches. It weighs about 170 pounds. Some of the 3,600 solar cells that are mounted on the surface of this microwave repeater can be seen. Also shown are various isolated cells and other devices mounted more or less at random on the satellite. Those

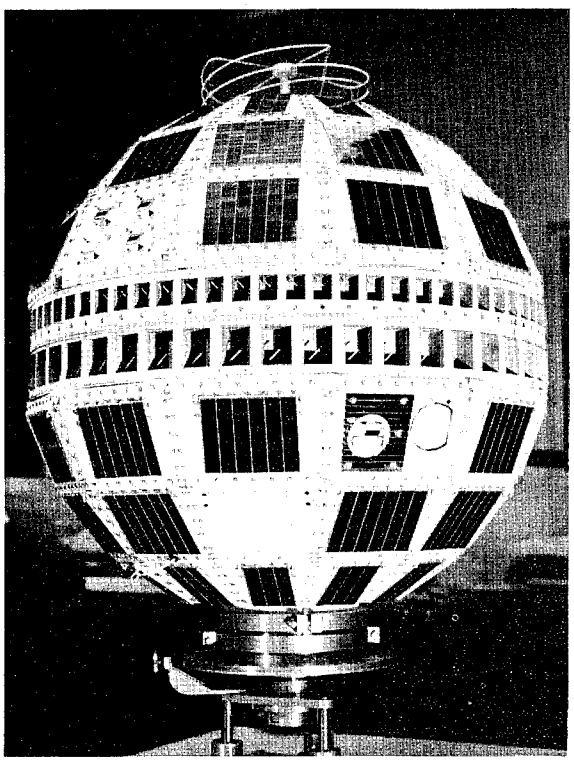


FIGURE 13–1. Telstar satellite.

are sensors used to gather data about the space environment. Of the thousand transistors in Telstar, about 94 percent are used in the environmental experiments and the associated telemetering equipment.

The average power available from the solar cells as the satellite swings around the Earth, in and out of sunlight, is 9 watts after 1 year in orbit. The battery, charged by the solar cells, can supply a peak power of 32 watts. The microwave communication channel can be turned on and off from the ground via a command channel at 120 megacycles. There is also a 136-megacycle beacon transmitter in the satellite which is used for tracking and telemetry.

The satellite receives broad-band microwave signals from the ground in the 6,000-megacycle common-carrier frequency band. This is the same band in which our TH ground microwave repeaters, among others, work. The receiving antenna is the band of slots just above the middle of the satellite. The satellite transmits to the ground in the 4,000-megacycle common-carrier band. This is the band in which the TD2 ground microwave systems operate. As can be seen in figure 13-2, the microwave plumbing fills much of the space inside the satellite. All the electronic apparatus is mounted inside a sealed canister, except for a few amplifiers which have to be mounted close to particle counters on the surface of the satellite for signal-to-noise reasons. A further idea of the construction of the satellite can be obtained from figure 13-3 which shows the canister without its cover.

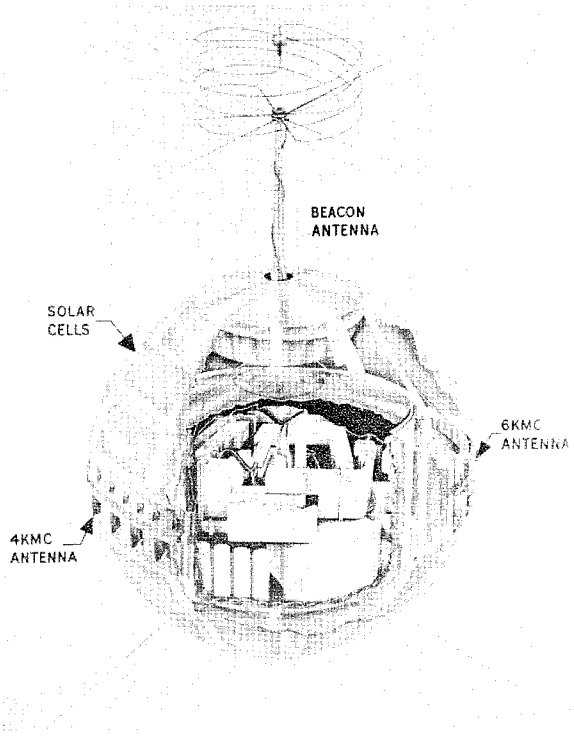


FIGURE 13–2. Artist's cutaway sketch of satellite.

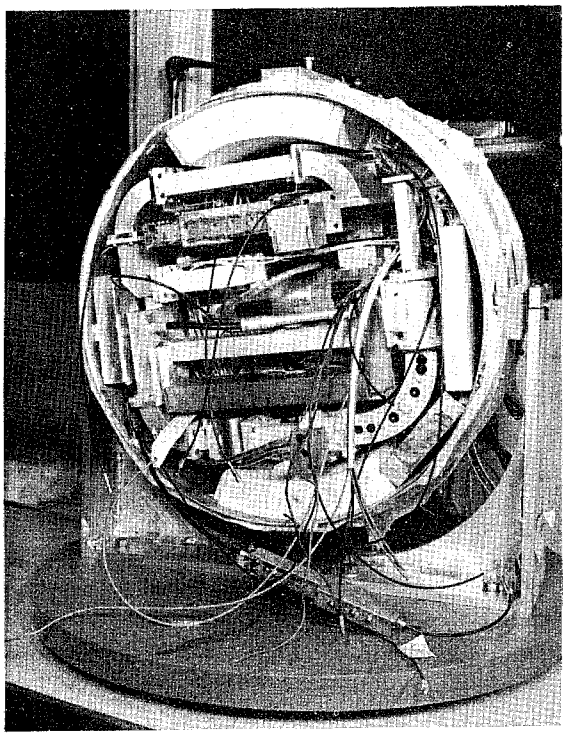


FIGURE 13–3. Canister without its cover.

Figure 13-4 shows two lower hemispheres of Telstar satellites in the process of assembly. The central ring into which the canister is slipped can be clearly seen. The designers faced an interesting problem when they had to decide how to mount the canister firmly yet flexibly inside the satellite. The solution adopted was to lace two rings inside the cylindrical frame with nylon cord. The canister was then solidly fixed to the two rings. Some of the lacing can be seen in the picture. Apparently, despite all the advances modern technology has made, there is still a place for a good strong piece of string. Before the canister is welded shut, it is filled with a foamlike material to provide support

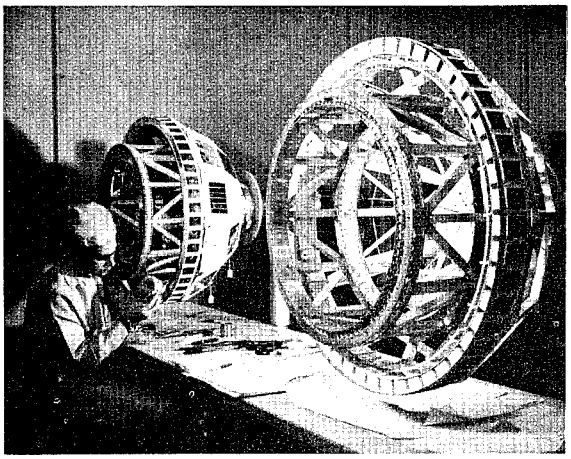


FIGURE 13–4. Lower hemispheres of Telstar satellite in process of assembly.

and stability for electronic components which include, in addition to the traveling-wave tube, a thousand transistors and about 1,500 diodes.

The mechanical design just described was dictated by the desire to achieve long life in our first satellite. Our aim throughout the design process has been to produce a satellite whose successful operation would be a big step towards demonstration of the techniques required for a commercially operable system. With all the parts embedded in foamlike material and the whole assembly sealed in a welded canister, any changes or modifications to the satellite are difficult and time consuming. In a device of this complexity and construction, the possibility for last-minute adjustments is as thin as the atmosphere 3,000 miles up.

In this paper, I have concentrated on the canister and its contents and may have left the impression that the canister contains the whole works. Actually, there are so many particle counters and other devices outside the sealed can that it is necessary to make over 100 electrical connections, all soldered, between the canister and the rest of the satellite. These connections are in addition to the three coaxial connections to the three antennas.

Some information on the electrical design of the microwave repeater may be of interest. The traveling-wave tube is operated in its linear region and puts 2½ watts into the slot antenna. The traveling-wave tube is the only vacuum tube in the satellite. The various microwave frequencies needed in the frequency conversion processes in the receiver are generated entirely by solid-state devices. Crystal controlled transistor oscillators generate basic frequencies at 17.34 and 15.94 megacycles. These frequencies are then sent through frequency multipliers which generate microwave frequencies of 2,220 and 4,080 megacycles. The 4,080-megacycle energy is sent through the traveling tube along with the communication channel and amplified by the tube to supply a hot source of microwave energy. Some of this is put on the 4,000-megacycle antenna and used by the precision tracker and the vernier automatic tracker. Some of the energy is used in an up converter to move the output of the IF amplifier—centered at 90 megacycles—up to the 4,000-megacycle band. A portion of this energy is also beat against the 2,200-megacycle energy to serve as a local oscillator source to operate the down converter which shifts the 6,000-megacycle wide-band frequency-modulated signal received from the ground to a band which can go through the 90-megacycle IF amplifier. By the use of such techniques, the entire microwave receiver and transmitter is realized with only 36 transistors, 93 diodes, and one traveling-wave tube.

A Telstar satellite mated to the third stage of a Delta launch vehicle is shown in figure 13-5.

The elliptical orbit will rise as high as 3,500 miles and will sink as low as 575 miles. It will be inclined at an angle of 45° to the equator. The period of the orbit is expected to be 158 minutes. As the days go by, the intervals for which the satellite will be mutually visible between the U.S. and Europe will vary. Twice a year the cycle will repeat. The largest interval of mutual visibility will be about 37 minutes. Thirty percent of the passes will supply an interval greater than 15 minutes.

Some of the initial transmission tests will be made from the Bell System's ground station at Andover, Maine, to the satellite and back to Andover. About one-third of the orbits will supply useful periods for this purpose of greater than 45 minutes. We also

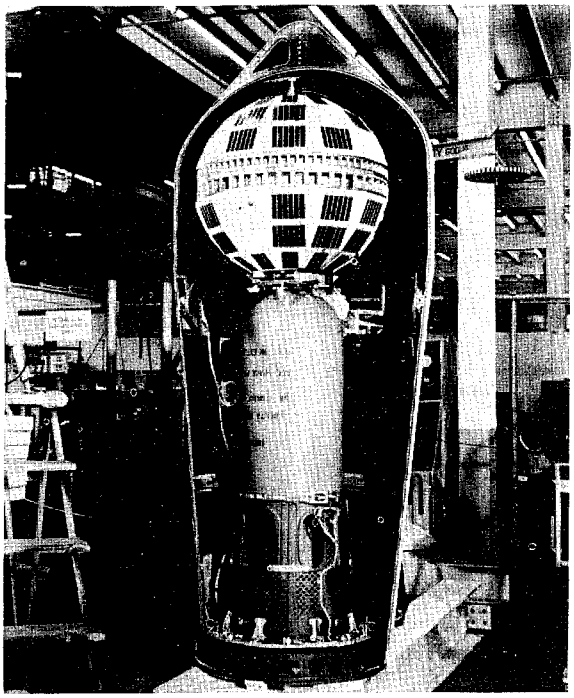


FIGURE 13–5. Telstar test satellite mated to third stage of Delta launch vehicle.

expect to carry out tests between Bell Laboratories at Holmdel, New Jersey, and Andover, Maine. The apparatus used at Holmdel in the historic Echo experiment is now being modified to work at the higher frequencies used with Telstar.

Ground stations are being constructed in several foreign countries for participation in satellite communications experiments. Both the British, with their ground station at Goonhilly Downs in Cornwall, and the French, with their ground station at Pleumeur Bodou in Brittany, expect to be operating this summer.

In some ways, the construction of the ground station at Andover, Maine, has been a more spectacular project than the construction of the satellites themselves. An aerial view of the Andover site is shown in figure 13-6. The 210-foot radome which covers the large horn antenna is the prominent object in the foreground. At the rear is the area containing the control building, the precision tracker, the beacon tracker, and the 11,000-megacycle microwave link to our national microwave network.

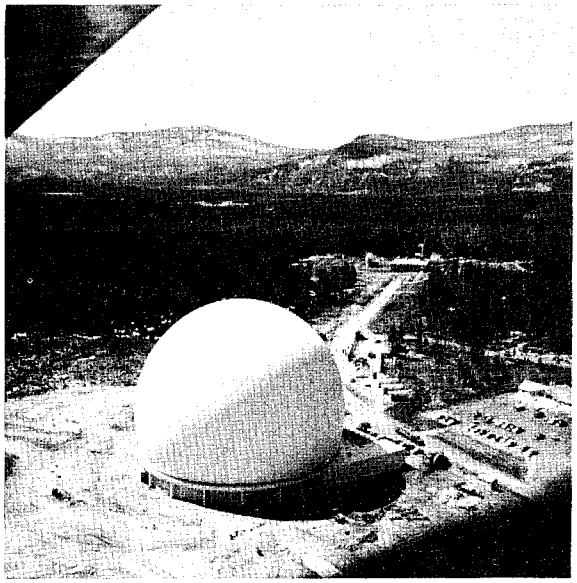


FIGURE 13–6. Aerial view of Andover site.

A few facts about the ground station may be of interest. The radome itself weighs 20 tons. The horn antenna, figure 13-7, weighs 380 tons. It is 177 feet long and 94 feet high. It has a pointing accuracy of 1 minute of arc. That would be rather good accuracy for a milling machine. The 380 tons of antenna rotate on two tracks ground flat to 30 thousandths of an inch. The ground station has been well checked out by tracking radio stars. Its performance has exceeded expectations. It is more rigid and yet more agile than we had expected. It has also been tested with a Telstar satellite mounted on a nearby mountain.

We recently removed the temporary radome and put up a permanent one. This turned out to be an adventure beyond our expectations. With the permanent radome half up, a snow

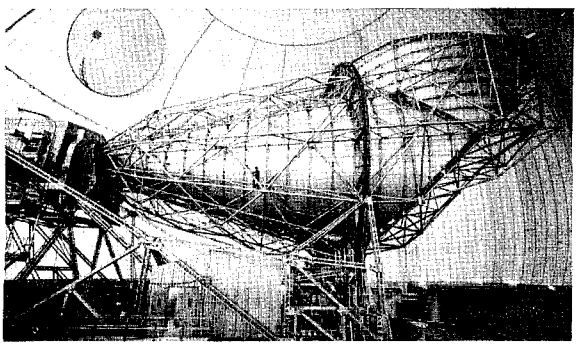


FIGURE 13–7. Horn antenna.

storm accompanied by high winds forced us to retreat. Twenty tons of rubberized dacron make a pretty effective sail. After the storm was over and a few repairs had been made, a second and successful attempt was made. On Saturday, April 21, 1962, at 3:00 p.m. a signal from President Kennedy at West Palm Beach in Florida caused the big horn antenna to move to the direction of the star Cassiopeia A. Radio energy from that distant star was picked up at Andover and sent to Seattle to open the World's Fair.

Eighteen hours earlier the installation of the permanent radome had been completed but the temporary radome was still draped over the big horn antenna. At that time the odds against being able to use the antenna the next day were assessed at about 1 in 10,000. By an effort that would have taxed Paul Bunyan, the temporary radome was removed from the horn without damage to the horn or the fabric, and a signal via the Earth station opened the Seattle Fair.

In this brief description, I have tried to give you a picture of some aspects of the Telstar project. This has been a big project for us. When the first satellite goes up, it will be the culminating act in a program in which we have already invested $45,000,000 in Bell System funds. We hope this investment will make it possible for millions of Americans to see live television signals from Europe this summer. We hope the project will represent a big step towards a commercial use of microwave repeaters in the sky, whether the repeaters are at 6,000 miles, 10,000 miles, or 22,000 miles.

We hope that Telstar and the other experimental communications satellites will serve as a vivid demonstration to the world of America's interest in and use of outer space for peaceful purposes.

14. Synchronous - Orbit Communications Satellites

By FRED P. ADLER, *Director, Space Systems Division, Aerospace Group, Hughes Aircraft Company*

Dr. Adler was born in Vienna, Austria, in 1925. He earned a B.S. degree in electrical engineering, University of California, 1945; an M.S. degree in electrical engineering, California Institute of Technology, 1948; and a Ph.D. degree in electrical engineering and physics, California Institute of Technology, 1950.

Dr. Adler is coholder of a basic patient on an infrared scanner for GAR–2 and GAR–4 Falcon missiles. He is author of numerous technical papers on missile guidance, gaseous conduction, information theory, and weapons system design. He is a member of Tau Beta Pi and Sigma Xi. He was recipient of Charles A. Coffin national fellowships, 1947 and 1948. He is a member of the New York Academy of Science, American Ordnance Association, Institute of the Aerospace Sciences, Institute of Navigation, and American Rocket Society.

Hughes Aircraft Company has been very much interested in the use of synchronous satellites for communications. We believe that synchronous satellites provide the optimum answer for worldwide communication, not only for the ultimate commercial system, but also for the initial operational system.

Some of the basic facts regarding synchronous satellites may be deduced from figure 14-1. By synchronous satellite we mean a satellite which is in an orbit having a period of 24 hours. Now if, in addition, we put the satellite into a circular orbit, and, further, make that orbit equatorial (in the same plane as the equator) as indicated in the figure, then this satellite will be "stationary". In other words, to an observer standing on the ground, the satellite will always appear to be in the same place in the sky.

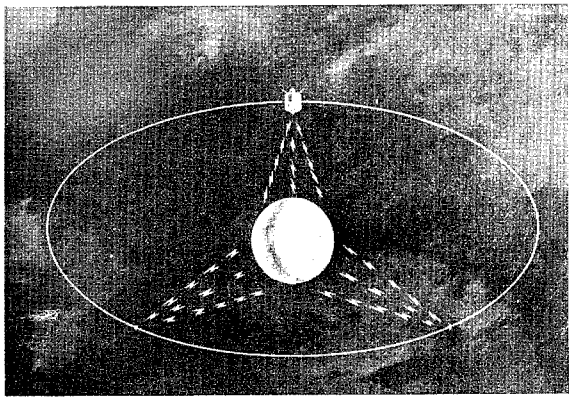


FIGURE 14–1. Synchronous-orbit communications satellites. Height is 22,290 statute miles and velocity is 6,872 miles per hour.

Now in order to have such a stationary orbit we have to place the satellite at an altitude of approximately 22,300 statute miles, roughly corresponding to a geocentric radius of about 26,250 statute miles. Once a stationary satellite is placed in orbit, then it can be used for communications like a very tall relay tower 22,300 miles high.

This paper will present (1) a discussion of some of the attractive features of a system using stationary or synchronous satellites, (2) some of the problem areas that we see in getting from where we are today to such a system, (3) a description of the NASA Syncom program, and (4) a very brief description of a more advanced synchronous satellite system.

The most obvious advantage of the synchronous satellite system, in comparison with other systems, principally low-altitude and medium-altitude systems, is the small number of satellites required. As indicated in figure 14-1, three satellites could, if spaced 120° apart around the equator, cover the entire Earth, except for a small region at the

polar caps. Actually, if three were available they probably would not be spaced equally apart; one would probably be placed over the Atlantic Ocean to join Europe and the United States, as well as Africa and South America; another one would probably be placed over the Pacific Ocean to join the United States with Japan and the Orient; and the third one would be placed over the Indian Ocean. However, there is no reason to have only three. There might be more than that in the future. On the other hand, if there were only one operating satellite, it, by itself, would be sufficient for a truly commercial operating system. If it were placed over the Atlantic, 25° west of Greenwich, it would link 100 countries; 100 countries could see that satellite, and these hundred countries contain 92 percent of the world's telephones. In addition, of course, you could have transatlantic television.

Now because there would be fewer satellites to put up, fewer lanuch vehicles would be needed and even though some of these launch vehicles would be somewhat larger than the launch vehicles required for low-altitude satellites, a good deal in systems cost would be saved, because the main cost of these systems is not in the satellite, but is primarily in the launch vehicle and launching cost. In addition, by requiring fewer launchings, the launching pads would be tied up for a shorter length of time. At the present time, on the average it takes something like about 1 month of setup time for each space shot at Canaveral and about 1 month of cleanup time. It would take several years of pad time to put up 50 to 100 satellites for an operational low-altitude system. It is obvious that this would cause a considerable delay; furthermore, it would interfere very seriously with other space programs. As pointed out in the various Conference sessions, there are a great number of important space programs and space shots being planned.

Another obvious advantage is the fact that since the satellite is stationary the antenna on the ground can also be fixed. There are then no rotating joints, no gimbals, and so on involved. Also, only one antenna per terminal is needed since there is only one satellite to be looked at from the ground station. In the case of low-altitude satellites more than one is needed: a minimum of three, and probably as many as ten antennas at each site in order to track continuously the satellites that are whizzing over your head.

Now look at the communication features. A very important feature of stationary satellites is what we call multiple-access capability. Basically, this means that any station that can see the satellite can communicate with any other station that is also within view of the satellite at any time. In effect, then, rather than putting one big point-to-point cable into the sky, we are putting a network into the sky, and a very flexible network, where, by means of a suitable master station, we can connect at any given time any two of the stations that want to talk to each other. This way we get maximum loading of the frequency capacity of the satellite, and this leads to the second point. The required allocation of frequency spectrum can thus be minimized. A system like this is conserving of frequency spectrum, not only for the reason just mentioned, but also because single-sideband modulation can be used and, very importantly, because it appears that frequencies can be shared with the existing microwave links on the ground. If you have a narrow beam which is fixed in space, it can certainly be arranged so that there is no interference with the microwave links, which of course would not be the case if tracking beams are moving all over the sky.

Finally, there is a very important advantage here, namely, that the ground stations can be sized in accordance with the traffic load required. A ground station that requires a lot of traffic would have a large antenna and a high-powered transmitter. One that requires less traffic would correspondingly have a smaller antenna. Just to give an indication of the sizes, a large station would be typically a 60-foot dish with 10-kilowatt radiated transmitting power; a small station would have an antenna half that size and use perhaps 2 kilowatts. Such a station would be economically justifiable even if only 20 voice channels were used about 3 hours per day. This, then, means, for example, that some of the newly emerging nations in Africa and in

Asia can have their own nationally owned, if you like, or privately owned communications stations and make these pay for themselves. This would thus give them direct access to a worldwide system put up by the West. It also means, as another example, that the State Department can put some of these smaller stations at their embassies and thus communicate directly with those embassies.

Satellites at an altitude of 22,300 miles are just beyond the outer Van Allen belt, as far as we can tell, at least from Explorer VI and some other space shots. Being beyond the Van Allen belt eliminates the problem with high-energy particles, except for some high-energy electrons which are easy to shield against. At this altitude the satellite is in the sunlight 99 percent of the time. The only time the satellite is actually eclipsed is during the vernal equinox and the autumnal equinox, and even then it is only about 1 hour per day. Thus, fewer solar cells are required, batteries discharge less, which increases their life, and it is probably also possible to use a purely passive thermal control system, one that does not use any active elements such as louvers or thermal switches. These advantages then make it at least reasonable that eventually a 5-year life will be attained. These are the chief advantages of a stationary satellite system.

Now consider some of the problem areas. There is a problem of delay and of echo. The path is about 25,000 miles up and 25,000 miles down. Even at the speed of light it will take 0.3 second to reach the person with whom you wish to speak, so that there is a 0.6-second total delay; if you are talking, say, from England to New Zealand and use communication satellite all the way, you will need a double bounce, which means that you will have a 1.2-second delay. Now that is a fact of physics and there is no way of getting around it. There is also an echo. If you have ever talked on the transatlantic cable you have probably noticed an echo. It is an echo that occurs due to reflections at the receiving and transmitting sites. It appears, however, that modern echo suppressors which are now being developed and in fact have been tried out, can successfully cope with this problem.

So the only potential problem then is the delay. A number of studies have been made on this. Stanford Research Institute has an NASA contract and has been working on this for some time; Bell Telephone has also been making extensive studies. It turns out, in fact, that the majority of the people tested do not know that a delay exists when they are put on a line without prior knowledge, even for delays over 1 second.

The second problem encountered because of distance from the Earth is the fact that a highly directional antenna must be used not only on the ground, but also on the satellite in order not to waste any transmitted energy into space. For this reason, most early designs had some kind of three-axis stabilization, using a stable platform or something equivalent to it, and this then pushed the whole design into a weight category which, combined with the higher altitude, required a next-generation launch vehicle and made for late availability.

Now it appears, however, that by using spin stabilization, by using an electronically de-spun antenna, which will be discussed subsequently, and by using lightweight ingenious electronics, existing launch vehicles can be used. So we feel that this problem area has been resolved, as well.

Figure 14-2 shows the Syncom Mark I satellite built for NASA by Hughes Aircraft Company. This figure indicates schematically what the satellite looks like, and also the orbit into which it will be placed. It is in an inclined orbit; it is not an equatorial orbit, but it will be a synchronous orbit. Thus, this orbit is synchronous but not stationary and,

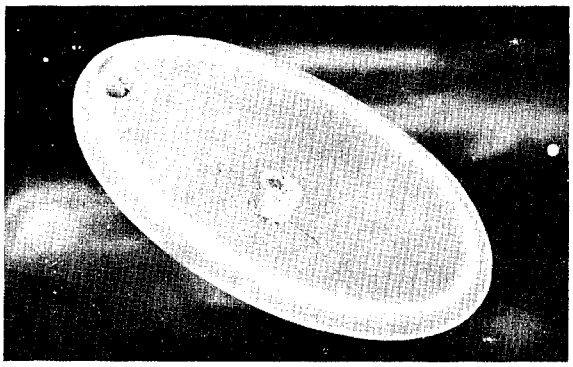


FIGURE 14–2. Syncom Mark I. Antenna gain, 8 decibels.

as pointed out in paper 6, if you were standing on the ground below it you would notice that the Syncom satellite traces out a figure eight on the ground.

The inclination of the orbit is about 33°, and the antenna pattern is a pancake shape as indicated in this figure. It thus has some gain; however, there are ways of improving on this. Some of the key characteristics are: a Delta launch vehicle is used to put this satellite into orbit, plus a small rocket which is an integral part of the satellite; the satellite when in orbit weighs about 75 or 78 pounds; it is spin stabilized; the payload is fully redundant, in fact there are two of everything—two control systems and all the electronics are duplicated for reliability reasons. There are two channels, so that you can have a two-way conversation, or data can be sent. The first satellite will be delivered late in 1962 and the first launch is scheduled either late in 1962 or early in 1963.

Now what will be the significance of this experiment? First, Syncom will use a rather unique type of injection method whereby after the third stage of the Delta burns out, at the beginning of the transfer ellipse, this last stage is left behind and the satellite is spun up and enters the transfer ellipse which gets it from the parking orbit to the apogee of the transfer ellipse; that apogee, if everything works right, will be at the synchronous altitude, at 22,300 miles. At that point the apogee motor is ignited (this is the so-called kick in the apogee) and this kick then adds another 4,800 feet per second of velocity to put the satellite into a circular orbit. This is a somewhat novel technique, which permits the use of a simple existing launch vehicle such as the Delta. Second, Syncom will prove out station keeping and orientation control with a spinning satellite, using attitude and velocity control jets. With a spinning satellite, this can be done by just using two jets, one of which acts through the center of gravity and the other of which is parallel to the spin axis to provide a torque. Third, the communication experiment itself is, of course, important since it will give us information on the propagation losses at this altitude, and so on. The frequencies, incidentally, are about 7,500 megacycles up and 1,800 megacycles down. Finally, we will get some life data in space, and some information about the environment. Thus, I think that it will be an extremely important and very significant experiment.

We have also been working on an advanced design which we have taken the liberty of calling Syncom Mark II. Just to make it clear, this Syncom Mark II design has, at present, neither the financial support nor necessarily the endorsement of the NASA.

Figure 14-3 is a cutaway design of this Syncom Mark II, which is an advanced Syncom system somewhat along the lines described in paper 6. Although I will not describe in detail the various features of this design, some of the general characteristics are as follows: At injection into the transfer orbit the satellite will weigh about 1,000 pounds; when it is in orbit it will weigh about 500 pounds. It will be about two times the size in linear dimension of Syncom Mark I and, hence, about eight times the weight and volume. With this weight, it can be launched with an existing launch vehicle, the Atlas-Agena B, by using the same technique previously mentioned.

This time, however, we would like to get more antenna gain. We would like to concentrate all the energy transmitted from the satellite on the Earth; thus, a high-gain antenna has been designed which has a 17° beam, 17° being the angle subtended by the Earth at this altitude. The antenna uses a phased array, which means that a number of radiators are excited in such a way as to produce a pencil beam; the phase is changed in such a way that this beam spins at an equal and opposite rate to the spin rate of the satellite. Thus, as the satellite spins, the beam is spinning the other way and, hence, the orientation of the beam will be constant and it will always hit the Earth.

A typical communication payload for such a satellite would consist of four independent transponders, each of which could carry one television program or 300 two-way voice channels. However, we would still maintain rather low transmitted power, just as for Syncom Mark I.

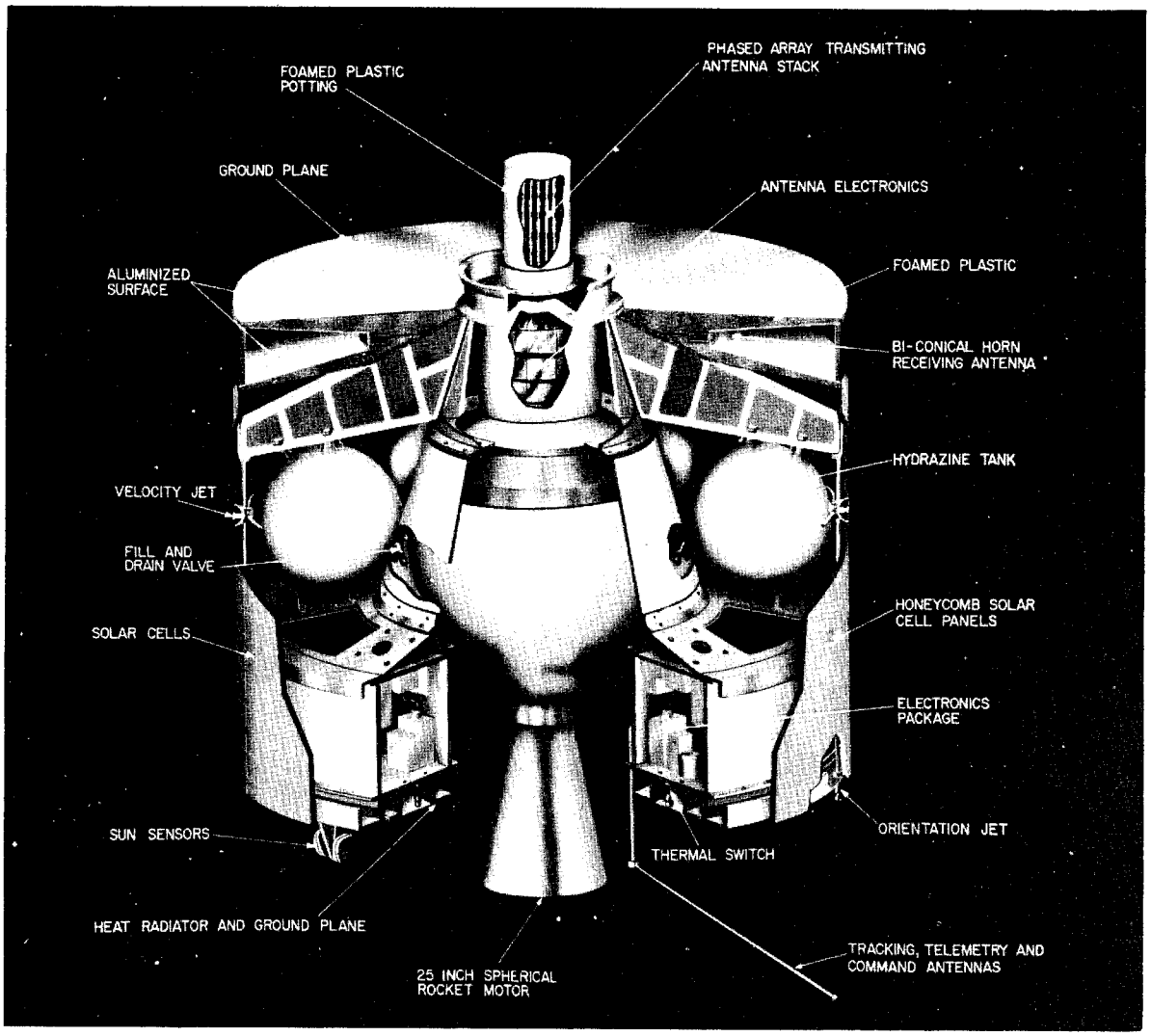


FIGURE 14–3. Advanced Syncom.

The ground terminals, depending on the traffic requirement, could be either the heavy-traffic type, 60-foot antenna, 10 kilowatts, or a low-traffic station, 30-foot antenna, 2 kilowatts.

The Syncom Mark II is both the forerunner of an operational version, as well as an important developmental experiment.

There are four areas in which such an experiment could be helpful. In the first place, it would be a demonstration of a truly stationary orbit as distinguished from the Syncom Mark I experiment, which is synchronous but not truly stationary. It would demonstrate long-life precision orbit control in both longitude and latitude to about a tenth of a degree. The experiment also would demonstrate wide-band communication at this synchronous altitude with the multiple-access feature, which is the multiple flexible netting of the various ground stations. Finally, the high-gain electronically de-spun antenna could be demonstrated.

We believe that t he Mark II design is representative of the operational communications satellite systems which we will see in the future.

15. Regulatory Aspects of Satellite Communications Sytems

By MAX D. PAGLIN, *General Counsel of the Federal Communications Commission*

Mr. Paglin was born in New York City in 1914, and was educated in the public schools of that city. He attended the College of the City of New York and received the degree of bachelor of science in social science (B.S.S.) in 1936. His law training was taken at Columbia University Law School from which he was graduated and received his bachelor of laws degree (LL.B.) in 1939. He was admitted to the bar of the State of New York in the same year.

From 1939 to 1942 he engaged in private law practice in New York City. In December 1942, Mr. Paglin accepted a position in the General Counsel's Office of the Federal Communications Commission.

In February 1959, Mr. Paglin was appointed by the Commission to be Assistant General Counsel in charge of the Litigation Division, in which position he was responsible for advising and representing the Commission in all matters of litigation to which the Commission was a party, and defending the actions and orders of the Commission when judicial review thereof was sought before the courts.

It is particularly fitting that this Second National Conference on the Peaceful Uses of Space should devote so much of its program to the discussion of communications satellites. For it is recognized that one of the major national objectives of the United States in the development of peaceful uses of outer space is to bring into existence a commercial communications satellite system as soon as possible. The necessary experimentation, such as the forthcoming Telstar shot, is going forward timely and there is every expectation than an initial commercial system should be operational by 1966.

The ability to use space satellites to relay communications over long distances is a development of the greatest importance to our nation. It is not only a most significant advance in communications technology, but provides us with an unprecedented opportunity to demonstrate to the world our desire that space be used to the benefit of all mankind. We shall be able, in cooperation with other nations, to increase greatly the capacity of existing worldwide communication networks and thereby accommodate the rapidly growing volume of international public correspondence. We shall be able to institute, on an international scale, new and expanded telecommunications services, such as transmission of high-speed data and television, which are now provided domestically. Space communication also promises to make possible direct communication on an economic basis with the newly emerging nations and the smaller countries of the world.

President Kennedy has characterized this program as one requiring the highest priority. To this end, under the aegis of the Space Council, chaired by Vice President Johnson, the interested agencies of the Government, including the National Aeronautics and Space Administrtaion and the Federal Communications Commission, have been cooperating with each other and have been coordinating their efforts in this field for some time. Commissioner T. A. M. Craven, who spearheads the FCC Space Team, addressed the First National Conference on the Peaceful Uses of Space, in 1961, at Tulsa, Oklahoma, and discussed in some detail the background of this government's intensified activities in space communications and the progress made to that date.

The coordinated program is going forward under policy guidelines enunciated by the President in July 1961. They will govern the establishment and operation of a commercial space communications system, to be owned and operated by regulated private enterprise, in keeping with the traditional free-enterprise philosophy under which telecommunications services of this nation have been so successfully conducted. Since, as the President recognized, only one commercial space communication system will be technically and economically feasible for the foreseeable future, the system must accommodate at least the following policy requirements: it should provide for potential global coverage; it should be open to participation of foreign nations through ownership and use; there should be nondiscriminatory use of, and equitable access to, the system by all authorized communication carriers in the United States; there should be effective competition in ownership and control and in supplying goods and services required by the system; and, finally, fully adequate regulatory controls must be provided to assure the development of an efficient and economical system at reasonable rates.

Mindful of the sense of urgency with which our government is approaching this matter, a number of bills have been introduced in Congress, and extensive hearings have been held before committees of the House and Senate dealing with the problems inherent in the establishment of an operational system. Legislation was passed by the House of Representatives on May 3, 1962, entitled the "Communications Satellite Act of 1962" (Report No. 1636, April 24, 1962 on H. R. 11040, House of Representatives, 87th Congress, 2nd Session), and similar action is expected on the Senate side. There is every indication that legislation on this subject will receive favorable action by the Congress before it adjourns.

Briefly, the legislation under consideration is designed to implement the policy objectives which I have already outlined. It provides for the formation of a private corporation, the ownership of which is to be divided equally between authorized carriers and the public at large. It sets forth in detail the responsibilities of the President, the NASA, and the FCC in relation to the proposed corporation and the communications satellite program as a whole. And it incorporates a number of specific provisions designed to strengthen the regulatory authority of the Communications Commission.

Against this background, let me highlight some of the major and, I think, quite novel regulatory problems which the Commission will face when the corporation comes into being and commences the challenging task of orbiting an operational global space communications system.

First and foremost will be the regulatory problems stemming from the fact that, initially and for the foreseeable future, there will be but one system. In order to accommodate the interest of all international carriers, the legislation authorizes, under appropriate safeguards, a joint venture in which companies, otherwise directly competing with each other, will now be permitted to join hands in this common undertaking. While every effort has been made to take advantage of the benefits of our private-enterprise system, the bill also contains a number of specific limitations on how the corporation will function, in order to protect the public interest in securing efficient and economical service.

For example, while the corporation will be principally responsible for constructing and operating the system, it is expected to make provision for effective competitve bidding in procurement. To this end, the Commission is charged with the responsibility of issuing appropriate rules and regulations to insure that the contracting procedures used are fairly designed to achieve that objective. This, of course, has been the traditional practice in Government procurement; but it is the first time, to my knowledge, that this salutary principle will be required of a private corporation. Moreover, it is also the first time that an independent regulatory agency will be charged with the statutory responsibility of assuring compliance with free competitive bidding procedures by a regulated licensee.

Even in the well-established field of rate regulation of public utilities, the concepts embodied in the legislation will present the Commission with challenging new problems. The plan envisaged is unique in the sense that the corporation will not serve the public directly, but rather will be servicing international carriers who, in turn, will serve the public. This is what is meant when we speak of a "carrier's carrier"—one who, in effect, "is a wholesaler" of communications service. Moreover, the capital investment in orbiting an operational communications satellite will be high at the outset, and it will be some time after the system becomes operational before its capacity will be in use on a fully economic basis. So, it is fair to predict that rate-making procedures will be a thorny problem and one which will require perhaps some new concepts and novel approaches by the Commission.

In this connection, it must be remembered that communication via satellite, though a new technology, is essentially but another means of relaying long-distance communications. It will perform much the same function as do existing cable and radio facilities of our international common carriers. Under no circumstances should it replace existing systems, which must be maintained by these carriers to afford diversification of facilities and routing, needed to guarantee continuity and security of service under all conditions between the United States and overseas points. Therefore, from a service standpoint, the utilization of satellites by any common carrier will require technical and operational coordination and integration with its existing modes of communication. Thus, the legislation provides that the Commission, with the advice of NASA, shall approve the technical characteristics of the system and shall insure such compatibility. The regulatory difficulties which may be encountered in keeping pace with rapidly developing space technology are indeed great.

I should also give special emphasis to another facet of regulation of the proposed corporation. The bill not only requires that there be equitable access to, and nondiscriminatory use of, the satellite system by authorized carriers, but also contains significant provisions respecting the ownership of the stock of the corporation. In addition to the statutory division of stock between the carriers and the public, and the accompanying limitations on domination and control by any one group, the Commission is authorized to compel existing carrier-owners of stock to transfer shares to other carriers who wish to participate. In this regard, the legislation empowers the Commission, after notice and hearing, to determine the number of shares to be so divested and to fix the price thereof. Such determinations are to be reached in the light of the estimated proportionate use to be made by the new carrier of the corporations facilities, and in keeping with the public interest and the purposes of the Act. It would not be unreasonable to predict that such proceedings may be highly complicated and difficult to resolve.

A further important regulatory responsibility is proposed to be given the Commission, a responsibility which has not heretofore been exercised in the international field —although use has been made of this authority in the domestic communications field. The bill requires that where the Secretary of State, after obtaining the advice of NASA as to technical feasibility, determines that a circuit to a particular foreign point is required in the national interest, the Commission shall forthwith institute proceedings under Section 214(d) of the Communications Act to require the establishment of such circuit by the corporation and the appropriate United States carrier or carriers.

Up to this point, I have been discussing those regulatory problems which affect primarily the Satellite Corporation itself. I shall now touch upon some of the broader underlying problems, the solutions of which are vital to the ultimate success of the venture.

For example, it is contemplated that foreign nations will participate in ownership and use of the satellite system by sharing in the cost of the satellites and by constructing Earth terminal stations in their own countries. Furthermore, it is contemplated that such ownership will entitle the foreign nations to use the satellites for traffic between their countries and other foreign points. All of this will require a maximum of coopera-

tion and understanding among nations in the development of arrangements, some of which may be most complex, so as to provide equitable and efficient sharing.

One of the prime elements of successful international sharing will be a fair and technically feasible plan of channel allocation and use. The limited nature of available frequency space is a matter of common knowledge which hardly warrants discussion. There is presently scheduled for 1963 in Geneva, Switzerland, the Extraordinary Administrative Radio Conference. That Conference will consider the allocation of frequency bands required to support both research and operational phases of the various categories of space radio communications. I would only add that the Commission regards the successful conclusion of that Conference as one of the key elements in the early establishment of a truly effective global satellite system. It should be emphasized that our experience over the years and the harmonious relationships which have already been established give every hope that the Conference will be productive and effective.

It is a tribute to the nations of the world, whatever their political complexion, that, in the field of communications, treaties have been negotiated and their provisions observed in good faith. Because the world community holds to the one view that communications are the "lifeblood" of international relations, I have no hesitancy in predicting that agreements will be reached which will assure a practical and efficient use of frequencies for space satellites, as a supplement to existing communication networks.

The establishment of a commercial satellite communications system will, as new uses emerge, develop, and grow, have a formidable impact on social, political, educational, and economic relations among the nations of the world. That is why the Commission regards the establishment of such a system as being of the utmost urgency and national importance.

16. Some Foreign Policy Implications of Space Science

By HOWARD FURNAS, *Deputy Special Assistant to the Secretary of State for Atomic Energy and Outer Space*

Mr. Furnas was born January 29, 1919, in Michigan; he attended Hillsdale (Michigan) College, and received an A.B. degree in 1940. He attended Harvard University from 1945–1947. Mr. Furnas entered the State Department in 1947. He has served abroad in New Delhi and Paris and in various assignments in the Department, including, as a member of the Policy Planning Staff and Alternate State Representative on National Security Council Planning Board.

The startling developments in space science of the past few years which are already affecting the everyday conduct of our lives have introduced problems of new concepts and dimensions into the formulation and conduct of United States foreign affairs. We in the foreign policy field are now forced to speak matter-of-factly, and we hope confidently, of boosters, synchronous orbits, lunar landings, and meteorological satellites—terms which still seem slightly unusual in the diplomatic vocabulary. These developments have not only changed our vocabulary, however, they have forced upon us a whole new way of looking at the rest of the world and at the role which the United States must play in the international community.

Perhaps the first impact of U.S. space activities on our foreign policy results from our realization that we need the assistance of other nations in our own national space program. Astronaut John Glenn's epoch-making flight in the Friendship 7 spacecraft in February 1962 was materially assisted by tracking stations in Bermuda, the Canary Islands of Spain, Nigeria, Zanzibar, Australia, and Mexico. In addition to the Mercury network, the United States has stations for other programs scattered in countries all over the globe. We have the minitrack network for tracking unmanned spacecraft, a deep space tracking network with stations in South Africa and Australia, a transit network for data acquisition on the Navy's navigational satellite, and a worldwide optical tracking system administered by the Smithsonian Institute. Our technicians indicate that it would be almost impossible to carry out our space research programs without these stations. At the very least, the programs would be much more expensive and the results less favorable if we were forced to rely only on United States based facilities.

In addition to tracking stations, other nations assist us in our space program by allowing us to launch sounding rockets from their territories, providing us with data from local observatories, and allowing us to use their facilities for logistics support of our programs. Our successes would thus not have been possible without the cooperation and assistance of other governments, and the effect on the participating countries of this kind of cooperative relationship has been significant. One noteworthy example is the extent to which the Glenn flight has been viewed as a triumph for the entire Free World.

It is obvious, however, that in addition to providing assistance to United States national space programs, other nations have an intense desire to conduct space programs of their own. Recognizing that other countries have a legitimate interest in the discoveries and developments in space, the United States is helping these nations to fulfill worthwhile national aspirations by offering to cooperate with them in joint programs. At the same time, through these programs,

we are enhancing the effectiveness of many of our international relationships.

A significant demonstration of this effort is in the cooperative programs of the National Aeronautics and Space Administration with counterpart agencies in other countries. The programs fall into several categories: the launching of experiments prepared by foreign scientists by means of United States satellite boosters or the smaller sounding rockets; the organization of programs of ground-based research abroad coordinated with orbiting space experiments; and programs for training foreign scientists and technicians in the United States. NASA extends cooperation only to foreign agencies sponsored by their governments, and each nation is expected to assume full responsibility for its own efforts, including the financing of its portion of the program. Projects must have scientific validity and mutual interest, and the scientific results of all experiments must be made available to the international scientific community. In the few short years of the existence of this program, strong interest has been stimulated abroad in space science research. National space committees have now been organized in more than 20 countries, and some cooperative efforts have been carried out with representatives from almost 50 countries.

I should also note that it is the policy of the United States to encourage international space cooperation through the United Nations. We believe that the benefits of the exploration and use of outer space should accrue to all mankind, and we see advantages to ourselves as well as other interested states in the establishment of an open, orderly, and cooperative framework for the conduct of such activities. To this end, the United States has taken the lead in promoting the establishment of the United Nations Committee on the Peaceful Uses of Outer Space and in the passage in December 1961 of a General Assembly resolution which set forth certain basic legal principles regarding outer space, provided for registration of space launchings, proposed preliminary cooperative measures in the fields of meteorology and satellite communications, and enlarged the membership and competence of the Outer Space Committee. That resolution was supported by all members of the Outer Space Committee, including the USSR, and was adopted unanimously by the General Assembly. It is our hope that the Committee will initiate constructive measures of both a legal and technical nature to facilitate and stimulate international cooperative efforts in the outer space field.

More recently, as a result of an exchange of messages between President Kennedy and Chairman Krushchev after the Glenn flight, United States and Soviet scientists have commenced a series of informal technical discussions looking toward cooperation in the conduct of specific projects within our respective space programs. In any agreements reached for such arrangements, classified information on United States space programs would, of course, be protected, and it would be a prerequisite also that the benefits from such projects be mutual and reciprocal.

Soon nations will be undertaking many more joint efforts in space, and it is our hope that these cooperative endeavors will represent an advance toward the U.S. goal of an international community of free nations working and living together in harmony.

As systems designed to make use of space science applications become operational, other nations will become more directly affected, and the technology itself is becoming an increasingly important ingredient in our foreign policy. Two particular applications of space science are now nearing operational status. Weather satellites have already been used in forecasting, and communications by satellite have been accomplished on an experimental basis. Both of these projects have important foreign-policy connotations.

International programs of weather forecasting by their nature cut across political boundaries and require cooperation. Weather satellite programs affect an even larger number of countries than the traditional cooperative weather programs and as such become even more international in character. The National Aeronautics and Space Administration and the Weather Bureau already have invited a large number of foreign weather services to mount special observations to be synchronized with cloud photography by

NASA's experimental Tiros satellites passing overhead. At the present time, 27 countries, including two Iron Curtain countries, Poland and Czechoslovakia, are participating in the program; it is expected that even more will participate in efforts with later versions of Tiros which will be able to photograph cloud cover over more countries.

In another significant development the first International Meteorological Satellite Workshop, coordinated with the World Meteorological Organization, was held in 1961 in Washington, D.C. to describe the techniques for utilizing satellite cloud-cover photographs for operational weather forecasting. In the future are operational satellite-based forecasting systems and even the staggering possibility of weather modification using, in part, information from satellites. This, of course, will call for multilateral efforts on a large scale and will involve recognition of the needs and desires of all countries concerned.

The other major space science application which has relevance today is the communications satellite. Satellites for communications purposes are primarily international, and although some large countries may ultimately augment domestic communication networks with satellite relays, the greatest importance of the latter will unquestionably come in linking points on the Earth across the oceans and continents. The creation of such a medium for international communications will, when economically feasible and make possible direct communications among all countries. The resulting capability for freer and more rapid exchange of information and ideas and of government and private communications could make a tremendous contribution to international understanding. Communications satellites thus offer one of the most hopeful ways of bridging the present sharp political divisions separating nations of the world. As we actively examine the possibility for space cooperation between the United States and the Soviet Union, the possibility of joint action in space communications has special attractiveness; we are hopeful that the Soviet Union will join us in this important effort.

Perhaps the most immediate foreign-policy aspect of the communications satellite, however, is that it will lead to opportunities for all members of the family of nations—large and small, developed and underdeveloped—to participate in a truly international venture which will clearly benefit mankind. United States leadership in the prompt development of an operational capability available to the world community will be of enormous benefit to our foreign policy by providing a tangible demonstration of our open and cooperative approach in the peaceful uses of space.

One of our traditional foreign-policy objectives is to expand even more our trade and cultural ties with the nations of Europe. The new channels provided by satellite relays will provide us the needed capacity for handling a greatly increased volume of communications traffic with our Atlantic Community neighbors.

Steps have already been taken in the direction of these foreign-policy goals by such actions as coordinating, through the International Telecommunications Union, frequency allocations for satellite transmission, and by encouraging participation in forthcoming experiments by countries in Europe and South America from ground stations financed and operated by the local governments involved. As the operational phase of communications satellites comes nearer, it is likely that nations in Asia and Africa will also wish to participate.

The manner in which we proceed to develop and use communications satellites, and the spirit of our efforts, will be closely watched by the rest of the world; it is our intention to use this technological asset, and the interest of other countries in it, to help speed the entry of the entire international community into the modern age of science and technology.

In summary, even though the practical applications of space science still await further development and experimentation for their complete realization, the present research and international cooperative space programs of the United States are already playing a substantial role in our foreign relations. It is our desire and expectation that this role will increase in importance, and it is a firm intention that our foreign policy stand ready to accommodate our space programs and to benefit from them.

17. The Economic Importance of Space Technology

By WILLIAM H. MECKLING, *Economic Analyst, the RAND Corporation*

Mr. Meckling was born in McKeesport, Pennsylvania, in 1921. He received a B.B.A. degree from Westminister College, and an M.B.A. degree from the University of Denver. He did graduate work at the University of Chicago. He was formerly an instructor in Economics, University of Denver; assistant professor of Economics, Butler University; and Assistant Director, Bureau of Government Research, Indianapolis Chamber of Commerce.

During its infancy over a century ago my profession, economics, became known as "the dismal science." The title was occasioned by Thomas Malthus and some of his colleagues who, convinced that population tends to outrun food supplies, condemned the vast majority of the world's populace to a life of bare subsistence. In the Western World, at least, this dreary view of man's fate has gone out of vogue, but it is still difficult for the economist to avoid the stigma of a killjoy.

One trouble is that economists invariably want to look at costs; they are eternally asking whether potential benefits will cover costs, and such questions have a habit of spoiling some people's fantasy life. To one who passionately believes "man belongs wherever he wants to go," asking whether going to the Moon is really worth the candle is pure heresy.

Resistance to cost-benefit comparisons, however, is only one facet of a broader problem, namely, the tendency simply to snub science in analyzing the social (including economic) consequences of space programs. Science is the keynote when it comes to the physical process which generates space technology. Outside of that realm, science to a very uncomfortable extent is displaced by faith. Mysticism supplants theorems and analysis, and wishful thinking supersedes scientific prediction.

One eminent scientist, for example, has been quoted to the effect that communication satellites will enable one to call anywhere in the world for 10 cents, and that such satellites will make international communications a $100 billion per year business. As far as evidence is concerned, these predictions are about on a par with a prediction that the Sun will not rise tomorrow.

Perhaps the area where a scientific approach has been most conspicuous for its absence is in the discussions of the international implications of the space effort and of some of the international problems that are raised. Questioning the effectiveness of space endeavors as a means of influencing the rest of the world is generally regarded as heretical or plain stupid or both. Meanwhile, one will search in vain for the research, body of verified theory, or analysis, which answers such questions as: Who is it in foreign nations that is impressed by our space accomplishments? How are their attitudes changed as a result? How is their behaviour and their government's behaviour changed as a consequence? How does that change in behaviour affect me as a citizen of the U.S.? How do those changes in behaviour compare with other changes that might be induced by alternative uses of the resources that are consumed in the space program?

Much has been made, for example, of the use of communication satellites in underdeveloped countries, not only for telephone and telegraph but for television as well. It takes very little research or even thought to convince one that international telephone and international live television mean virtually

nothing to the mass of the citizens of low-income countries around the world, and will mean little for years to come. The television point is particularly obvious. The only advantage that communication satellites offer for TV is live broadcasts. If TV is the way to educate people in underdeveloped areas, we can do that today simply by flying films to wherever we wish to use them. Indeed, that will likely be the most economical way even after communication satellites are available. The primary reason we do not use TV in Africa today is because most Africans do not have TV sets, not because we cannot send live broadcasts there. Nor is there a theory of economic development which attributes special qualities to international communications as a stimulant to growth. When it comes to typical intranational communications, satellite systems would have to be an order of magnitude cheaper than anyone anticipates in order to be competitive with microwave relays. Finally, it is not necessary, as has often been assumed, to provide each nation with its own ground station in order to tie it into an international communications system. Radiotelephone, microwave relays, and cables can be, and already are, used for this purpose. Indeed it needs to be emphasized that citizens of Seattle also are very unlikely to have *their* own ground station, but that will not prevent them from using the system.

If nothing else is clear, it is understandable by now why I predicted that I would not be very popular. Having aired my personal crusade for a more scientific approach to the question of the social consequences of space programs, however, I would like to turn to the question of what we *can* say in a positive way about the economic implications of space technology.

I would feel much more comfortable on this occasion if I were in a position to unveil a menu of exciting applications of space technology and with confidence predict both that they soon would be realized and that they would significantly affect all our lives. Unfortunately, research and development is a very uncertain business, and confident assertions emanate only from the uninitiated, the unbridled enthusiast, or the charlatan. What at first seem very promising lines of development frequently turn out to be quite disappointing. Significant new technology often emerges from ideas that the experts agreed would never work, and technology developed for one purpose frequently turns out to be most valuable in some use which no one anticipated.

One example worth recalling is the atomic energy program. After World War II there was a good deal of excitement over using atomic energy to produce cheap electrical power and about the use of nuclear engines in a wide variety of applications—automobiles, airplanes, and so forth. I think it is fair to say that the results on the whole have been quite disappointing. On the other hand the value of using isotopes in medicine and in production quality control has been a very pleasant surprise. When the British Ministry of Supply declined to support the development of Whittle's jet engine, they gave him the patent rights with the flat statement that this engine would never be of any military value. Whittle himself thought in terms of using the engine for a mail plane, and even after Whittle had run his engine, a U. S. Navy Committee reported that turbine engines would be valuable in ships but would not be useful in aircraft.

The applications of space technology that are closest to realization today are communication satellites and meteorological satellites. Studies of the economic impact of both were initiated by the National Aeronautics and Space Administration early in the game, and are continuing. Other agencies, private firms, and individuals have also undertaken independent studies of communication satellites. Despite these efforts the future of communication and meteorological satellites can be discerned only in dim outline. This does not mean that their future is dark. What it does mean is that we do not know enough yet to predict very accurately how big an impact they will have, or in what particular areas and ways the impact will be greatest. We can be fairly confident that some sort of communication satellite system will offer significantly lower costs in long over-water links where communications traffic is heavy—U.S. to Europe, Hawaii to the mainland, Alaska to

the mainland, and Japan to the U.S. By itself that is no mean accomplishment. Beyond that, the picture becomes decidedly hazy. What type of satellite system—synchronous, low-altitude, passive, active, and so forth—will be most economic? To what extent will new sources of demand like television and data transmission materialize? What kind of ground terminal network will make sense economically? We are a long way from having definitive answers to these kinds of questions. Realistic evaluations will be possible only *after* experimentation forges a reasonable basis for such evaluation.

The situation is even more equivocal when it comes to meteorological satellites. We are very uncertain at this point how much or in what respects weather forecasting will be improved as a result of meteorological satellites, and if we resolved that uncertainty, we still would not know how to quantify objectively the value of the improved forecasts. NASA has sponsored some studies that have attempted to measure the value of improved weather information to particular industries or in particular geographic areas, but how much is it worth to travelers, to golfers, to a fisherman, to baseball fans to have improved forecasts? In the absence of a market in which weather forecasts or weather information is sold, it is nearly impossible to answer such questions.

Nor does the uncertainty end there. In the long run, better weather information could improve our understanding of the determinants of weather conditions, and thereby enable us to control or affect the weather. It takes very little imagination to see that if that situation ever is realized, the economic effect could be dramatic. On the other hand, we have no very good reason at this juncture for believing that meteorological satellites are the key that will open the door to this happy state of affairs.

If the outlook for communication and meteorological satellites is somewhat fuzzy, the economic implications of other space programs and the technology they will generate is pure conjecture. It would be futile to discuss specific applications, but I would like to make several personal observations. First, any really significant innovations are almost by definition going to be ones we now do not foresee. If we could foresee them, we would already be working on them. Second, it seems likely that any indirect economic benefits that accrue as a result of space endeavors, like the lunar landing program, will take the form of improved or new products used here on Earth. Mankind is not going to be enriched either by exploiting resources on the Moon or by establishing residence there. Indeed, it seems unlikely that space travel (as distinguished from space exploration) will be a good investment in any time period in which our generation has a serious interest. To put the matter a little differently, I would not buy stock in a company that was proposing to acquire a valid title to the Moon for a price that was even a small fraction of what we are proposing to spend in getting there. What *is* likely to come out of such programs is (a) scientific knowledge which enables us to exploit resources on Earth more effectively, and (b) new technology which enables us to improve products or provide new ones here on Earth. The list of possibilities here is too long to enumerate, but one example is long-lived lightweight batteries that could variously be used as power sources, perhaps even as a substitue for combustion engines in automobiles. Because the existence of new technology of this sort will not itself insure its use, National Aeronautics and Space Administration has recently initiated a program to identify promising possibilities generated by the space effort and bring them to the attention of potential users. Both contractual work and in-house activities will be canvassed and screened, and the results published.

The exploration of space is a very exciting affair indeed. If glamour displaces science in guiding national policy, however, the results may be very disappointing. A communication satellite system that charges prices not very much different from present prices and that must be constantly subsidized and protected from competition is not much of an accomplishment and may make us the subject of ridicule rather than admiration.

Discussion Period

DR. GODSEY: Perhaps Mr. Felker would like to comment on some of the economic aspects of the communications satellite.

MR. FELKER: I think William Meckling said a lot of things that needed to be said very badly. Communications satellites are not going to be a golden opportunity for anyone to get in on the ground floor and get rich. Communication satellites, we believe, will fit into the communication network in the same way that other facilities have been introduced. When the first microwave was used, for example, on land, it wasn't cheaper than the coaxial cables that we were using; it was more expensive. Why did we do it? If it had not been introduced at that time you would not have it now, and as it became operational traffic grew to where the very great capacity of a microwave could be used; then the microwave became a very sound investment. And this is why about 35 percent of our circuits today between cities go via microwave. When this first communications satellite is put up, the Satellite Corporation will presumably have to sell circuits to the common carriers at no greater cost than those common carriers could put cables in, and that means that the Satellite Corporation will not make any money on these initial circuits. But as the demand for circuits grows, the peculiar virtue of microwave in comparison to submarine cable, that virtue which may permit thousands of circuits between two points, may begin to pay off, and I say may; it is a speculative thing. There has been a lot of talk about people buying stock on this new corporation, and giving everyone a chance to get rich. I think, as William Meckling suggested, this is not good thinking; this is something that we have gone into as our normal business of bringing new art forward, solving the problem, of getting it into use soon enough so that when you have the traffic demand, it will be there. I believe that we will have the traffic demand; for example, in the next 20 years we expect the overseas traffic to increase by a factor of 20. Now, in spite of the satellites that we are putting money into, and we have spent $45 million on this, we are putting in new cables; we are participating with the Japanese and a Hawaiian company in a cable to Japan in 1964, for example. We are putting new cables in the Carribbean area. Those are things that we can do now and are justified on the basis of the traffic that exists. In 1965 and 1966 we think it will then be a good time to make a prudent investment in a commercial system; unless somebody is willing to make investments now and next year, the day will never come when this system can be used on a solid economic basis. So I would say we are not at all pessimistic about this, but we do not regard this thing as a certainty dollarwise. I would say, as William Meckling said, if that were so we would have been proposing it several years ago. You always work on these things at a time when they are speculative.

DR. GODSEY: Those sound like very common-sense remarks. Maybe for once we are going to get a freeway before it is already overcrowded by the time it is built.

MR. FURNAS: I hate to inform you, Dr. Godsey, that I do not disagree with very much of what Mr. Meckling said either. You will notice that in my paper about the foreign-policy implications of space science activities, I did not say anything about educating Africans by television, or any other way, for that matter. I did not say anything about developing underdeveloped countries or providing ground stations to tie in with communication satellites.

As far as the interest of other countries and governments in space science and in U. S. activities in this area are concerned, I think there is plenty of evidence about that. A large number of European countries have gotten together and formed a European Research Organization. They have done this with our encouragement because we think it is better for them to cooperate and spend their money than for us to spend

all of ours doing research. They have even gotten together and formed a European Launcher Development Organization contrary to our advice, because we think this is an uneconomical and inefficient thing. But the point here is that our cooperation and our relationships with these countries are many times designed to keep their efforts toned down, to make them responsible, and to keep their efforts in proper perspective; if we do not do this they are likely to extend themselves farther than they otherwise might or than we might. I think that if the United States does not exercise some leadership in this new and exciting and glamorous field, that particular ingredient in our image of leadership, I think, is going to pull the whole image down.

Finally, I would just like to say one more thing, make one more observation about Mr. Meckling's remarks. I think he would be extremely well advised not to buy any stock in any company intending to take title to the Moon, because that resolution which we introduced into the United Nations, and which was passed unamimously by the General Assembly, accepts a legal principle that celestial bodies are not available for appropriation into national sovereignty.

MR. PAGLIN: I do not think that it is a question so much of reasons why we should not be doing this. I think it is a question of what will happen if we do not do it. From my little stall, there has been literally an explosion of international communication since the end of World War II. Not being in the State Department, I do not want to comment on Mr. Meckling's attitude as to the prestige factor involved, but just as an individual I think that is very important. Even without that—without the question of the prestige involved in the space race with Russia, and the need for us to be there, and be there first with an effective system—I say just as a technical matter that there has been a tremendous crowding of the spectrum since World War II. The increase in direct circuits to all the nations of the world, not only for economic purposes, commercial traffic, but the press traffic has been of an order that has required a tremendous number of circuits to be instituted, and consequently the use of many frequencies. We are going in this direction; I think Mr. Felker reported or referred to the order of magnitude in the next decade. We have to find additional means for additional communications, even if only to handle our own commercial traffic. We will not find it in the spectrum; we will not find it in cables. The satellite affords a practical means. When I say practical, I do not necessarily mean a profitable means, but it affords a practical means for increasing the facilities for long-distance communications, and also, and probably what is equally important for increasing the quality and security of these communications. I think that for reasons of reliability alone we could not afford to stand still; we have to move ahead. This country needs additional communications facilities, and this appears to be, at least to the people who are willing to put their money into it, one of the means of obtaining them.

DR. GODSEY: Well, Mr. Meckling, I am going to defend you. I think it is important that we all get together from time to time and talk the same language, and certainly there has been a great deal of loose conjecture and loose talk appearing in conversation and in print over the radio and over TV about all the wonderful things that are going to occur; some of the sources have not been very well informed, and it is always good and healthy to sit back and analyze the situation from time to time and see where we go from here.

It is possible that some of the members of the audience have comments or would like to ask a question. I will be glad to recognize anyone who wishes to speak.

MR. POLLIS, Lockheed: I speak as a private citizen. I have a question for the advocate of the low-altitude communication satellite system. To establish and sustain a system of low-altitude satellites and random incline orbits, there will over a period of time result hundreds of spent rockets, and active and inactive payloads. Does not the attendant space debris and so forth endanger the problem of military defense against a missile attack? Even if the considerations of the

capability, availability, and cost are comparable with the high-altitude system, would not this junk at least confuse warning systems and possibly permit, or even trigger, a missile attack?

MR. KREUZER: I tried to make clear the fact that we believe there may be a place for more than one kind of system. In an attempt to answer the question, though, I think the only comment I could make is that as with any other system, there will be a requirement for an active inventory of everything that is in orbit. The use of this inventory I think would go a long way toward solving the problem.

DR. GODSEY: There is a great deal of material already in orbit, and I believe that anything of any reasonable size is tracked and data are kept on it now. I do not know when we are going to get around to sweeping it up, but eventually we will have to, because it is going to be much worse than bumping into a door in the dark.

MR. PERENTE, Senate Space Committee Staff: Mr. Meckling, are you saying, sir, that the budget for our space research and development program is too high?

MR. MECKLING: Let me put it this way. I am not saying that the budget for the space system is too high. What I am saying is that it comes in terms of determining two things: the size of the budget for particular kinds of activity, and the use to which some of the developments of space will be put. We have, I think, been somewhat less than honest with ourselves in talking about what the product of this will be and how these things should be operated.

Let me say in the case of communication satellites, for example, that although Mr. Furnas is quite right when he says that my comments did not apply to his remarks, they do apply to something which Mr. Paglin said in his paper, which is that the current bill providing for the establishment of the Communication Satellite Corporation authorizes the State Department to order this corporation to put in ground stations anyplace in the world. The only reason the State Department would want to have this authority is that it wants ground stations established in areas where they are uneconomic. The pure economic question in that sort of instance is, "Is it the sensible way for us to give foreign aid to countries?" The point I was making was this: I think it would be very difficult to make a case for foreign aid in the form of communication satellite subsidies to underdeveloped countries.

The other part of it is in respect to missions like the lunar landing program, which I think has a great deal of appeal to the normal citizen, and I think the American people would approve in terms of expenditures in any case. We do not have to attach to this lunar landing program, I think, all kinds of odd justifications of the sort we have seen from time to time in print as reasons why we are undertaking the lunar landing program.

MR. PAGLIN: I just want to add a word with respect to the authority given to the Secretary of State under this proposed legislation and its implementations. I think the authorities in the field recognize that you will not be able to tie in a foreign country, particularly one of the newly emerging countries, by merely building a ground station. In fact, it is recognized that you must first develop the domestic communication network or else you have nothing. It may very well be that in terms of the nation's foreign relations program, they may wish first to develop the interior communication system of this country and then by bridging the gap, instead of going through the normal phase of development, be able to tie either directly or through a network of an adjoining country, into the space satellite system which will be developing. I do not think it is a question of putting television sets in the midst of a jungle that does not even have telephone wires to carry current, or the power lines to carry the current. I think it does represent a method of being able to bridge a gap which otherwise would take a long time to span.

MR. TERRIANTINE, Houston Chamber of Commerce: It happened that 1 year ago, I took a delegation of Houston businessmen

on a trade trip to Europe, and we were there when Alan Shepard made his flight. The reaction that we got in Europe from leading business people, diplomats, and so on convinced me that every penny that Uncle Sam had spent on that program was money well spent.

MR. WILLIAMS, student conferee: Mr. Felker, it seems that every time a communication system becomes saturated we move to some higher frequency band in the radio spectrum. I notice that the radio spectrum has an inherent upper ceiling. Now, will the communication satellite system ever become saturated or overloaded, and if so, what is next?

MR. FELKER: The frequency spectrum does become crowded and, you are right, that is why people move to higher frequencies; if you just get 10 percent you pick up a tremendous communication capacity in that 10 percent. The highest frequency used today in commercial communications is about 11,000 megacycles; the common carriers operate in that band. It may be possible to go as high as 25,000 megacycles. You would get some disadvantages, but just think of the advantages. There is more bandwidth between 11 and 25 kilomegacycles than there is in all the existing radio spectrum that is in employment today.

Now the next step beyond that in the use of radiofrequency spectrum will be radiofrequency waves inside waveguides. We have quite an extensive program at Bell Laboratory concerning this; the method is to use these radiofrequency waves inside pipes where the atmosphere can be controlled, where the atmosphere attenuation which would ruin them out in the open air will be avoided. We will have repeaters and bandwidths of 75,000 megacycles or so and will be able to get perhaps 100,000 voice circuits in one pipe; in that pipe we would have several times the entire usable radiofrequency spectrum. Now that is not going to come about in the next few years. It may be here by 1970, and it will be quite expensive at first, but we believe that there will be traffic to justify it someday.

Then, after that will come the use of light beams inside pipes, where you would expand your frequency spectrum by a factor of a thousand. So you can see solutions to the problems you mention; the answers will come.

MR. ROYALS: I would like to recall to Mr. Meckling's attention the remarks of Mr. Webb in which he discussed the historic relations between government and explorations. I am wondering if the methods he uses in determining the economic feasibility of space activities, when applied to, let's say, the Louisiana Purchase or the Lewis and Clark Expedition, would not demonstrate that they were economically unfeasible in terms of the existing technology at that time. It seems to me that there may be something wrong with his methodology, which, I submit, should consider projections of the existing technology. For example, concerning the question of the African educational television, if one projects the rising income of the Africans and the declining prices of transistorized radio and TV, I think it is not too unreasonable to think of at least a radio or a TV in the hut of many chieftains in the villages throughout Africa.

MR. MECKLING: It is a question of time that is involved. The question of time is one of the important considerations in terms of economics of all these activities. Let me simply point out that at 10-percent interest per year, a promise to pay a return at 40 years from now of a dollar is worth today roughly 2½ cents; in making economic calculations it is precisely this kind of thing which we are most likely to ignore. If we make investments now which we do not expect to pay off for 40 years, we have to consider the loss in terms of alternatives at interest rates which are at least 10 percent; in business today it averages somewhat greater than that, something on the order of 15 percent. So that in 50 years, for example, 15 percent interest, the value of a dollar today is something like nine-tenths of a mill. So you can imagine what rate of return you have to produce in terms of technology in the future to offset the effect of that.

MR. MOORE, Tolt High School: I would like to ask a question, and make a comment.

What are the possibilities of a manned spacecraft, or any spacecraft, for that matter, being struck by space debris?

DR. GODSEY: We will try to give you a number on that. The probability of being struck, I think, is so extremely low that it it much safer than the Los Angeles Freeway.

MR. MOORE: The comment refers to the last paper, and you might say it defends the author, in a way. I think it does have bearing on the case. Sometimes a person is accused of objecting to the scientific attitude or a scientific method, but maybe he really is not, because we should remember that science is a dispassionate objective collection of knowledge, for scientists are humans, and he may only be objecting to them. Being human they err, and they also have prejudices and biases.

MR. DEGRAPHENREDE, Sanders Associates, New York: I wonder if others feel perhaps as I do that the cross-fertilization of a high-speed computer with meteorological satellite objectives will result in one of the biggest payoffs that we have ever seen, namely, in the ability to forecast, for instance, rainfall, and to tell the ordinary farmer on any continent what to plant, when to plant, and what yield he might reasonably expect.

MR. JOHNSON: As I mentioned in my paper, and I think it applies equally well to computers, the computers on the weather satellites themselves do not make the forecasts. I do not wish to indicate by this statement, however, that I am belittling these tools. They are fantastic and certainly will open up new vistas in meteorology. I believe it was Sir Francis Bacon many many years ago who described the logical progress of science through various phases: the first, being able to observe, and based on one's observations, to describe what is happening, and once you have this description, hopefully, you can evolve and understand the processes involved; then once you understand these, you are finally in a position to make predictions or forecasts of what will happen in this particular realm in which you have been observing, describing, and understanding. There have been discussions of weather modification; going ahead then with the development of science, once you can predict with great precision what is going to happen, then conceivably you can intelligently approach the last step, which is, modify what is happening.

Now where do these various tools that we have been mentioning fit in? The meteorological satellite, for example, helps the scientist in the very first step of this process of science. The computer is simply a gigantic moron which arouses the meteorologist to process data, allows him then to present these data in a form in which he can better describe what has happened, and aids him in developing his understandings.

When we get into the understanding process we start talking about hydrodynamics and thermodynamics; we develop equations that explain motions in the atmosphere, and computers have in the past 10 years been a tremendous help in meteorology in allowing us to solve very primitive forms of these equations and motions. There are many terms in these equations which we even today cannot adequately use because we do not have the right type of measurements that would allow their use without making rather gross assumptions.

As we go on in the future, we hope that we will be able to refine these equations and certainly in order to refine them, one of the things that we will have to have is more adequate computers, computers which are faster, have larger memories, and so forth. But throughout this process we must keep in mind this ability to describe and understand before we make the prediction step, and the description and the understanding so far still come from human beings and human minds; they are aided by these other tools. So I think it would be very difficult for me, or any other person, to conjecture at this stage when we can give perfect weather forecasts, certainly a forecast in which we could say that next June 20th we are going to get a good thundershower on the south 40; I think these forecasts are a

long way off. I think if you look objectively, though, over the past 20 years, that you do recognize improvements, and substantial improvements. I am quite confident that we will see much greater improvements through the next 20 years, but I certainly would not want to say when we will have perfect weather forecasts, or marked increase in forecast accuracy over a period of say 3 months in the future, or 6 months, which is generally, I think, what you were referring to in your question. There will be improvements; when everyone will be happy with the forecasts, I do not know.

Session IV

PANEL DISCUSSION: HOW WILL SPACE RESEARCH AFFECT YOUTH'S FUTURE?

Moderator: Dorothy Gordon

DOROTHY GORDON, *Founder and Moderator, Youth Forums*

Watching the constant indoctrination of youth in totalitarian countries, Dorothy Gordon became a crusader for democracy and was inspired to create the Youth Forums, in which young people with clear, well-formulated ideas on today's world issues meet to exchange opinions. The forums were initiated on radio in 1945 under the name of The New York Times Youth Forums. They were put on television in 1951 and are now presented each week as the Dorothy Gordon Youth Forums over WNBC-TV and the NBC radio network.

Dorothy Gordon received her early education on the continent and speaks several languages fluently. She came to radio from the stage, where she was known here and abroad for her costume folk song recitals. Miss Gordon gave her first radio program for children in 1926 over Station WEAF in New York City. Author of a number of books for children, her book, "You and Democracy" translates the basic principles of democracy into terms that any boy or girl can understand. Dorothy Gordon is Consultant on Youth Activities for The New York Times. She was awarded the honorary degree of doctor of laws at Fairleigh-Dickinson University.

The Youth Forum has received numerous awards, among these are the George Foster Peabody Award and the McCall's Gold Mike Award.

YOUTH PANEL

JUDITH ANN PAULSON, Senior, University of Seattle, Seattle, Washington; major, psychology

CHARLES MORROW, Senior, Whitman College, Walla Walla, Washington; major, mathematics

CAMDEN HALL, president of Student Body, University of Washington, Seattle, Washington; senior; major, political science

CHARLES F. ROGERS, Senior, Ft. Vancouver High School, Vancouver, Washington; winner, Westinghouse Science Foundation Award

EXPERT PANEL

D. D. WYATT, Director, Office of Programs, NASA

ROBERT R. GILRUTH, Director, Manned Spacecraft Center, NASA

LEONARD JAFFE, Director of Communications Systems, NASA

JOSEPH A. WALKER, NASA Chief Test Pilot, X–15 Project

How Will Space Research Affect Youth's Future?

MISS GORDON: The question that we have posed for our panel is, how will exploration of space affect youth's future? Before we go into our discussion I would like to read President Kennedy's statement. He said, "It is the policy of the United States that activities in space be devoted to peaceful emphasis. All of us in the United States, and all nations, can derive many benefits from the peaceful application of space technology."

In relation to President Kennedy's statement, let's go to the young people on the panel and ask them, what do you see ahead, how do you feel about the entire space program, its peaceful uses; anything you want to say.

MISS PAULSON: I would like to know, just how big is the Nation's space program?

MR. WYATT: Judy, you can measure the size of the program in several ways, and any way you measure it, it comes up pretty big. In the year to come there are going to be almost 26,000 employees of the Federal Government directing this program in the agency known as NASA. They will be directing the work of hundreds of thousands of contractor employees throughout the country. We are now flying from 20 to 30 satellites and deep space probes each year. Within the next few years this number will increase to perhaps 50 to 60 per year. Perhaps the best way to answer your question is in terms of the money going into it, our dollars. This year, 1962, we are spending almost $2 billion in support of the NASA space program, and in the fiscal year starting this coming July the President has asked the Congress for almost $4 billion to carry on the program.

MR. MORROW: I would like to know, how large a role will manned space flight be playing in America's future space program?

MR. GILRUTH: Well, Charles, over half of this effort which Mr. Wyatt has just discussed will go into manned space flights. I think most of you are familiar with the initial program, Project Mercury, as part of which Colonel Glenn made a three-orbit flight February 20, 1962. This is the initial step. This will be followed by Project Gemini, which involves a two-man space vehicle, and then later on still by Project Apollo, which is the manned lunar landing program. This whole effort will encompass more than 50 percent of the entire space effort.

MR. HALL: I would like to know what the practical aspects and advantages of the space program are?

MR. JAFFE: Well, Camden, it is a little difficult to determine what the practical output of any space program is going to be; however, there are two applications that are perhaps rather immediate: The use of satellites to provide meteorological observation, and the use of satellites to provide global communication.

MR. ROGERS: I foresee the exploration of space as a possible means of improving relations right here on Earth, before we actually go out into space. We can't even solve the problems which we have today right here. Space seems to be one of the answers to a possible solution to this problem.

MISS PAULSON: I think that is a very good point, and I think there is also another approach you can take on this whole problem of the impact of space exploration on youth. I read an article in a national magazine that described a Gallup poll. It was on youth, and the picture that it presented was not favorable. It described youth as a conforming, conservative, self-satisfied, and vicious sort of a group. They have so much that they want very little; they are not trying to grasp something beyond their reach. In other words, they are not trying to reach for the stars. I think that there are several ways that we can counteract this, that we can excite, motivate, and challenge youth, and I think one of the main things that is

going to do this is this infinitely retreating frontier, analogous to our early American frontier. Secondly, I think that schools, and such things as this fabulous fair and its exhibits, are going to stimulate the interest of youth, because I feel that once youth realizes the challenge at the present time they are going to respond. Then, finally, I think what youth needs is a hero; they need to see the importance of the individual and teamwork.

MISS GORDON: Do any of you adults want to come into this discussion? Mr. Walker, did you want to say something?

MR. WALKER: I had a thought while Judy was talking. Oftentimes we are making so much of the bigness of what we are doing that perhaps there is an overwhelming sense of inferiority involved in how you get started, and this may appear to be a lack of interest; I don't really believe there is a lack of interest, from some of the visits that I have made. There is considerable interest. I think one point we ought to remember is that everybody started out small and worked their way up. We didn't land in the spot we are in out of nowhere.

MR. HALL: I think you could most accurately state that this is an age of emphasis on the natural sciences. I think that in this area of discovery and research and advancing progress, the space age has in store for the youth of America, and perhaps for those of us who are not so useful, a great many things; in the field of communications, for example, satellites will be broadcasting messages from one part of the Earth to other parts. As you can imagine, this would have a terrific effect on the relationship of one country or one people to another. In the field of meteorology, the weather satellites will help the meteorologists predict the weather; perhaps some day they might be able to control the weather, so that the farmers in the mid-West and the West and throughout the Nation would be more accurately able to decide when to plant their crops so as to avoid crop failures. Also, in balance with this, I think, is the field of humanity, the social sciences, which probably as the years go by will become more integrated with the natural sciences in a working relationship so as to promote a program of the peaceful use of space in this advancing exploration.

MR. JAFFE: I think you are right, Camden. We are very fortunate in both the areas of meteorology and communications that there is a long history of international cooperation already established. Because of the very nature of communications and meterology, they are both global in their aspects. The weather doesn't observe international boundaries. And, therefore, I think it is fortunate that these two applications of space, if you will, are the first ones to come along where there is this history and there is the possibility of international cooperation.

MR. ROGERS: I think along the same line as international cooperation, let's also consider what will happen when we get international teams working in outer space. By that I mean teams of astronauts from several different nations. It might be, then, that once the different astronauts get out there we will find cooperation, where before there was conflict. I think this will lead to a greater potential for peace in the future.

MISS GORDON: Does anybody here want to comment on this?

MR. WYATT: This is perhaps not a wild hope, although we have to temper our thoughts about what kind of cooperation we can have in space in terms of the technical problems. But first, right now, in the Antarctic, we have a very good kind of international cooperation in which there are stations or camps, whatever one calls them, set up by many nations; the highest degree of cooperation has occurred between these explorers and scientists, particularly in times of need. However, I think we want to emphasize that when we are talking about something as complex technically as space flight it is not easy just to bring people together and do something commonly. What is necessary is that you bring people together for months, or more likely years, ahead of time and they work at the highest level of technical cooperation in order to make something as complex as a manned spacecraft, for example, a working entity

in outer space. You just don't decide that it is a good idea to have a composite of astronauts and bring them together.

MR. GILRUTH: Well, to go back to the theme that was discussed a minute ago. I think we will have to get this kind of cooperation here on Earth first before we get it in outer space.

MISS GORDON: Well, how do you think we can get it here on Earth? I mean, there is a question in your statement.

MR. GILRUTH: I don't think there was a question in my statement, Dorothy, but I would like to say this: As far as our program is concerned, Project Apollo will be handled in the same way as Project Mercury. Everything about this spacecraft and every reaction of the astronauts are known completely, worldwide. I think that if other explorations of space and other experiments were as well known as our own, we would have gone a long way toward this cooperation goal.

MISS GORDON: Do you feel that there should be greater cooperation between scientists throughout the entire world?

MR. GILRUTH: Yes, I think this is what I mean. I think in order to have complete cooperation you must have complete exchange of information.

MISS PAULSON: I think this idea of cooperation has several implications because cooperation has to be emphasized and peaceful uses have to be emphasized, but who are we cooperating with? Cooperation with our allies to the fullest limit is ideal, and yet, too, we should leave the door open for cooperation with the Communists. But I really don't think that we should be naive enough to think that the Communists are going to change their goal of world conquest and to think that they are going to give us anything that we can really use. I just think that they are not going to change their goal of world conquest any more than they meant that they were going to change it in World War II. Possibly something might force them to cooperate with us. I suppose that is possible; for example, if communications come to such a point that it makes secrecy and isolation impossible, that might force them; also the fact that their people might come to realize what it is like on the other side and what the other people are really like, that maybe they are not quite as bad as they have been told, that sort of thing. But I think it would be very difficult to hope for cooperation with the Communists.

MISS GORDON: Mr. Jaffe, with all the information that we get and we read, we lay people, we have heard the expression that communication satellites will open the window to the world, which might perhaps be an answer to the statement that Judy has just made.

MR. JAFFE: Well, I sense a little bit of a pessimistic attitude here, and I want to dispell this. There is, in certain areas, a great deal of cooperation, as I mentioned earlier.

In the meteorological program of NASA, the information that is being accumulated by Tiros is being given to the rest of the world, and the rest of the world is extremely interested in using these data. In the area of communications we do have a rather small United Nations complex of our own, in that we have five nations intimately involved in this program, and I think there will be more in the future.

At the risk of changing the subject, I would like to go back to somethink that Mr. Walker said very early in the discussion; it occurred to me as being something that we ought to consider. We talked about a very large program, very broad. It is very extensive, and it is overwhelming. But there are a great many little pieces to this program, and the amount of attention that has to be paid to these little pieces determines the success or failure of each of the missions, and I hope that we can discuss perhaps what kinds of things we have to do to pay attention to these details, what kinds of things, perhaps, the youth can do to assist us in paying attention to these details.

MISS GORDON: Mr. Walker, since Mr. Jaffe referred to you, do you want to come into this first? You had to prepare yourself in very minute details to make the record flight that you made.

MR. WALKER: Well, if you would like a little slant on that, I can sum that up by saying that the entire working career that

I have put in so far eventually wound up in those preparations for that record flight. I believe if anybody had asked me when I was in college something along this line, I would have come up with a great question mark. It never occurred to me that I would have wound up in this place, but I just kept plugging along and worked at a particular job, and this is the way it came out.

MISS GORDON: How long did it take you, how many years, to prepare for this, after you left college?

MR. WALKER: Well, that is what I was just getting at. I got out at the age twenty, and I made this flight at age forty-one.

MISS GORDON: And it took all that time; all the preparations led up to it. Well, now, let's go to the youth on this. This is a very important question, because whatever happens in the future, in the space age, is going to affect you young people more than it will any of us, actually. They are here, the adult experts, who are preparing this future for you, the young people. As you speak about it, would you think of it as a glamorous thing? Everybody thinks of this space age, going up into space, as something very glamorous. Let's get down to the practical things. What is this going to do for mankind, and should we go ahead with it? Has it a meaning?

MR. HALL: Well, certainly one aspect of space exploration, and I believe it is quite glamorous, and even to some degree practical, is that it cannot help but reduce to some degree this area of "unknowledge," if I may use that word. Of course, I think that one thing that man is constantly trying to do, from the very beginning of civilization, is to discover why and what, and this program certainly will achieve this.

MR. GILRUTH: I would like to make one point here that I think is different in the case of youth today, in particular relation to the space age. Most everyone of us so-called experts in this business are really retreads from some other area of technology. We have come into space after having had careers in some other fields, and there are very few people in advanced positions in the various programs that don't fit this description. For example, in my case, when I was the age of these young people here, the airplane and aviation was the goal out in front of many of the young people. It occupied the same kind of a goal that I think space does today. So these young people have a chance to go into space work and be there throughout their entire careers, unless there is some other major age that is going to supplant space in another 10 or 15 years. I think this is rather unlikely. So I think this is the major difference. I would also like to comment on one of the earlier questions or statements. I believe Joe Walker said that he spent 21 years preparing for this mission. It takes all kinds of people to do a mission like he just made. It takes, in addition to the man who flies the airplane and to the scientist who may have conceived the wing section or the kind of metal that is used to resist the heat, all kinds of engineers and mechanics and painstaking work to produce the airplane. And one of the things that the space age needs as much as anything else, one of the very important items, is engineers that can translate some of these long-hair ideas into things that actually work.

I would like to make a plea to the young people: Please don't all try to be long-hair scientists, because the engineer who can make things work is very, very greatly needed. There is a shortage of engineers in all fields, and not everyone can be a nuclear scientists or a Van Allen, but also not everyone can be an engineer. And as I said earlier, it takes all kinds of people and all kinds of talent to make one of these efforts go.

MR. WYATT: I was just going to say amen to this last point. I think in some respects there is a somewhat distorted view of what science is, or what space is. There is an awful lot of emphasis on this word science. True, the basic experiments we perform are scientific but, offhand, I would say the actual space effort is probably 2 to 3 percent scientific, and 97 to 98 percent engineering. It is the technology that has the real problems, and I think it is a triumph of technology more than a triumph of science at the present time.

MISS GORDON: Well, you all heard what Mr. Walker said; it took him 20 years, a little more, to achieve this record flight that

he made in the X–15. Do you think that the present generation of young people, your peers, if they hear a statement like that will say, "Well, I'm not going to go into this thing, I'm not going to spend 20 years of my life getting ready for this record in space; what is it for, why do it, is it worth it?"

Mr. Walker, do you feel it was worth it; what will it achieve; what is the future of the thing; the why of it?

MR. WALKER: We had better get back in focus again, too, because some of that period of time was not a strict requirement for the preparation; it was a chronological progression, advancement, that led to it, so that I don't want to get carried away on a wrong tangent.

MISS GORDON: All right. But please tell us: What is the future of aircraft? What will aircraft do for the space age, for the twenty-first century? What will it do for travel in the future, for instance? You have given sort of a springboard into shorter periods of flight, new kinds of wings, aircraft, and so forth.

MR. WALKER: In the first place, the purpose in being of the X–15 is to obtain basic information. As a result of the research carried on with it, information was obtained relative to aerodynamic heating, the resultant stresses on the structure, and on forces and pressures which industry needed to develop the metals and construction. We verified the theory involved in designing the X–15, and we verified the fact that human beings can fly it, that they have no trouble, and that they can handle it in space. All this information can be applied to any current or future program that has any connection at all with any of the areas which the X–15 is covering. One of the first things you can think of coming up would be a supersonic transport.

MISS GORDON: Which would lessen travel time a great deal, wouldn't it?

MR. WALKER: That is right.

MISS GORDON: I think we should get down to the practical uses of the space age, shall we say the by-products. You had something, Fred?

MR. ROGERS: Yes, I would like to refer to what Mr. Gilruth mentioned, namely, that it takes all kinds. And I think one of things about the space age that has influenced my friends, for example, is that there are so many fields being opened up. Every time we push back one barrier of knowledge a new frontier opens up. And I think this provides inspiration for everyone. In other words, maybe I wouldn't want to design Apollo capsules, but maybe I would like to go into health and medicine in some of the new areas that are being opened up as a result of the space age. It is this way with some of my friends, and if a new field is being opened up that they are interested in, then they will be inspired.

MISS GORDON: Do you know any of the fields that will be opened up?

MR. ROGERS: Well, I think in addition to health and medicine we have the other fields that have already been mentioned, such as weather technology.

MISS GORDON: Well, I was thinking of health and medicine. Do you know anything at all about what will evolve in medicine and health?

MR. ROGERS: I think one very exciting possibility, at least it excites me, is the idea of some of the new methods of surgery that are being developed from space applications, for instance, the laser technique, which is being contemplated for use in the satellites as a communications technique.

MISS GORDON: Judy, you had your hand up?

MISS PAULSON: Well, when you mentioned the by-products I thought of the housewife, because it seems to me that many of these kind of accidental or by-products of space research are going to make a tremendous difference to the women in the home, because it seems that soon housework is just going to be reduced to a matter of pushing a couple of buttons, and in a way it makes you think that possibly it isn't so important then for the wife and mother to be home except when the children are home, of course, and rather than wasting talent, and often 4 years if not more of higher education, that possibly the women should try to contribute

to the larger family, the community, by going out into the professions and into industry.

MISS GORDON: We have an audience of young people, scientists, and NASA representatives, but we are going to ask for questions to the Panel from the students in the aduience. I see a young gentleman standing there.

MR. BROWN, Sealth High School: My question is about the creation of jobs and opportunities for students in space. I know they have them, but can you tell me the extent which they will include students?

MR. WYATT: Well let me say that we have touched in the last few minutes on something that I think is extremely important, which is that the space age is going to offer opportunities for youth, in fact, in many broader areas than space itself. Judy has mentioned the household, as an example. There are some practical things right now that have arisen from the space era and developments leading up to the space era; for example, the pyroceram cooking ware which permits you to take your frozen food out of the freezer and put it directly on the stove and cook it without having to worry about breaking the utensil. The use of coating material such as teflon to make frying pans to which food does not stick. These are direct, although perhaps to the layman not obvious, results of the kind of technologies that have been developed and applied to the very high speed launch vehicles and the spacecraft themselves. In the future we in the Space Agency feel that this tremendous investment which the country is making in terms of its dollars will probably pay itself back to the country many times over in terms of the technological ideas that it gives all industry and commerce. And here, I think, is one of the big challenges for youth. Those who perhaps do not identify themselves directly with going into space or with designing these very complex vehicles might well look to the challenge of how to pick up the ideas that fall out of the program and apply them to our commerce and industry for the betterment not only of ourselves, but of everybody in the world, because here the thing that we are buying from our space program is knowledge. Some of this knowledge is directly identifiable with understanding the nature of space; some of it is identifiable with how to use space. I don't think at this point that we can talk about practical transportation systems out to the Moon or the planets. We talk about the parallel with Columbus' expedition, the discovery of America. I think we are not starting off on the false premise that we are looking for India yet; we are simply looking for the capacity to do things in the future, and I think that there is a tremendous challenge ahead for the young people today to pick up the by-products or the direct products of all this work and all this expenditure, to pour them back into our economy so that our lives can be a lot different and a lot better in the future.

MR. CHAPMAN, Ingraham High School: Mr. Walker, I would like to know if the information gained from Government research craft has been made available to general industry, and, if this information is made available, just how is it done.

MR. WALKER: Yes, information is made available to industry. It is made available in the form of preliminary information as quickly after a flight, say, an X–15 flight, as it can be analyzed from the recorded and reported information. The eventual outcome is a documented report of this and all other flights of the X–15, which is distributed to the industry, and anyone desiring this information merely has to ask for it if he hasn't gotten it already.

MR. MORROW: Going along with the idea of increasing cooperation in space, I wonder what might be an initial effort in promoting some type of cooperation with the Communists in some type of space effort, what would be a logical basis for initiating a program of this type?

MR. WYATT: We are at the present time undergoing discussions with representatives of the USSR based upon the famous exchange of letters between President Kennedy and Premier Khruhschev. I cannot, since these discussions are not completed, say too much authoritatively. We feel, and apparently the Russians feel, that the way

we start cooperating in space is to find those areas where we each have something to offer to the other; in other words, where neither nation will obtain a single-sided advantage. Now, for example, some of these areas are in the region of meteorological satellites. It is quite conceivable that we might work out a cooperative program with the Russians in which we alternately launch one of our meteorological satellites and they launch one of theirs, that we provide each other with the technical information required for each nation to acquire the pictures and other data from each other's satellite, because while Russia covers a tremendous expanse of the Earth, it does not have worldwide coverage, and any craft that they fly is bound either to have to store a lot of data for a long time in order to read it out over Russia or it will have to discard data from much of the world. We could supplement their weather program by providing tracing services, and the same in reverse. There are sections of a transit around the Earth in which we can't acquire data; if the Russians could provide tracing data coverage it would help our program. This is one way of cooperating. Another is in the mutual use of tracing facilities. Now the United States made this offer several years ago in respect to manned flight, that we would be very happy to use our tracking facilities in support of a Russian manned-flight program. But the regions we are looking for, I think, are not those in which we have an unrealistic involvement of technical people from both sides on an intimate day-to-day basis, but rather those regions in which it is natural that what we could do would give some advantage to the Soviet program, and that what they could do would give some advantage to our program, so that both of us benefit.

MR. ALEXANDER, Roosevelt High School: Some time during the discussion the satellite communication system was mentioned, and it was said that there were at least five countries involved. I understood, from what newspapers and magazines reported, that the system was to be controlled by private enterprise. My question is: Is this system to be controlled internationally or by private enterprise?

MR. JAFFE: Well, the cooperation that I talked about is cooperation in the research and development program that is going on today. Now I would like to make this clear, and perhaps what I say refers not only to the communication satellite program, but to all the applications program. We are in the research and development stage. One cannot say that we have communication satellites that can be used operationally at this stage of the game, and it will take some time before we do have these. These nations are involved in the program to investigate the problems and do experimental work in this area; how they will become involved in a commercially operable system is a subject for a great deal of study. It is being debated in Congress.

MISS HEGGENWALL, Franklin High School: I was just wondering if the panel has any ideas about the social problems that might be created by advanced technology, because we will produce a great big crop of scientists, and lay people will not be capable of understanding a great deal of this technology.

MR. GILRUTH: Well, speaking of my own field, which is really engineering, but which is on a little different level, I think, than most engineering, there are social problems in simply managing a project that gets as gigantic as, say, a project to land men on the Moon. When you think in terms of the kinds of money that Mr. Wyatt is talking about, in total lumps, like so many billion dollars, this is hard to comprehend. But if you translate it down to what you will spend per day in carrying out this project it comes out to be something like $5 to $7 million a day. Now if you translate this into the size of the team, or the size of the group on the job, this means that you have something like 100,000 technical people all bending their efforts toward this one end. And the problems of coordination and integration of all these technical efforts into the common goal becomes quite a problem in human relations on a scope not attempted before. So there are many of these kinds of problems that have to be solved, in just carrying out a technical or scientific project of this sort.

And these are the kinds of problems that we are facing up to for which we have to find good working solutions.

MR. MORROW: I think that one of the problems which we discussed earlier was that between the nautral and the social scientist. Certainly I feel that if this is to be solved, the two areas of science will have to work much more closely together; for example, in coordinating the advance into space with outer space law, which is a subject of considerable social concern. So, I think there is room for the natural scientist, of course, and also room for the social scientist. But a coordinated effort between the two is going to be necessary and certainly desirable.

MR. WILLIAMS: I would like to know what is being done in the field of formulating space laws.

MR. WYATT: There is work going on now and for the past 3 years on this question of space law. I believe that the United Nations has now set up a special panel in this area. We are probing to find out how we can extend those laws which now govern our so-called international waters and international air near the Earth to cover space. I am not a lawyer and cannot speak authoritatively on what the real problems are. I know that physically speaking, when you put a spacecraft into orbit around the Earth it obeys Kepler's laws of motion; it does not obey any man-based legislative act. And almost by definition at the present time the spacecraft is incapable of being significantly altered in its course so that it could avoid a national boundary, and, of course, the basic question is what is that national boundary in space as the Earth rotates on its axis. So it is my understanding at the present time that here is the area of one of the legal concerns: How do you define the extent to which national sovereignty should extend into the skies? Should it only extend up to those altitudes at which you can consciously control the path of, say, a craft like the X–15 airplane, or a similar kind of maneuverable system that is within the atmosphere? Perhaps we have to start from scratch in our concepts of what kinds of laws apply, where you cannot actually define an extension of the boundaries of a nation nor control the path of the object that is going around the Earth.

MISS GORDON: Mr. Jaffe, I would like to ask you to tell us something about communication satellites in relation to television, because that is part of the program, isn't it?

MR. JAFFE: Well, I think perhaps this is the most glamorous application, or promising application, of communication satellites, the possibility of relaying television programs throughout the world. Technically, this is a distinct possibility; certainly the capability will be there. I think though that there are many problems which one has to face in determining how much these satellites can be used for television broadcasting. We have done a little bit of looking at this, and there are many problems, problems associated with the time differences among the various areas of the world. There is a 5-hour difference between the United States and Europe.

MISS GORDON: Can't you tape programs and put them on later?

MR. WYATT: This is indeed fact, and it may very well prove to be cheaper and more desirous to tape or film programs and send them by transport; transport, as Mr. Walker indicated, is going to increase in speed even more that the 5 hours that it takes to cross the Atlantic today. So that perhaps communication satellites will not be used too often except for internationally significant events. There is a language problem associated with simultaneous broadcast television across large distances. I think it will be put to use; we will see demonstrations of television. How often satellite systems will be used for international television, I don't know.

MISS GORDON: Mr. Walker, how quickly will we be able to travel 5,000 miles?

MR. WALKER: Well, it would be dependent upon what your cruising speed is. If we can get up to 5,000 miles an hour for a transport, it will be an hour. It won't be that fast in the immediate future; it will be somewhat less.

MISS GORDON: We are talking about the peaceful uses of space. What advantage

do you young people see in traveling 5,000 miles in 1 hour? Do you feel that this has a meaning, and something that is needed for the future? What advantage is there in this quick transportation?

MR. ROGERS: I think, again, we have to go back to the idea of cooperation in breaking down some of the barriers that do exist in the world. I think if people are able to see other people in the world, living under other governments and so on, the common people will find that there is a great deal of likeness, which will improve our prospects for peace, because it will give people a chance to see each other, where now they can't. Mr. Walker, I would like to know some of the differences between the X–15 and conventional aircraft.

MR. WALKER: Fred, one of the best things about the X–15 is that it flies very much as the current Century series of fighter airplanes; however, it does cover a wide range of speed and altitude conditions, so that the handling of the airplane changes radically; we do get out of the atmosphere and have to fly it the same as a spaceship. In most respects it is similar to the Century series.

MISS GORDON: What about navigation? We haven't touched upon navigation. I have been reading a great deal on all the peacefull uses of space. And this has to do with X–15 research, Mr. Walker. Can you give us an answer on what will happen in navigation, in sighting land and so forth, for the pilot of a boat, should we say?

MR. WALKER: Well, the problem in navigation is going to assume different aspects; it is literally going to become astronomical as we go into space; in interplanetary travel, we will have to alter our notions of how to get from point to point, for initial intercontinental transportation. Probably the means we use now will be improved.

I have a point, though, on what this fast travel is going to do, sort of an analogy. We are going to squeeze nations together, in time, about the same as we are squeezing cities together now, and I think everybody can understand what the problems are on that scope and apply them, plus the language differential, to international problems. I had the pleasant experience of actually working on a flying job with a French company, hardly understanding one word of French; I found out that both the understanding and language barriers rapidly disappeared as we struggled along with the program, until by the end of 2 weeks we were chatting away as though we had known each other all our lives.

MISS GORDON: That is a step toward peace, isn't it?

MR. WALKER: This is a way of approaching cooperation, by working out small deals before you try the big ones.

MISS GORDON: I also found that in research there were a great many benefits to industry. Mr. Wyatt spoke about the teflon pan. There must be other benefits to industry that will be coming along?

MR. WYATT: Well, there are definitely many kinds of benefits; for example, the people here who have looked around the Seattle World's Fair have seen the tremendous exhibits showing the computer technology, for example. I am sure most of us lay people don't realize the extent to which the computer is revolutionizing business itself, making the stocking, the maintaining of inventory much easier, all our commercial transactions, as well as the solution of technical problems by high-speed computations. Well, the types of technology that we are developing for space flight are going to accentuate this as an area. It is going to be necessary to have very, very compact onboard computers, as we refer to them, in the spacecraft itself, which can predigest, precalculate, and cut down the amount of data that we actually have to send back to the Earth. I think that one can almost certainly forecast that the developments in this area are going to find their way very rapidly back into normal commercial and industrial applications. But beyond this, we are working with materials that have to withstand extreme temperatures, that have to withstand stresses; we are working with structures that must be extremely lightweight. We will be learning these kinds of technological bases that in turn will be plowed back; we will change

our concepts of how we build buildings, how we build things that we use here on the Earth. Certainly, the space communications problem (we referred to that part of it applied to our own communications from point to point on the ground), the problem of communicating out, say, a hundred million miles into space, is, I think, going to have tremendous feedback to our ground communications concepts.

MISS GORDON: Mr. Gilruth, why go to the Moon; what profit will there be in going to the Moon?

MR. GILRUTH: I think Mr. Wyatt has covered this point extremely well. I don't know of any analogies, but I do know that this program will be a tremendous stimulant to all phases of the technical industry in the country, a stimulant to science, a stimulant to engineering and technology; there will be all of these by-products, but I think it will be very interesting if we can accomplish this feat in the time period that has been set for us. I think everyone will be greatly interested to know what man will find when he gets to the Moon.

Session VI

PANEL DISCUSSION: IMPACT OF SPACE PROGRAMS ON SOCIETY

Moderator: Jack Beck

JACK BECK, *Staff Producer, CBS Reports*

Mr. Beck is now rounding out his third year with the award-winning "CBS Reports" series. During that time he has been staff producer on such productions as "Why Man in Space?" and "Year of the Polaris".

Before joining "CBS Reports" Mr. Beck had been news director for KNX, Hollywood, and the CBS Pacific Radio Network since 1946. Before he joined CBS News in 1941, Mr. Beck had been with United Press in various capacities: in the bureaus at Sacramento, California, Salem, Oregon, and Chicago, Illinois, and on the cable desk and in the foreign news department of the New York bureau of United Press.

Mr. Beck is a native of St. Louis and a graduate of the University of Missouri School of Journalism, 1938.

LEE A. DuBRIDGE, *President, California Institute of Technology*

Dr. DuBridge was born in Terre Haute, Indiana, in 1901. He went to public schools in several midwestern states and attended Cornell College in Mount Vernon, Iowa, where he received his B.A. degree in 1922. He did his graduate work at the University of Wisconsin and was awarded the M.A. degree in 1924 and the Ph.D. degree in 1926. His major field was physics.

Dr. DuBridge has taught at Washington University in St. Louis, Missouri, and the University of Rochester in New York. From 1940 to 1945, while on leave of absence from the University of Rochester, he was engaged in radar research as Director of the Radiation Laboratory at the Massachusetts Institute of Technology under the U. S. Office of Scientific Research and Development.

Dr. DuBridge is a member of the National Academy of Sciences and of the American Philosophical Society, and Fellow and past president of the American Physical Society. He serves as a board member for a number of organizations and foundations, both national and local, including the National Science Board, The Rockefeller Foundation, Mellon Institute, and the Los Angeles World Affairs Council.

He holds honorary degrees from nineteen universities and colleges. Among other awards which he has received are the King's Medal for Service in the Cause of Freedom (British), 1946, and the United States Medal for Merit, 1948.

JACQUELINE COCHRAN, ***Aviatrix***

Miss Cochran holds more aviation records than any other pilot in the world. She is, at the same time, a highly successful business woman.

In aviation, she holds numerous records for reciprocating and jet aircraft. She was the first woman to fly supersonically, at Mach 2 (twice the speed of sound). She was also the first woman to make an arrested landing in a jet on an aircraft carrier, and to be catapulted from a carrier. Her awards include the following: the Clifford Burke Harmon Trophy, the De La Vaulx Medal, the Frank M. Hawks Memorial, and the Distinguished Service Medal.

Miss Cochran was elected president of the Fédération Aéronautique Internationale (FAI) at the fifty-first FAI General Conference in 1958 and reelected president at the fifty-second Conference, held in Moscow, Russia, in 1959; she is currently U.S. vice president of FAI. She is chairman of the Board of the National Aeronautic Association, which is the U.S. affiliate of FAI.

Miss Cochran received an honorary degree of doctor of humane letters from Russell Sage College, Troy, New York, in 1955, and an honorary degree of doctor of laws from Elmira College, Elmira, New York, in 1955.

During World War II she was Director of the Women's Air Force Service Pilots, the WASPS, of the U.S. Army.

CHARLES E. ODEGAARD, ***President, University of Washington, Seattle, Washington***

Dr. Charles E. Odegaard became president of the University of Washington on August 1, 1958. He came to the University from the University of Michigan, where he had been dean of the College of Literature, Science and Arts, since 1952. His major field of teaching interest is medieval history.

Born January 10, 1911, at Chicago Heights, Illinois, Dr. Odegaard was educated in Chicago schools. He received his bachelor of arts degree from Dartmouth College in 1932. Continuing his education at Harvard University he received a master of arts degree in 1933 and a doctor of philosophy degree in 1937. He has taught at Harvard University, Radcliffe College, and the University of Illinois.

A member of Phi Beta Kappa, Beta Theta Pi, the Mediaeval Academy of America, and the American Historical Association, his achievements in the field of higher education are reflected in the numerous committees and commissions on which he has served. He was on the Selective Service Scientific Advisory Committee, 1948–54; chairman of the Commission of Human Resources and Advanced Training, 1949–53; and a member of the U.S. National Commission of UNESCO, 1949–55. He is also a member of the International Council of Philosophy and Humanistic Studies, a member of the advisory committee on cultural information for the U.S. Information Agency, a member of the Board of Directors of the American Council on Education, the Board of Visitors of the Air University of the U.S. Air Force, and the Regional Advisory Council of the U.S. Forest Service.

ANDREW G. HALEY, Attorney, Haley, Wollenberg, and Bader

Mr. Haley was born November 19, 1904, in Tacoma, Washington. He has been a specialist for more than a quarter century in the development of communications law and astronautics.

He received the following degrees: A.B., George Washington University; certificate for studies in international law and historical jurisprudence, University of Cambridge, England, 1926; LL.B., Georgetown University, 1928.

Mr. Haley was president and manager of Aerojet Engineering Corporation (1942–1945). He has been legal advisor to many international organizations and conferences. He has been active in many technical societies and has served as president of the American Rocket Society and of the International Astronautical Federation. Mr. Haley has written more than 100 articles on various aspects of communications regulation, international law, and space law.

Impact of Space Programs on Society

MR. BECK: I think I should say at the outset that the people who put this program together quite obviously like to live recklessly, because introducing an unfrocked reporter into the role of a moderator of a panel discussion is something like turning the goat loose in a cabbage patch. So I can't say for sure whether we will do this according to established procedural rules for orderly conduct of a panel, but I hope we can provide some interesting information.

I think in the order of procedure I might ask Dr. DuBridge first to take what period of time he wishes to address himself to the subject of the impact of space exploration and technology on the field of education.

DR. DUBRIDGE: We are talking this morning about the impact of space on social programs and on society. I think the first thing to remember is that we cannot predict and we do not now know just what those impacts will be. A few social impacts, of course, are already evident, but in 50 years from now the biggest impact on society of space research will be in new knowledge which has been acquired from our space program. And since we do not know what that new knowledge is going to be, it is extremely difficult to estimate or to predict what its impact upon society will be. I think it is probably true to say that out of a thousand predictions about what is going to be true as a result of our space program in 50 years, maybe one of them will actually indeed be true. And the one who makes that one prediction out of a thousand that comes true will, of course, be hailed then as a great prophet.

Now I would love to play the role of a great prophet, but since the odds are so great that I would be called a fool instead of a prophet in a few years, I think it is best not to take this kind of a gamble. However, there are some things that can be said. There is no question that it does not take a prophet to predict that space programs are going to lead to new systems of world communications, that there will be new systems of navigation, new methods of predicting the weather and all these, of course, will have obvious social impacts. There are those who say that as we learn more about the weather, we will also learn to control it, a prediction about which I am extremely skeptical. We understand the sunrise, but we cannot control it; all we can do is set our clocks back so it rises at a different time. Of course, we also know already that our space programs are going to have important economic consequences. New industries are being built, new technologies are arising directly out of space technology and space research, some parts of the country are showing important economic benefits, and others are not, and this obviously has important political consequences which we have seen. And then there is one more impact that is already being felt, which may be, I think, the most important of all, and that is the impact on education.

It is not true to assert that it was Sputnik I which awakened the American people to the importance of improving their educational system, because a move was under way many years before Sputnik I to improve our elementary schools, our secondary schools, and our colleges and universities. It is, however, true to say that Sputnik I and other Russian successes and the rise of the space program have had an important effect in accelerating public interest in education and public insistence that the quality of our educational program up and down the line be improved. I would like to give a couple of examples of what has already happened which has important implications for the future. Six years before Sputnik, a group of institutons, later joined by the college entrance examination board, began a program which is now called the Advanced Placement Program to give more advanced courses in high school so that students going on to college could have a head start, and possibly could even skip some of their fresh-

man courses in college. Last fall 13,000 high-school seniors entered college with advance placement in one or more subjects as a result of having had advanced courses in high school in college material. For example, at Harvard, out of 1,200 freshmen admitted last fall, 134 were admitted directly to sophomore standing, skipping the entire freshman year, as a result of the excellent preparation they had had in their high-school work. Second, several years before Sputnik, new kinds of high-school courses in mathematics, physics, chemistry, and English were being introduced. A group of high-school and college teachers and a group of outstanding universty scholars collaborated in bringing modern mathematics, physics, and chemistry into the high-school courses, and these are now having a wide impact; thousands of teachers in high school have been reeducated to take advantage of this new course material.

A few days ago, for example, a distinguished visitor who took his Ph.D. degree in physics in Germany many years ago came to California Institute of Technology and visited our freshmen lecture given by a famous theoretical physicist, Dr. Richard Feinman. At the end of the lecture this visitor remarked with astonishment that the material Dr. Feinman was presenting to our freshmen was precisely the same material on which he was quizzed in his Ph.D. oral examination by Dr. Max Planck, one of the great physicists of Europe a number of years ago. This illustrates the change which has been occurring in our college courses.

Now the advances in space technology, concurrent with changes in our industrial technology, the thing we call automation, have made it clear that the modern industrial worker, whether he is in space or in any other field, must be an educated worker. At an American assembly conference held recently at Arden House in New York State, the one unanimous recommendation of the participants there who were industrial leaders, businessmen, labor leaders, and educators was that the key to the future advance of technology in industry and an advancing prosperity in our society was better education, and they recommended that educational programs be continued to be improved all up and down the line.

Now the entire space program is going to require a large number of engineers and scientists and technicians, skilled workers, able managers, scholars of all sorts, as well as a host of well-educated people in industry. And the advancing of automation proves that no longer is the unskilled worker the prime mover in our industrial system, but it must be the educated worker, the skilled worker, the versatile worker, and this comes directly back, of course, to our educational system, the importance of all students able to do so, to remain in high school, continue on with their college careers, and proceed as far as their talents and abilities will take them. So maybe it will be true as we look back 50 years hence that one of the most important impacts of the advancing technology exhibited in the space program will be that America has acquired a better-educated citizenry and a better educational system. If so, this will be the most important result of the space program.

MR. BECK: Miss Cochran, for some years I have seen pictures of you climbing in and out of airplanes, flying to distant parts of the world, setting records, and I think most of the time trying to work a common agreement and understanding among people in many countries who were interested in the future of aviation. I would ask you if you might want to address yourself to what seems to you the implications of the fact that people who are now going to fly will do it without wings?

MISS COCHRAN: I would like to review what I think will happen to the woman in this new jet-propulsion age and the space age, rather than trying to say how much impact it is going to have generally on society, because I think Dr. DuBridge has done a very fine job, and I am greatly encouraged to find that 134 out of one college were able to skip one year of school, because I think the average person spends far too many years in school for what he learns; so, to me, that is encouraging.

In World War II, I was fairly hardpressed to find, out of all the women who held pilot's licenses, 40 to take their checkouts in Canada

and to get 25 women to volunteer to go to England early in the war, in 1941. But when we started the training program in the United States we had more than 33,000 applicants all of whom claimed on paper that they had the equivalent of 2 years of college; we processed on paper about 7,000, about 5,000 through their medical examinations, and trained a little over 1,000. There was no other program for women in any of the armed services with that many voluntary applicants. They had to search hard to try to come up with the numbers. Most of the services were in a numbers racket, as I called it, rather than quality.

I get many, many letters a week. Every time I do another flight I get a flood of letters, hundreds of them from high-school girls, and boys too, I might add, and many, many from women through the country, saying, "Is there a chance; although I have three children, my children are in school; I would like to fly an airplane; is there any way to make a living at it."

It is hard for a woman to have a remunerative job in flying per se. There aren't very many so employed. But in my opinion, this whole new era of motion and movement in the air has had a great impact on women, and I think it will have on our future generations. I think it is going to stimulate, I hope, a lot of the young people; when they are preparing to take their first year in college, at least they will enter it with some idea as to what they would like to major in, where they would like to fit into society with their education. But, again, I have gone to so many universities and colleges to speak and I have asked the direct question, "How many of you have made up your minds as to your major?" A very high percentage have not in their first year. So, I think that we also have another job to do, and that is to educate the parents a little bit to try to encourage their children to do some serious thinking in their last 2 years of high school, if they are going to prepare for higher education, to decide what they want to do and stick with it because there aren't enough of them, I think, who are doing this.

Now, I do feel that there is going to be a place in this new space age for women. I don't believe there is a scientist that I have ever talked to, and I have talked to a great many, who can precisely say at this moment what the exploration of outer space is going to give to us. We certainly know it will give something. Already they are developing very fine instruments which are being used in medicine; they certainly have found out a little bit more about the behavior of weather, even at this stage. Now whether, as Dr. DuBridge said, it can ever be controlled, I also doubt very seriously. But at least maybe we can be forewarned a little more quickly so that we might take some precaution against freezing of crops, destruction from floods, the evacuation of people, the saving of lives, and so forth. Today it is impossible to get a forecast that will hold good until tomorrow morning, to go from Seattle to Washington; I know, because I just tried to get one. So we haven't gone very far even in weather forecasting. I just did a very interesting flight, and although some of the weather was fairly accurately forecast a week in advance, the winds were not, so you see, we only got 50 percent of it. But I do think that this space age will have an influence; I do think that women will follow into space if we find there is any reason for continuing into space. I don't think anybody is going to know within another 4 or 5 years, frankly, what the benefits will be and whether it will justify the expenditure involved. I hope it will. But, then, I think that if it does prove worthwhile, women will have their place in this space world, as they have had in aviation.

MR. BECK: It has become somewhat commonplace to say that we stand on the threshold of discoveries, the impact of which we can't yet foresee, but in some degree in the history of the human race we have gone through this before; how many times I don't know exactly. The immediate parallel that occurs and that is usually used in the literature of this subject is the discovery of the Western Hemisphere. I would like now to ask a historian, Dr. Odegaard, whether he feels there are any parallels from history which point lessons for us in this impending period of exploration on a scale hitherto unknown.

DR. ODEGAARD: I am sure that every one of us alive these days witnessing the events of the last several years as man has launched himself into space has felt a surge of history, a slipping of familiar moorings, and an entrance into an unknown sea. It could be, though, that I exaggerate, that for some, and indeed for some who are attending this conference, these events represent business as usual. Change, yes, but in a smooth and orderly progression. However, against my background of education as historian, I cannot take these matters quite so casually. There have been many episodes in human history, to be sure, when men have built in orderly fashion upon the works of their fathers. But there have been other times when they have taken steps which have quickly shifted their horizons outward and altered their whole perspective on the human scene. In connection with those events of my own time by which man has launched himself into air, into atmosphere, into the overhead which we now call space, it is impossible for me not to think about the Fifteenth Century when the outreaching explorations of the globe by our European ancestors inevitably closed one chapter of human history and ushered in another. The world changed for men of the Fifteenth Century and there were innumerable consequences in the material, mental, and spiritual aspects of their lives. Mr. Webb in our day is indeed a sort of latter day Prince Henry the Navigator. When this Portuguese patron of exploration began sending his oceanonauts, if I may call them that, beyond the Pillars of Hercules, the Rock of Gibralter, and down along what in those days was the fearsome African shore, their probing voyages did not lance deeply into the South Atlantic Ocean. It took almost 20 years before, in 1445, a ship went far enough south, down the African shore, to reach the first large river that enters the Atlantic Ocean, and it was not until about 40 years later that the equator and the Congo River were reached. But then the pace over the ocean speeded up. In the 3 years from 1484 to 1487, navigators zoomed to the tip of Africa, to the Cape of Good Hope, and these tentative beginnings in oceanic explorations built the background for the great voyage of Columbus to America in 1492 and the girdling and circling of the Earth by Magellan and his party which was completed in 1522. So in our time, probings by balloon, propeller planes, jets, and now by missiles seem the successive steps in voyaging into space through the Earth's atmosphere to the Moon, the planetary system, and who knows, the galaxies beyond our own; so in our time, adventures in space have been transformed into the realities of ventures into space. The Boeing Space Area in the Federal Science Building is no longer entirely a matter of speculative contemplation; it is rather, the study of a chart table with massive areas of yet unknowns, to be sure, but with coast and geodetic survey notations on the chart, nonetheless. The dream one sees there has a shattering impact because it has the awesome touch of realizable reality. A man may be born into a world which in one sense he never made. But since the dawn of remembered history in the Near Eastern area of the planet Earth, the species Homo sapiens has made the world increasingly accessible to himself, and more than any other creature yet, he has remade the face of it.

As the first page of this next chapter of human history begins to turn, we cannot help but wonder what new revelations, new understandings man may find, what new things he will add to his repetoir of culture, what new dimensions for the human condition he may establish. Perhaps we can pick off a few queries. Our major preoccupation of the moment may well be scientific and technological in character, and it would be presumptuous of me in this galaxy of talent to pretend to questions in that domain; I leave them to my betters.

Julius Caesar had a certain sense of priorities when he said, "I came, I saw, I conquered." When it comes to the first part, "I came," I shall leave this part, the navigation into space, to my scientific friends. The incredible difficulties in getting there far surpass me, but I have faith enough in scientific colleagues to believe that they thrive on these impossibilities and that they will get us there, or at least get some of us there. As a humanist, I follow with what

could still be some nagging questions about outer space. "I saw, and I conquered." What will man see, what vistas may there yet be for man to behold in his mind's eye and in his heart as these ventures into space proceed. This puny creature, man, not the weakest, but by no means the strongest creature evolutionary process has cast upon the surface of this planet Earth, has by his own actions over time placed himself in the center of a cosmic drama. Will man still find himself apart from whatever reverence he may have for his spiritual being at the center of a widened yet anthropomorphic man-centered universe. And what will be the material conditions of his life? The requirements of the prepackaged, closed ecological systems for human survival in interplanetary, and perhaps even interstellar space, suggest such a host of changes in the bread and wine of life that all the concepts that we have inherited about the staff of life are thrown into a quandary. And since we are given to our own opinions, separated by our languages, what hope will provide a line of demarcation among the whirling galaxies of space to keep us, at least part of the time, off collision courses amongst ourselves. Perhaps I will leave that to Andrew Haley, the space lawyer.

To ask these questions is merely to infer that all the old categories of man's thinking about his conditions may be stretched beyond all present beliefs, and yet I can only say, as a historian, that man since the dawn of history has been the marvelously resilient animal, and perhaps he will find it within the compass of his mind and heart to accept the challenge of space as he accepted in the Fifteenth Century the challenge of the globe. Perhaps even we in our generation will have a chance to see the birth of new philosophies, new visions, new forms, new processes. Let us not discount, yet, man's potential not only to come, but also to see, and to conquer.

MR. BECK: A favorite analogy of a great many who have written about space is that it is the new ocean. If we take a look at man's history in riding the old oceans, it is not too encouraging. What about the law of the new ocean? Will we have to establish freedom of space, and how are we going to do it? Mr. Haley.

MR. HALEY: It seems rather curious that the accumulation, storage, and recovery of knowledge should have made more progress in the last 10 years than in the entire history of humanity prior to the past decade. It also seems strange that the world, the community not only of natural scientists but also of social scientists, should have forgotten in the process of this great adventure, the role of man himself. What good are all our great technical accomplishments if they don't have the proper impact on man? Now looking at the technical sciences, we find this tremendous progress; looking at the social sciences we find a bit of sociological speculation but very little clear attention to the problems of justice. Justice and jurisprudence have been neglected in the process that we have gone through in the past two decades. No matter how much progress we make in the technical and scientific fields, this is of no consequence to man except with respect to its impact upon man, that in any event, justice, equity, and principles of honor among people must precede man into outer space. I am pointing out that up until now the peer of social sciences, namely the science of jurisprudence, has found very little expression in the progress we have been making.

First, however, in considering space law we must consider the law of Earth. Is there any application of terrestrial law to outer space? This problem at first worried me very much. I looked at all the statutes available in the English language; I looked at the treaties that are now in effect, the Warsaw Treaty and others, all of which relate to air law, and to the statutes of, as I said, our country and countries using the English language. I found that there were about 3,000 national statutes relating to air law. And I was bewildered at the task of just assimilating what all these statutes have to say and how they might have some impact upon the space age. I could not afford to translate in so many languages, so I asked Senator Magnuson to have this done at the Library of Congress. We came up with a book of several thousand pages of statutes outlining and expressing the viewpoints of the various tribes of Earth with relation to the use of air. We come down to this proposition, that at

this time the only law as such, is that, relating to the ocean of air around the Earth, there is no law. The people who drafted the treaties have no concept of space navigation or space uses. The people who drafted the individual laws of nations, including the laws of the United States, have no concept of space law or space requirements. So that here we have a situation where air law ends. Now in air law you have this problem: Air is air. Air is not a hydrogen atom. Air is not a dissociated oxygen atom. Air is a mixture of molecules which provide a vehicle atmosphere upon which people can live. Air is air. It is not a question of dogs being wolves, or something like that. There are efforts being made to claim that air jurisdiction extends beyond the ocean of air around the Earth. I have been opposed to this viewpoint because if we ever did have a criminal trial or a trial involving civil rights, I know very well the courts couldn't uphold this fantastic theory which is trying to be broached by some lawyers and many scientists who do not know what they are talking about in the realm of law. On this problem, after receiving the help of Senator Magnuson, I was able to confer with several experts on high-altitude technology, and particularly with Dr. Theodore von Kármán, who has been my colleague in many matters over a generation. We arrived at a point called the Von Kármán line, which is about 280,000 feet up, where air is no longer called a vehicle substance, and also, where there is no longer any aerodynamic lift, where airplanes can't fly as such, where air-breathing engines have no air to breathe, where no combustion system will work, and where there is no aerodynamic lift. So the first point we are trying to establish in air law and in space law is the present limitation of air law on terrestrial jurisdiction where crimes, torts, civil and criminal liability of all kinds, and rights of nations end; for example, did the adventure in Russia of our U-2 pilot violate the laws of Russia. Was this a legitimate prosecution that the Russians made again this pilot? On the other hand, in our B47 adventure off the coast of Russia, was Russia correct or within her legal rights in shooting down our aircraft? So many questions have arisen in that respect. So I think in this field of jurisprudence, one of the first tasks is for the nations of the Earth to decide upon the limits of terrestrial jurisdiction and where space jurisdiction begins. Yet with space jurisdiction we are almost bound to have different rules than we do on Earth. Our terrestrial rules have been built up over a period of hundreds of years, so that we must in some ways segregate the mass of municipal positive law which we call international law from new concepts which will enable us to shape the use of outer space. Immediately we ask why the laws of the sea wouldn't apply to outer space? Well, this might be questioned because of the concept that outer space must be used for peaceful purposes, because you can deploy fleets, submarines, and anything else of warlike nature on the high seas without any restrictions whatsoever, but this should not necessarily be the case in outer space. By this I do not mean that we contemplate in any way abrogating the first law of all laws, namely, the right to self-preservation. This law goes back to primitive man. The right of self-preservation has been included in all documents, including the charter of the United Nations, the old charter of the League of Nations, and very briefly it might be said that a nation has the right to protect itself against unlawful asault, unjust warfare under any circumstances, whether the attack be staged on the high seas or be staged on the Moon or in outer space; it doesn't make any difference. If we know that some antagonistic power is staging an attack upon the United States, we have a right to go to the place where the attack is being staged and to protect ourselves against such an attack. This is the primary principle of law. I am not trying to advocate here any fantastic idea that outer space is completely free for the perpetrations of the acts of an agressor; this is not the case. The body of scientists that made up the Committee on the International Geophysical year, will recognize this proposition, that outer space, the space above the air, is free for all purposes, for all peaceful purposes, and this is a doctrine now that has been adopted by what we call the Doctrine of Consent, by the nations of the Earth. This is the first great concession made, or the first great new inter-

national law, created under the Doctrine of Consent, namely, that outer space is free for the use of all nations, all people, all mankind, without restriction, if it is for peaceful purposes.

I hope that this brief little discussion of jurisdiction, which could fill volumes, will serve to point up that factor.

The first problem is to define outer space, to define jurisdictions of missions on the Earth, to fight for the principle that outer space is free for all peaceful purposes. Then we come, of course, down to the speculative question of what the law should be with respect to liability for damages for any reason in outer space. We come to the question of space communications. We have solved many problems domestically, very few problems internationally, and we face among the tribes of men a great problem in connection with communications because right now we have not perfected but we have achieved the possibility of direct television from any part of the Earth to any other part of the Earth. Now there are already discussions among the heads of state that no antagonistic propaganda may be bounced off an Earth-circling satellite to another country, and we have also received proposals that under no conditions can television be directly broadcast via an Earth-circling satellite to another country. In other words, they don't want our type of civilization and they don't want our programing, so therefore they don't want it disseminated directly to the peoples of their countries. And, then, there is also the matter of the language barrier. Now these are very stark and devastating things in themselves, because they again freeze culture and prevent the dissemination of direct communications among mankind; so it might take us two or three generations, maybe two or three hundred years, to overcome this problem. This is one of the problems that is very important, namely, the right to use the artifacts of civilization for the general welfare of mankind. This is going to be a very serious problem as time goes on.

Then we have the problem of safety of life and property in outer space. For the first several exploits in Earth-orbiting satellites and also lunar and deep space probes we made no provision against, or concerning, safety and the preservation of property, and things of that nature. The second Earth-circling satellite that we sent up, Vanguard II, is still broadcasting, and it has the ability to keep on using a frequency for another 2,000 years. Also, it has the ability to keep on orbiting for several thousand years, and here it is a piece of useless material in outer space that we can neither shut up nor can we get it back to Earth again. So there must be laws adopted that will (1) necessitate the turning on and off of all radio emanations of artifacts in outer space, and (2) enable us to destroy them so that they cannot be out there as a perpetual hazard to property and life in outer space.

Now there are so many other points that I would like to discuss but time does not permit. I think I will just summarize with one or two words concerning each of two problem areas. The first is the probable launch and landing. Here, the problem is, can we launch a vehicle that goes over Canada or over Mexico without receiving their prior consent, or landing without the same consent. Of course, this is the case now. We have already received permission to fly our vehicles over British territory from our Cape Canaveral range.

Then, we have the problem of contamination, quarantine, immigration, piracy, so many other legal points that are coming up now. I only hope that one of these days we will be able to have a session such as this which will have more than one session or one speaker devoted to space law.

MR. BECK: Meetings like these are largely taken up with discussions of the development and refinement of techniques and technology, but to the citizen who will read and watch accounts of these proceedings I think there is a large question mark which hangs over it all, and the question is "Why?" And from that comes, "What will it mean to me?" Some spokesmen have told us of the benefit which will be acquired by the translation of space technology to existing technology, but to my knowledge, no one has yet spelled out the possible impact of man in

space. Administrator Webb has observed that many things that get done in this country with funds voted by Congress are nominally done for one reason, but are actually done for another. That is not news, I know, and I know he didn't mean it to be. But can we say something here today about the possible meaning of that for which we are about to spend $10 million? If we are now fabricating the key which is likely to open the door on a staggering body of new knowledge, what is likely to be its impact? When the Soviet space expert was in Washington last summer he was asked by a reporter if all mankind would not benefit if both nations would put aside space rivalry and mount a mutual effort. With a wry smile he observed that if that happened, neither nation would have a multibillion-dollar space program.

Do you regard that comment as cynicism or realism? What is likely to come of this competition in the new ocean of space? I wonder if one of you would care to speculate on the impact of man's view of himself if by reason of space exploration it becomes apparent that we are not alone in the universe? What happens, for instance, to the tenants of organized religion? Are we, without being aware of it, subjecting ourselves to the danger of overthrowing some of the basic tenants of our society without having a program to assimilate what new knowledge may be gained? Ecclesiastical authorities of Galileo's time were not so shocked by his espousal of Copernican ideas as much as they feared the unsettling effect upon the society of that time of his proclaiming them as fact. In short, are we preparing people for what we may find? Dr. Odegaard, could you respond to that?

DR. ODEGAARD: With all the new knowledge we have acquired through the centuries, a reading of history reveals that there are some old questions that survive, that are sometimes asked in somewhat different ways. "What is man, that Thou are mindful of him?" is a way of putting a very deep and probing question. And another is man's question, "What am I?" I do not believe that all this new knowledge is going to discount these questions. In my judgment it will only raise them to a still greater peak of urgency in the human heart. We have great organizations of men making machines, and we have individual men at a given moment playing the decisive role with regard to the fate of those machines, as well as of himself at the control panel. So it seems to me that quite apart from all the work of the scientists and the technicians in making these devices for probing into outer space and in attempting an assessment of the scientific meaning and interpretations of these probes, there will be projected by these projectiles into outer space, I think, the deepest questions in the heart of man. So I believe that there will continue to be a pressing requirement for our philosophers, our men of literature, and our artists to try to absorb within the meaning of human experience this new knowledge in some form that can be readable to man and make life livable. To throw this into a comparative light, may I suggest that the world has known in the past different kinds of answers, and I suggest to a large extent the questions which Mr. Haley propounded to you with regard to jurisdiction grow out of a Western way of looking at the natural world and of man as an individual in it, in terms of rights and privileges of individuals. I think there will be in this impact of space the reassertion of the question of man's importance, whether he is important, important to himself above all, and if so, how will he justify himself in the face of the kind of universe opening up before his eyes. Now it would be absurd of me to suggest any answer to you here, but I do not see how men can escape the urgency of raising these questions, and I do not think that we can act as civilized human beings if we act in utter disregard of these, because we can build all the great plans for the great explorations of the planets, but there will be required a mobilization of energy and of human motivation, an alertness of mind and a dedication of heart required, and these are still within that fairly finite biological creature, Homo sapiens, who still runs on the average something under 6 feet high. And so inside man I think there are these questions and we cannot afford to neglect them.

Mr. Haley referred to the desirability of conferences where space law could be discussed. I would not disagree with that, but Iwould go beyond it to say that I think we need to add, and this gets us back to C. P. Snow and the Divided Cultures, along with our scientific and human questioning, a recognition of the continued vitality of the great humanistic questions sometimes cast in purely human terms and sometimes cast in theological and religous terms. But whichever way they come, I believe they are going to be with us, and I don't think that men will get to the outer reaches of space if we don't at the same time recognize that the men at the control panel are human, and that even they one day may ask "Why?"

MR. BECK: I would now ask Dr. DuBridge to comment on the same question.

DR. DuBRIDGE: I don't want to disagree with what Dr. Odegaard said, but I would like to go back to a question which Mr. Beck raised in his comment: Why are we going into space? I am not asking the question of why Congress voted the money; Congress voted the money to put a man on the Moon ahead of the Russians. It was said in here yesterday, I believe, that if we did not get a man to the Moon ahead of the Russians that we would become a second-rate power. I think that is utter and complete nonsense.

The purpose of the space program, as far as the civilian space program is concerned, operated under NASA, is to conduct scientific research. It is a quest for more knowledge. And a man is going to the Moon, not to put an American flag there, but to find out what the Moon is like. Man is an instrument of exploration, and he can be a more powerful and more verstatile instrument than instruments and machines operating alone can be. And so, during the next 20, 50, 100 years, an enormous program is going to be going on in this country to find out about the solar system in which we live, about the Moon, about the planets, and about the space that lies in between. And as I said in my opening remarks, the major question is, what will we learn, and the answer is, we don't know until instruments and men get out there to find out. So knowledge is the purpose of the space program, and I think all citizens should keep that in mind.

Now this has been a great achievement to be able to send instruments and capsules out into our solar system, but we shouldn't get too egotistical about it. We don't want to be ridiculous in our claims that mankind has conquered the universe; and to illustrate that I would like to give you a couple of simple numbers. We can explore the planets around our solar system, Venus and Mars first, and later on perhaps, Jupiter and Saturn, and possibly eventually Pluto. It will take 6 months of travel to get to Mars via the most efficient route, but the months will stretch into years as we go on to Jupiter and the most distant planets. I think Dr. Odegaard suggested in his original remarks that maybe we will get to galaxies beyond our own. If we wanted to journey to the next nearest star to our Sun, the next object beyond the outermost planet of our solar system, and we could go at many times the speeds that we now are able to go, could get away from the Sun's gravitational pull, and get off into space beyond the Sun at a speed of 20 miles per second, which is an achievement that we cannot yet visualize definitely, but if we could, and then started out to see whether around the nearest star there was another planet which might have life on it, the journey to that nearest star, the very nearest one, would take, at those speeds, 40,000 years. We are not going to accomplish that journey to even the nearest star for many generations. Even if we could travel with the speed of light, which is something quite physically impossible, but even if we could get to half the speed of light, it would take 40,000 years to visit the nearer parts of our own galaxy, 80,000 years to get to the outer—the rest of the galaxy, a million years to get to nearer galaxies, and 6 billion years to get to the most distant ones. Man is like a little butterfly; he is out of his cocoon, but human lifetime is far too short for him to get very far away from home.

MR. BECK: Now I would like to ask Miss Cochran to say a word on the same thing.

MISS COCHRAN: Well, really, I am not as learned as these gentlemen, but the eighth

Psalm in the Bible ordains that man will have dominion over everything in the Earth as we know it. Maybe that is why these other planets were put so far away that man's mind would continue in the next generation, and the generation after that, but I don't think that Major White and Mr. Walker, and the 10 men who have been above 100,000 feet, and there are only 10 in the United States, probably in the world, had nearly as hard a trip, or as difficult a trip as the men and women who crossed this great country of ours, this North American continent, to settle in the West.

So I am sure man will have dominion over all; I am sure that man will be able to live with the environments that he finds, and if there is such a thing, to establish that there is life in outer space. I don't think that this generation or the generations just following this will get there, but they will finally get to stages in which I believe that man will conquer; it may take generation after generation after generation, and 40,000, 50,000, or 100,000 years, but it is ordained that they will get out there and find out what is going on.

MR. HALEY: I was interested in the question the CBS reporter asked my good friend, Dr. Sedov, and his somewhat sophisticated reply. I was also interested in the comment of Dr. DuBridge concerning the statement made yesterday. I must say that I spent 3 days, almost 24 hours a day with Dr. Sedov just a few weeks ago in Paris, and we had some other discussions about this matter. Let us not become too sophisticated. Maybe, after all, the primary objective right at this moment is to hit the Moon in order to preserve our place on this world itself. There is an overlay of problems. I don't know of anybody who has done more than I have in this business of international cooperation in space; I went through all the turmoil of the Antarctica Treaty negotiations, and we outlawed military and other installations in Antarctica, and here Mr. Krushchev just a few weeks ago said, in effect, "Mr. America, all the billions you have spent upon the early warnings systems and so on are but ashes in your mouth, because we have now perfected suborbital ballistic missiles which can go around and strike you from the west, and go through this area which the nations of the world have said are secret and serve peaceful purposes only." He had come forward and stated categorically to the entire world that he has the means to devastate the United States with high-yield, hydrogen bombs by using a path over the Antarctic Ocean.

Now I have given talks in practically every capital in the world, in most capitals in the world, anyway, except on the continent of Asia, and I find that the individual achievements of the USSR since that fateful day in 1957 have given to the USSR very, very great prestige, and I think that even though our objective is as sordid as merely getting to Moon first, it is a national objective to which we must give very careful consideration.

MR. BECK: I think it is time that we open the panel to questions from the floor.

MR. SORENSEN, National Commander, Civil Air Patrol: I have a question for Dr. Odegaard.

Both Dr. Odegaard and Dr. DuBridge have implied that education is probably the most important objection that will come out of space exploration. I assume that in our nation the parents and the teachers, especially in our public schools, share the leadership responsibility in educating citizens for this world which we hope to come.

I am asking you, Dr. Odegaard, what are your institution and the other institutions in America doing to improve the chances of our preservice teachers to include this in their teaching skill?

DR. ODEGAARD: Dr. DuBridge referred to the fact that there had taken place before Sputnik developments with regard to education in this country which were in the right direction. For a number of years there have been special institutes held in the summer for teachers of science—I take it this is what you have in mind, the science and technology; there have been year-around institutes which teachers could attend at the universities to be brought up to date on the latest developments in a variety of fields. There are literally dozens of universities in the United States participating in such programs. I know that my own university, the University

of Washington, and Seattle University have had projects in this area, and I think an effort is being made to overcome the gap in general understanding of contemporary sciences on the part of schoolteachers. Under the National Science Foundation these projects are going forward.

MR. FRITTSON, Blanchett High School: I notice that Miss Cochran mentioned that only 10 men in the United States have flown above a certain mark, and that she stated there were probably only 10 in the world who did this. It may be a minor point, but I have heard that certain people believe that in the Russian fight for space, the achievements of Titov and some of the other Russian astronauts were partially faked, and maybe they didn't really orbit the Earth. I was wondering if she feels that these flights were really valid.

MISS COCHRAN: We certainly have no evidence except what we have received through communications that the Russians have orbited. I am speaking purely as a person, and on behalf of no one but myself, but I have been sitting in conferences with the Russian people on an average of every 3 or 4 months for the last 10 years. They kept everything they did to orbit their man in deep, deep secrecy; it took several months on the part of Fédération Aéronautique International to get sufficient data from the Russians. We all know that we can simulate voices from the spacecrafts. We even had the voice of the President of the United States booming out good will to man and peace on Earth for about 2 weeks. It was his voice because I heard it. So, personally, they haven't proved to me that they have orbited a man. And I say that we have 10 men that have been above 100,000 feet, and this has been witnessed by foreign people and by many Americans. I pleaded very hard to have the Commander of the Fédération Aéronautique International present when Commander Shepard made his suborbital flight, and the same thing with Colonel Glenn. So I will just leave it to you to have your own doubts; I have mine.

MR. BECK: I think this question relates very directly to the technology involved, and I will ask Dr. DuBridge to comment on it, too.

DR. DuBRIDGE: I agree with Miss Cochran's comments, that the evidence is most incomplete, but I have no doubt but that the Russians did exactly what they say they did in orbiting these individuals around the Earth. We tracked their satellites, they appeared over the horizon always at the predetermined times, their tracks were precisely those announced, and they were certainly large enough to have men in them; we are only kidding ourselves if we think we are ahead of the Russians because we don't believe them. I think everything that they have announced about the scientific results of their flights, that we could check, has been correct. They have not lied or faked about anything that could be checked. They have hidden a lot, and I am sure a lot of information has been suppressed about their failures, but I hope we won't kid ourselves that they have not done these things, because everything we have been able to do to check them has turned out to be in accordance with their announcements.

MR. OLSON: I would like to know if any system has been worked out whereby a nation or the United Nations can claim territory on Mars, or how will they claim it? Can the whole planet be claimed by the first person who lands on the planet, or how will it be divided?

MR. BECK: That sounds like a question on space law, Mr. Haley.

MR. HALEY: We could take a long time answering that question, but I'll do it very briefly; I was in Moscow when Lunik II hit the Moon, and that was the day that Krushchev also embarked on his first peace mission to the United States. On that occasion the scientific community at the USSR Academy of Sciences said the fact that they put the pennant of the USSR on the Moon, the fact that they hit the Moon first, did not mean that they claimed sovereignty on the Moon. And since then the heads of state of several nations have enunciated the proposition that at this time, at least, and until further international study, no nation can claim any sovereignty or jurisdiction over the Moon. So at least the heads of states

of the world now take the viewpoint that hitting the Moon, placing a flag on the Moon, or exploring the Moon does not confer sovereignty. However, they have all reserved this proposition: that if you hit the Moon first and have effective control of the Moon, you might actually then assume jurisdiction. By effective control of the Moon is meant having a police force up there and forcibly repel other nations from coming on board.

MR. KILLIAN, Seattle University: I know that one of the problems that is bothering many people, including Mr. Haley, is the boundary of space; where does space begin and air end? To my mind this is a rather unimportant question because as with the 3-mile limit, any definition at the present time will be made obsolete by new inventions.

However, the question I am going to bring up is one in which I think each of you as individuals is tremendously interested. What are the rights of the man of the Earth, the citizen of the Earth (not the citizen of the United States, nor the citizen of the USSR) in space? And by space I am also going to include time, because you take time and multiply it by the velocity of light and you have space. My specific question is this, and perhaps Mr. Haley can answer it: What steps are being taken at the present time, first of all, to define these rights, second, to recognize these rights, and third, and this is a big step, to protect them?

MR. HALEY: First, I want to say that your analogy to the 3-mile limit has no discipline whatever. We have radio regulations based upon accumulating families of curves, billions and billions of families of curves now, and translating those into median curves and saying, here, you can't interfere beyond this point or you go to jail or you get fined.

Now to get to your other point, we have set up in the United Nations, in 1959, a subcommittee on law, a legal committee on law of outer space, and I went through some of the points raised by that committee. That committee has been reestablished and is meeting on May 28th in Geneva; we will be there watching out for man as best we can in this world that we live in. A few weeks ago in New York the American Rocket Society had a seminar on space law attended by official committees of Congress, as well as ambassadors from 23 foreign nations. The only thing we can do is hope that we will become more civilized so that we can implement the forces of the United Nations in time so they can enforce the rights of man, and above all, we must hope to get away from the anthropocentric concepts we have had on Earth for so many thousands of years and try to project into space principles of pure equity, pure justice.

MR. DICKSON, Blanchett High School: I would like to bring up what seems to be a rather controversial question. Dr. DuBridge brought up the long time that it would take to get to the nearest star, even by using speeds many times what we have now. Do you actually think we will get to the stars?

DR. DuBRIDGE: Do you mean by "we" the members of this generation. If so, my answer, of course, is no. I think the best we can hope to do in the next 50 years is get to a speed of one ten-thousandth of the speed of light, and at this speed, as I say, it would take 40,000 years to get to the nearest star. People say I am too pessimistic; we ought to be able to do 10 times better than that. We probably will, and then it will only take 4,000 years.

As the generations go by we will be able to increase these speeds step by step, but I point out that getting from a ten-thousandth of the speed of light up to, say, half the speed of light, going up by a factor of 5,000, which is a factor of 25,000,000 in energy, is a colossal undertaking, and nothing we have even thought of yet comes near to putting a sizable capsule at anything like the speed of even a hundredth the speed of light. It takes millions of dollars worth of equipment to get even one electron up to 90 or 95 percent the speed of light, and a sizable space capsule is something quite different.

But even if you advance in a hundred or a thousand years to the place where men could send capsules at, say, half the speed of light, it will then take 8 years to get to the nearest star and 8 years to get back; it would take 40,000 years still to get to the center of our galaxy and 40,000 years to get back. We

aren't going to get very far beyond the solar system as long as we remain human beings.

MR. FITTER, Roosevelt High School: I would like to ask Dr. Odegaard about this question "why" that he has raised; whether it is at all possible to clarify this question by scientific methods, or whether one needs other methods for enlightenment.

DR. ODEGAARD: Well, I suppose this gets us back to what you mean by scientific methods. Man has learned many things in his experience by a variety of methods, and the latest and most-used depends upon close observations and quantitative measurements. I happen to think that man is impressed by some kinds of reasoning on some kinds of issues and by certain types of science, and these are appropriate for finding answers of certain kinds; however, other kinds of reasonings are required for other kinds of questions. I hope I have sufficiently confused the issue to make it clear. But I don't think an easy and objective answer to this question "why" is going to come from any computer. I think there is going to have to continue to be a searching for the meaning of human experience involving the use of all man's senses. It has been amazing how some artists have in a sense prefigured new visions of the way man would look at the Earth scientifically. I sometimes wonder when I go to galleries today how many intuitions will later be questioned by scientists with computers which have been inspired by this other kind of man's seeing. So I would say the answer to the question "why" is likely to be complex and of many forms, but the ultimate question perhaps is whether man can continue to keep his inside up with his outside.

MR. GIBALL, Roosevelt High School: I would like to direct my question to Dr. Odegaard. Do you feel that in order to prepare our students better for the modern era we need to develop accelerated programs in our schools, which separate pupils into levels of ability?

DR. ODEGAARD: I definitely do. I think one of the major mistakes that has been made in American educational practice in the last generation or two has been the lack of observation of individual difference. It doesn't follow that because a given student is very apt and fast in one line of human inquiry that he is equally apt and fast in others. I think one of our needs has been to develop both at the high school and the college level a greater flexibility, a recognition of individual difference, and to grasp the opportunity in each individual to move as fast as possible and within the means available in our schools and colleges to build flexible programs for their challenge and interest.

MR. SEIFERT, Grays Harbor College: I would like to direct this to Mr. Haley. This point that he mentioned about the diffusion among countries of information from satellites and other objects that we put in space is an interesting one to me, in that in our country and under our constitution the freedom of speech and dissemination of information is one of the essential factors, and I believe that this is a primary factor in any advancement that we make. I am wondering if the United States can possibly allow it to happen that treaties will be made which enable other countries to block this type of cooperation in a field that is larger than any single nation or group of nations, such as the field of outer space is. And I would like to bring it back to a practical point and ask if we are working in this direction; what are some of the groups that are active today and actively working towards this goal of cooperation and treaty making.

MR. HALEY: I think that you almost answered your own question. That was a very sensible discussion. May I add a word of optimism for the first time this morning; there is an American, Gerald C. Grose, who is Secretary General of International Telecommunications Union (ITU), which is the oldest official international organization in the world. It goes back to before 1854. Gerald Grose used to be Chief Engineer for the Federal Communications Commission in this country and is imbued with the idea that we must have freedom of communications, that we must be able to broadcast from any point in the world to any other point in the world, we must be able to televise, and we must be able to disseminate information; this must be the vehicle for the tribes of men to get together and know each other and be the

first assault on the language barrier, the barrier of culture, and all these things, and he has a staff of men working with him who are also imbued with these ideas. So there we have at the top official spot as far as the world is concerned, a very good group of people who are trying to accomplish the very thing that you believe should be accomplished, and, of course, I agree with you most heartily. Circumstances on this globe are such that we can't avoid each other, actually. And in time, I think, by the very impact of our own geometry, the customs and the language barriers must consolidate and man must know other men and respect everyone. So we have ITU, and in this country we have the United Nations organization, and you have many student organizations.

Session VII

REPORT ON MANNED SPACE FLIGHT

Chairman: William Magruder

WILLIAM A. MAGRUDER, *President, Society of Experimental Test Pilots*

Mr. Magruder is Chief Engineering Pilot of the Douglas Aircraft Company, Inc.

Born May 26, 1923, Mr. Magruder joined the Douglas Aircraft Company in March 1956, serving initially as the Project Engineering Pilot for the Turbopropeller Logistic Support C–133 Transport. In May 1958, he was assigned as the DC–8 Jet Transport Project Engineering Pilot. During these assignments Mr. Magruder performed in the dual capacity of test pilot and engineer, participating in the design, testing, and operation of the equipment. In February 1962 he was assigned the additional duties of Chief of Market Development in Advanced Engineering Development.

Prior to joining the Douglas Aircraft Company, Mr. Magruder served as an aeronautical engineer in the United States Air Force Flight Test Division at Wright Field in the capacity of Chief, Bomber and Cargo Section of the Performance Engineering Branch. He was awarded the Legion of Merit medal in 1957 for work involving the B–52 functional development program.

Mr. Magruder graduated from Air Force Experimental Test Pilot School in 1953. He has an FAA Airline Transport Pilot Rating and is an FAA Flight Test Pilot Representative. He has a total flight time of 5,000 hours and total jet time of 3,000 hours.

We are privileged to participate in bringing together a group of young men whose diverse careers and activities have had a well-integrated impact on the progress that this country has made in the peaceful uses of space.

I emphasized the words "young men," and I would like to explain. In 1920 a young man in his early twenties, having adequate education and training, spanned the Atlantic in an airplane. The world found Charles Lindberg that day, and the impact of that feat upon aviation was enormous. The authors of the papers in this Session average 38 years of age. They have completed a combined total of some 51 years of university-level formal education. They have a combined total in excess of 32,000 hours of flying, mostly in exploratory test work. Now, these men are young in the professional sense, because to qualify with the proper training and education they must have formal education to an advanced degree, they must be trained by one of our test pilot schools or other training installations, and they must have flown a sufficient number of hours to become expert in their field, requirements far in excess of those in the 1920's. The youngest possible age to acquire all these requirements in their proper order is 31 years. It is a tribute to these men that their experience far exceeds the equation I have just outlined. This is because each of them had been carrying the triple duties of accumulating their education and their training, while aiding in the development of complex systems.

The important thing to consider is not so much what they are doing now, but how these efforts will reflect in the next 10 to 20 years. They represent the industry, the NASA, and the military services in the real sense of a joint effort.

Now much has been written about the loss of the first space pilot. But those of us who are close to the profession feel that this unhappy milestone has long since been passed. The lives of Mellant, Iven Kincheloe, and Victor Prather were lost during the preparations for the peaceful conquest of space.

These panelists are charter members of the 100,000-foot Club, all having flown higher than that altitude. However, I prefer, in deference to our theme, the Peaceful Uses of Space, to introduce them to you as this country's most useful pieces of space.

18. Manhigh Balloon Flights in Perspective

By DAVID G. SIMONS, *Lt. Col., USAF, MC, Chief of the Biocommunications Section, Physiology Branch, School of Aerospace Medicine, Brooks AFB*

Dr. Simons was born on June 6, 1922, in Lancaster, Pennsylvania. He earned a bachelor of science degree from Franklin and Marshall College, and a medical doctor degree from the Jefferson Medical College of Philadelphia.

He attended the Advanced Course in Aviation Medicine at the School of Aviation Medicine, graduating in the summer of 1950. In 1952, he became Chief of the Space Biology Branch of the Aeromedical Field Laboratory at the Air Force Missile Development Center located at Holloman Air Force Base, New Mexico. In this position, he was in charge of the U.S. Air Force program for evaluating the biological hazard of primary cosmic radiation at altitudes above 85,000 feet. In his research he uses stratosphere plastic balloon vehicles to float animal subjects at altitudes from 90,000 to 120,000 feet.

On August 19, 1957, Dr. Simons set a new manned balloon altitude record by soaring to an approximate 100,000-foot altitude in a balloon having a 3-million-cubic-foot capacity. For this accomplishment, he received the Distinguished Flying Cross, the Dr. John J. Jeffries Award, the Dr. Arnold D. Tuttle Award, and the Gold Medal Award for 1957 from the Fédération Aéronautique Internationale.

Dr. Simons is a Fellow of the American Rocket Society, a Fellow of the American Astronautical Society, and a Fellow of the Aerospace Medical Association.

How do the Manhigh balloon flights relate to our present and future manned space efforts? Let us first review the objectives, experiences, and lessons learned from the balloon flights.

Although conceived and completed before the orbital flight of Laika in Sputnik I which hearlded the arrival of the space age, the objectives of the Manhigh II flight of August 1957 asked two questions of manned space flight. First, were the life support techniques then available fully adequate to support a man under space equivalent conditions for a full 24-hour period? Second —more vaguely conceived, but considered equally important—what sort of tasks and challenges will man encounter in space and how well can he accomplish them?

Achievement of the highest levels of human performance in space has now become a national concern. At the luncheon address given during the recent American Rocket Society Space Flight Report to the Nation, General Bernard A. Schriever, Commander, Air Force Systems Command, who carries a wide range of responsibility in the Air Force military space effort, described man's mission in space thusly: "While satellite-borne instruments can gather a variety of information, they are no substitute for the unique abilities of man to observe, to make judgments, and, most important, to exercise control based on these judgments."

The Administrator of the National Aeronautics and Space Administration, James E. Webb, recently addressing the Aerospace Medical Association, emphasized the importance of man's ability to observe the unexpected in the following words: "Even the most advanced instruments can gather and transmit only information that they are pro-

gramed to obtain. They have no flexibility to meet unforeseen situations. We have had almost 70 successful unmanned spacecraft to date, but none of their instruments reported the 'fireflies' that John Glenn saw on his February 20 flight in orbit."

These are functions that cannot be programed into any "black box." They are functions only a man can perform, and then only if the man is functioning at peak mental efficiency. We have learned that a man's performance may at times be reduced to the level of a second-rate black box.

Returning to the Manhigh II flight, we were quite confident that the answers available to the life-support problems would be adequate. For several years we had been exposing animals to cosmic radiation above 90,000 feet for continuous periods up to 36 hours. For convenience, we related the amount of life-support capacity (oxygen supply, temperature control, etc.) to that required by a mouse. We were flying 100 mouse-unit capsules. For instance, we used this unit as follows: The metabolism of one of our guinea pigs was eight times that of a mouse. Whenever we loaded one guinea pig onboard, it would account for 8 of the 100-mouse-unit capacity of the capsule. Our studies indicated that a man required 300 times as much oxygen as a mouse. As we saw it, the problem of conducting a 24-hour manned flight was simply a matter of building a 300-mouse-unit capsule big enough for a man. The Manhigh capsule was just that. Each life-support system operated on the same principle used in the animal capsules but was simply increased in capacity by at least a factor of 3. This included the concept of designing the capsule so that it would be warm at night without supplemental heat, but would require cooling during the day.

The approach to the second question of what tasks and activities to plan was equally direct. The pilot could observe phenomena suggested by scientists of appropriate disciplines, or he might observe new phenomena not anticipated. I prepared for the former by taking advantage of every opportunity to discuss what phenomena might be observable with astronomers, meteorologists, upper atmosphere physicists, and others throughout the 2 years preceding the flight. By August 1, 1957, I had collected some 33 specific experiments and observations to be made, many of them recurrent at frequent intervals.

I prepared to record unpredicted observations and phenomena by taking along a miniature tape recorder.

The possibility of a green flash occurring at sunset or sunrise had been predicted. Since I was watching carefully for it, I saw it as expected. The complete lack of scintillation of the stars to normal eye viewing had been predicted, but the marked increase in how colorful they appeared was unexpected. Gossamer clouds at 70,000 feet were a complete surprise. So I went through the 33 experiments, with but two exceptions. I had planned to note carefully the appearance of the zodiacal light in the dark sky near the twilight zone and to look for the gegenschein near midnight. I forgot to do both, despite extensive preparation for them. I had awakened to start flight preparations more than 24 hours before, and it was uncomfortably warm in the capsule. Fatigue was taking its toll.

This called attention to the quantitative aspect of human performance in space. How well had I been able to conduct planned observations? The tape recorder proved a reliable source of information as to how much time I had spent making spontaneous (unprogramed) observations. The percentage of time spent dictating tended to decrease progressively throughout the flight except during occasions of special interest such as sunrise and sunset. This is clearly illustrated; Between 1300 and 1730 of the first day, I spent 15 percent of the time dictating spontaneous observations. Between the same hours of the second day, after 40 hours of continuous duty, I dictated nothing. There was no lack of phenomena to report. At one point, the 6 inch telescope focused the image of the Sun on my pressure suit and it began to smolder. I was functioning at too rudimentary a mental level to generate the little initiative required to report the details to the recorder.

Another example of the serious reduction

in the level of my performance was the set of omniradio beacon readings attempted on the second morning. This was a task I ordinarily did easily and quickly. My performance was described in the Manhigh II Holloman Air Force Base Technical Report as follows: "I had become vaguely aware that it was taking me an excessively long time to take a set of omnirange readings. I was prone not only to make the 180° error in reading, but to repeat the error on a second reading. I was unable to concentrate, sometimes forgetting what I was doing in the middle of an activity. I passed this off as fatigue and was not concerned." The ground crew to whom I was making the readings for triangulation of my position above the clouds could not get three consecutive coherent readings.

Clearly, at times I was functioning at a high level of initiative and creativity and at other times, I was unable to execute simple tasks and showed no initiative. What made the difference? Two factors stood out. One obviously was fatigue due to prolonged continuous duty without adequate rest. The other was more subtle. Project personnel had observed that whenever the capsule temperature reached or exceeded the 78° F region, the performance of the subject wearing the pressure suit in the capsule dropped markedly. This was expressed in the Manhigh II Technical Report by the task scientist, Captain E. R. Archibald, as follows: "Specific examples of performance decrement caused by high temperatures occurred many times during ground tests; for example, the subject would refuse to answer intercom messages, planned activities were not carried out, position reports were not given, and the pilot would exhibit marked irritability in contrast to previous attitudes toward the test." The difference in behavior is illustrated by the tape recordings during two portions of the comments made during the flight. The first was recorded at 1453 during the first afternoon when I was not yet severely fatigued and the capsule temperature was comfortable. This recording is as follows: "I tried to compare the color charts to the sky color, the green . . . one was too green, the other, too purplish violet, because this sky has the blue of an ocean blue, pure clean lapis lazuli blue, at the interface between the dark purple sky above, and the white typical of looking through the atmosphere horizontally toward the horizon. The color above this is deep indigo, intense, almost black . . . In fact, the point is, what little color is there is very deep and intense. . . Although there isn't very much. It is nearly black."

Contrast that alert manner of speaking to this voice recoding: "It is now 1105, no, 2305. . . We just now have got the air conditioner plugged in and . . . and . . . I am . . . we are . . . un . . . it is very, very hot until we could turn the air conditioner on just now . . . so I will . . . uh . . . be feeling much better here in just a few minutes."

This record was made during the preparation of the capsule before flight. I certainly was not fatigued yet, but I was uncomfortably warm.

Summarizing the importance of these factors to space flight in the original Manhigh II report published in 1958, I made the following comments: "In manned space flight, one of the most important human-factor problems will be the degree of mental alertness and creativity of crew members. The concept of expressing human drive to note important details and make new scientific observations under space equivalent conditions is called the creativity index. On such a trip, crew members must efficiently monitor the environmental situation, detect incipient emergencies before they develop to the irreversible uncorrectable stage, and, if necessary, take ingenious corrective action."

Initiative index may be a better term than creativity index. However you name it, this concept was a central focus of the objectives for the Manhigh III flight piloted by Lieutenant McClure a year later, October 1958.

We first aimed to make the flight as scientifically productive as possible. Valuable in itself, the flight was structured to encourage the pilot to demonstrate maximum initiative in making observations. A second approach to improve pilot initiative was to reverse the temperature control system to a normally cool capsule requiring supplementary heat

at night. This was done to insure that the observational competence of this pilot would not be compromised by uncomfortably warm temperatures. Third, we placed major emphasis on documenting the quantity and quality of all aspects of the pilot's performance as completely as possible throughout the planned 24-hour flight, using photography and tape recording. Physiological data then obtainable via telemetry—heart beat, respiration, and basal skin resistance—were continuously recorded on the ground. Skin and internal temperatures were read and reported by the pilot. We were interested in the possibility of a relationship between a reduced level of performance late in the flight and changes in the physiological measures.

The observational program was implemented through a panel of experts. The purpose of this panel is described in the Manhigh III Technical Report as follows: "It is obviously not practical to take along a group of scientists to stratosphere altitude at the present stage of development of balloon technology. However, it did appear reasonable and feasible to provide a selected panel of experts with an opportunity to converse with the pilot during the flight, letting him be their eyes, so to speak, so that they could ask their questions while the balloon pilot is actually making the observation. In this way it was expected that the number and quality of observations made on a given topic would be equal to that attainable only after two or three consecutive flights, using ordinary flight-debriefing-repeat flight techniques." Experts on hand during the Manhigh III flight included specialists in psychiatry, aviation physiology, meteorology, astronomy, and cosmic radiation.

The revised temperature control system failed, exposing Lieutenant McClure to a life-threatening 95° F rather than the performance-threatening 80° F experienced on Manhigh II. This was discovered 2 hours after he reached ceiling altitude and demanded immediate termination of the flight. The physiological monitoring proved invaluable by indicating the magnitude of vital stress to which Lieutenant McClure was subjected and how he was reacting to it. These data were the determining factor in the decision to have Lieutenant McClure land the capsule using the balloon in a normal manner. Without them, we very likely would have compounded the heat emergency with an emergency parachute descent into mountainous terrain. When he landed his internal body temperature sensor read 108.5° F which corrected to at least 106.5° F.

We learned little about using physiological measures as possible indicators of the level of human performance, but the flight did prove the value of thorough physiological monitoring.

On prolonged solo orbital missions near the Earth or on the programed three-man 7-day Apollo flights to the Moon, objective criteria of the reliability of astronauts' judgment will be of fundamental importance. When an astronaut has pushed beyond the point of sound judgment, how is he to know? Experiments have proved man's own insight unreliable. He is likely to be much too irritable to accept corrective suggestions from fellow crew members. How can medical monitors on Earth be sure they understand the complete situation 400,000 miles away?

The brain is the seat of decision, judgment, and other higher mental functions required of man in space. Many physiological phenomena measurable on the surface of the body are greatly influenced by activity of the central nervous system. Brain waves, pulse rate, respiration, skin resistance, and body temperature are available, to name a few. Some of these are largely under voluntary control, others are more reactive to emotional states and involuntary nervous system activity. Each tells part of the story of the activity going on in the brain.

The crude instrumentation used on the Manhigh II and III flights has now been modernized into a minaturized six-channel physiological telemetry system placed on the person himself.

Patterns of physiological response observable using these techniques are clearely demonstrated in figures 18–1 and 18–2. These two records were obtained on an individual during sleep and wakefulness, respectively. During sleep (fig. 18–1), heart rate shows a

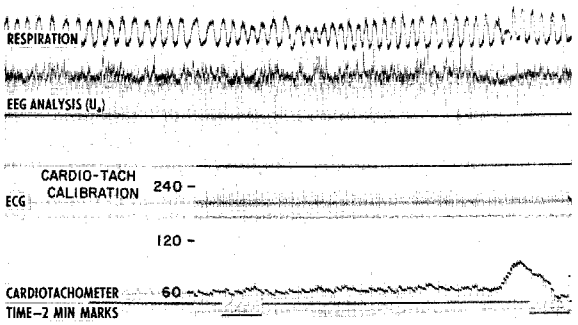


FIGURE 18–1. Subject asleep; observed between 0435 and 1438 January 13, 1962, during Biotel experiment No. 12. Cardiotachometer record varies rhythmically at a frequency corresponding to respiration, averaging about 60 beats per minute. The domeshaped heart-rate pattern occurring shortly before 0438 peaks at 90 beats per minute and lasts 20 seconds.

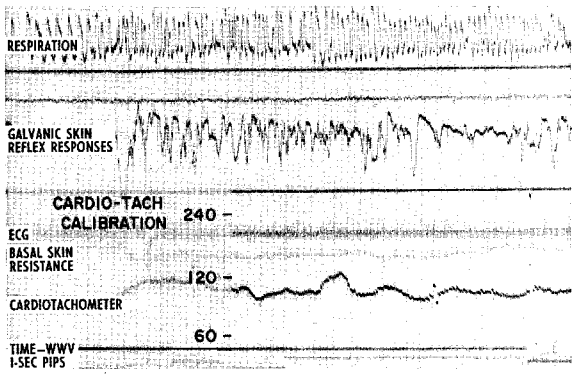


FIGURE 18–2. Subject awake and alert; observed between 1003 and 1006, January 13, 1962, during Biotel experiment No. 12. The subject was walking around the laboratory quietly watching research activity. The respiration pattern on the top line shows a relatively slow regular pattern for the first half minute, abruptly changing to a more rapid irregular pattern for the following minute. It concludes with a less rapid, relatively regular pattern. The frequency of GSR refiexes correlates closely with the slow, as opposed to rapid, respiration patterns. The first half minute shows a lack of GSR responses. The basal skin resistance drops with the onset of marked GSR activity as would be expected. The first half minute of cardiotachometer record shows respiration coupling as seen during sleep, but averaging about 90 beats per minute as compared with 60 beats per minute during sleep. The subsequent record is suggestive of a series of superimposed dome-shaped events comparable to those of figure 18–1 but in frequent succession.

slight, but regular, rhythmic change directly related to respiration characteristic of sinus arrhythmia. At one point, this regular rhythmical variation of heart rate is interrupted by a marked smooth increase in rate. It is interesting to note that at the same time there is an interruption of the even respiratory pattern. Whenever these changes in pattern occur, during sleep there is frequently galvanic-skin-reflex activity accompanied by motion of the subject.

Figure 18–2 presents the corresponding physiological picture when the same subject was freely browsing around the laboratory the following morning. The respiration pattern divides into three distinct patterns. The first half minute of the 3-minute record shows a slow regular respiratory pattern. The next minute is characterized by rapid irregular breathing, and the remainder of the record by less rapid but regular respiration. The galvanic-skin-reflex (GSR) record shows a few small reflexes during the first 30 seconds with an abrupt change to frequent large reflexes during the following minute. The remainder of the record was marked by a reduction in frequency of GSR activity. The abrupt drop in the basal skin resistance with the onset of rapid irregular respiration slowly recovers during the final minute of regular more rapid respiration. The first 30 seconds of heart-rate analysis show a strong coupling to respiration (sinus arrhythmia). The remainder of the record suggests a superimposed series of events similar to the one illustrated during the last 30 seconds of figure 18–1. The fact that this episodic increase in the heart rate characteristically occurs with a change in respiration, and with GSR activity, suggests that it may at times be the orienting reflex described by Pavlov. It is also referred to as the investigatory reflex of the central nervous system.

This greatly facilitates multichannel monitoring in operational space flight situations. A team of research scientists at the School of Aerospace Medicine is intensively exploring whether there is sufficient information hidden in the measures now available to reveal the functional state of the central nerv-

ous system. At present, this is primarily a challenge of data analysis. It is already clear that this research approach can greatly clarify many functional relationships between the mind and the body. These promise to become keys for unlocking many of the frustratingly elusive problems of phychosomatic medicine.

The Manhigh program was born of the challenge beyond: Space. I believe the lessons learned from that program define a new challenge: The challenge within. This is the challenge of relating the performance of the mind with function of the body. This can only be done through a rigorous step-by-step neurophysiological understanding of how the mind works. Modern brain research and electronic advances open new paths into this frontier. Advances here are essential for space medicine and promise great benefit to all medical science.

As each of us more fully accepts the challenge of the exploration of space, it increasingly influences our daily lives. Little by little, without our realizing, it changes our concept of our relation to the physical universe, to eternal verities, and to each other. As new understanding unfolds, revealing the relationships of our minds to our bodies, this, too, will influence our fundamental concepts.

19. Discussion of Project Excelsior

By JOSEPH W. KITTINGER, JR., *Capt., USAF, Escape Section, Aerospace Medical Laboratory, Wright-Patterson AFB*

Capt. Kittinger is a test pilot with 4,900 hours of flying experience, 2,500 in jets. He is a test parachutist with 47 premeditated jumps, and a balloon pilot with 65 hours of experience. He holds the parachute altitude record of 102,800 feet.

In June 1957, Capt. Kittinger was pilot of the first flight in the Manhigh Project, reaching an altitude of 96,000 feet in a sealed gondola. He was also project test director of Project Excelsior, an investigation of pilot escape from high altitudes. In three successive jumps, he descended from 76,000 feet, 75,000 feet, and finally from 102,800 feet, the record.

For these tests, he wore a special full pressure suit as his only protection against the extreme cold and vacuum of space. While descending, he carried a self-contained life support system and maintained continuous voice and telemetry contact with the ground. Thus he was able to record first-hand observations and physiological and environmental data enroute.

He was the recipient of the 1959 Harmon Trophy.

There were two basic objectives of Project Excelsior, which was conducted by the Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Dayton, Ohio. The first concerned the psychophysiological aspects of escape from high altitude and the second concerned the protection of a man in a space environment. I will not go into any great detail in defining the problems and describing the preparations that we went through before the first high-altitude tests of this Project. It had been demonstrated in previous dummy drops, from aircraft and balloons, that a body free falling from high altitudes, needed some sort of stabilization. On one occasion a dummy, free falling (without any stabilization), spun at the rate of 200 revolutions per minute; certainly above the physiological limits of a man.

The first high-altitude tests of Project Excelsior occurred on November 16, 1959, at the instrumental range at Holloman Air Force Base, New Mexico. Because of a procedural problem the parachute could not deploy at the proper velocity (since the test was initiated from a balloon at zero velocity). As a result of this, the entire free fall from 76,000 feet was made without any stabilization. During the early stages of this fall the subject was able to control the slight turning experienced (by using sky diving techniques). However, at about 30,000 feet a violent spin was encountered that rendered the subject unconscious. Recovery of the subject was effected by the automatic reserve parachute, opening at 10,000 feet, while the subject was unconscious. Instrumentation carried on the subject disclosed that the maximum spin rate that occurred was 87 revolutions per minute at about 30,000 feet. This is considerably lower than the expected spin rate that would cause unconsciousness. So, on this first test, even though it was not planned, we obtained a control, an unstablized free fall from 76,000.

On the Excelsior II test of December 11, 1959, made from 75,000 feet, the procedural problems encountered on the first tests were corrected and the parachute deployed and provided perfect stability during the free-fall phase of the test. The subject was able to correct the slight turning encountered (through the vertical axis), by merely extending an arm and leg in the direction of

the turn. Hence, if the turn was to the left, the left arm and leg were extended; this corrective action stopped all turning.

As the fall progressed and denser air was encountered, only a leg was extended to stop the turning. The free-fall velocity with the 6-foot-diameter stabilization parachute deployed was three-fourths terminal velocity for that altitude. I had confidence in the Beaupre Multi Stage parachute; all of us on the Project Excelsior team knew that it would perform, given the proper opening conditions. I would have never made the Excelsior II tests if I had any doubts about the capability of the parachute, as I felt that one test like Excelsior I was sufficient for me.

Comparisons of the flights of Excelsior I and II are given in figures 19–1 and 19–2.

Following the Excelsior II test, our team returned to the Aerospace Medical Research Laboratories for additional tests in preparation for the Excelsior III tests. The Excelsior I and II tests were performed at 76,000 and 75,000 feet, respectively, at a pressure of about 25 millimeters of mercury. I had thought during these tests that if I experienced any failure of the pressure suit, the helmet, the oxygen regulator, and so forth, I could make a rapid exit from the gondola and probably survive. Psychologically this was a very comforting thought. However, as we prepared for the Excelsior III tests, at 103,000 feet or a pressure of about 7 millimeters of mercury, I realized that if the protective equipment malfunctioned, there would be no escape from the consequences.

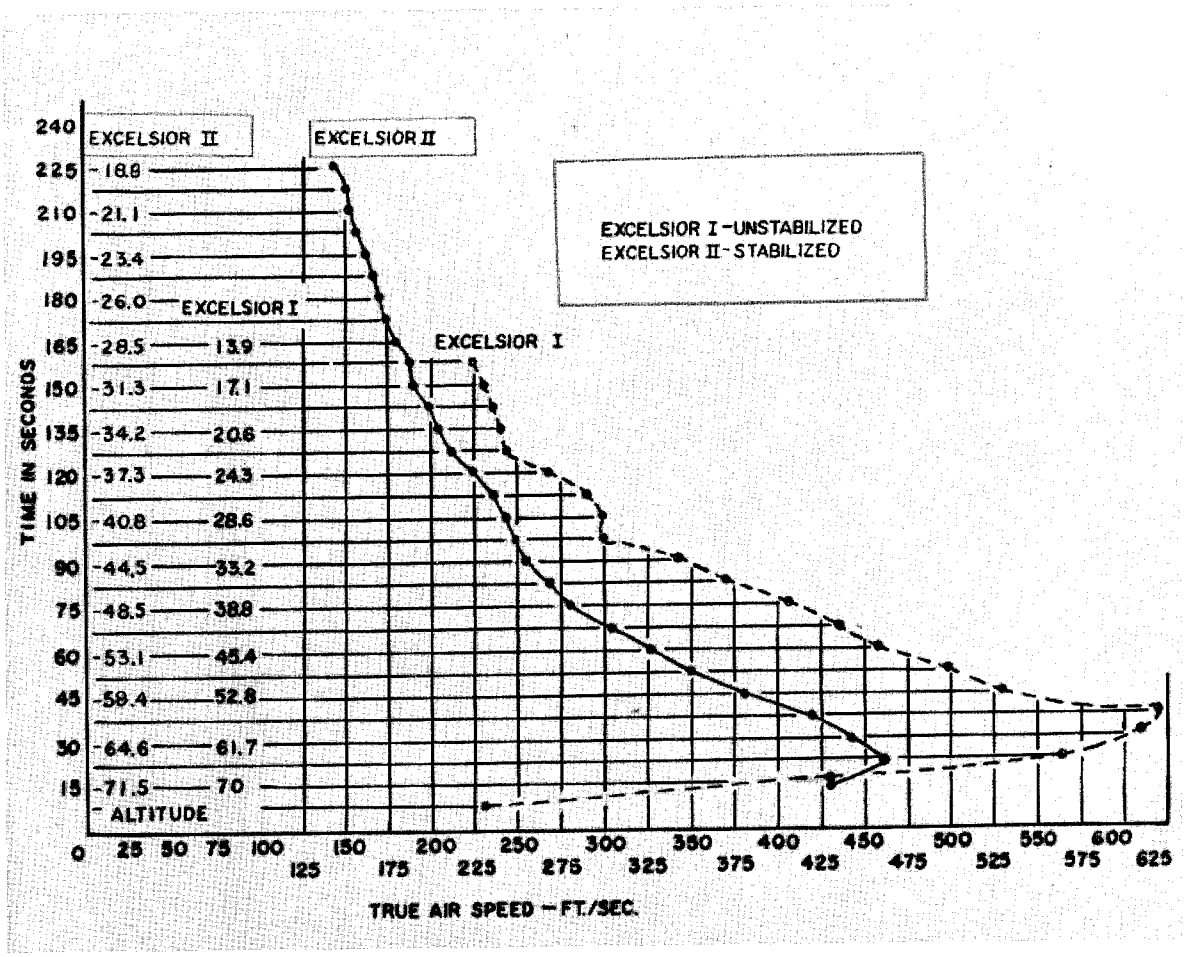


FIGURE 19–1. A comparison of flights of Excelsior I and Excelsior II. Altitude in thousands of feet.

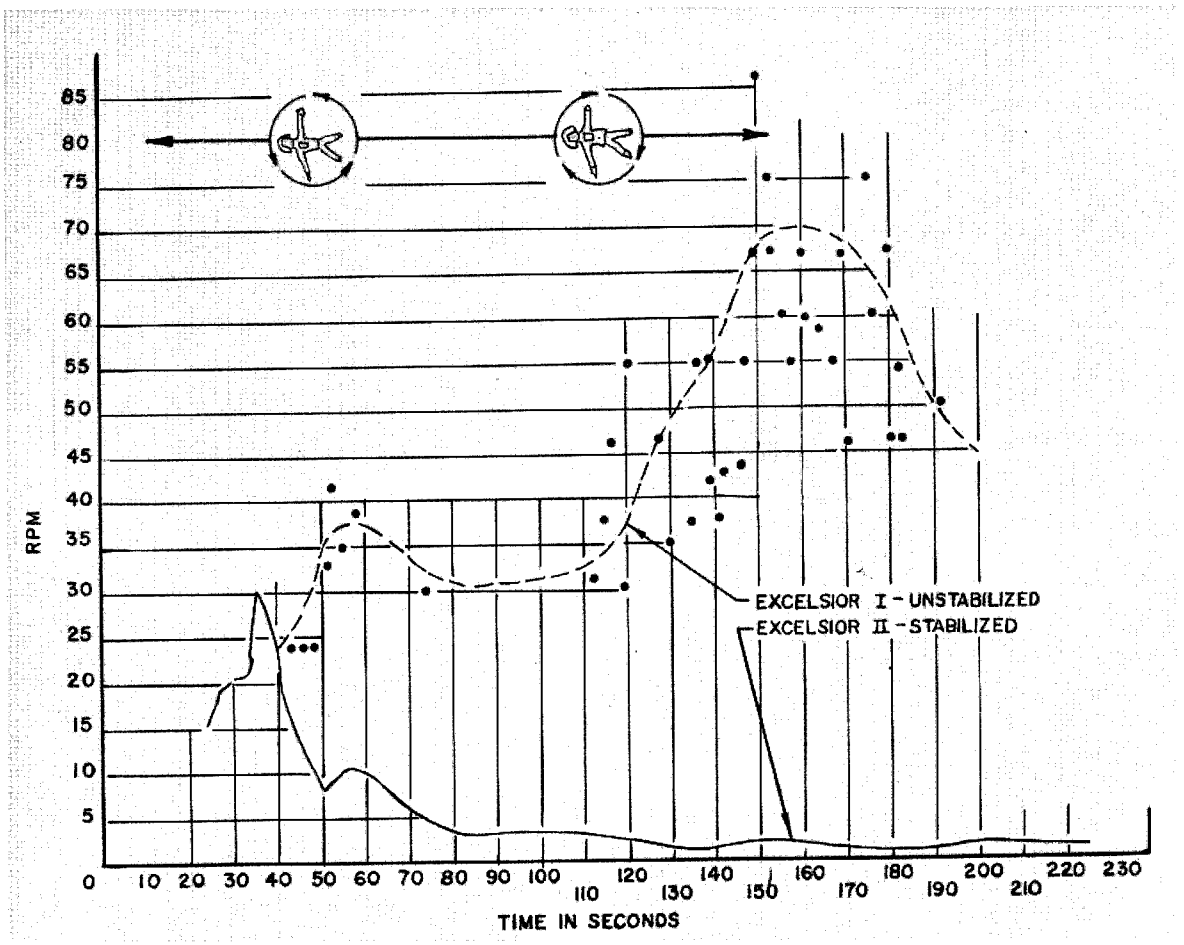


FIGURE 19–2. A comparison of the revolutions per minute experienced by subjects in Excelsior I and II flights.

The Excelsior III flight was performed on August 16, 1960, once again over the instrumented range at Holloman Air Force Base, New Mexico. (See fig. 19–3.) Figure 19–4 is a radar plot of the horizontal travel during the flight. Figures 19–5 to 19–9 show different phases of the Excelsior III flight from take-off to landing.

In summation, the primary objective of Project Excelsior was realized in that we were able to demonstrate that a man given the proper stabilization could be afforded an escape means from altitudes in excess of 100,000 feet.

The secondary objective of Project Excelsior, that of the protection of a man in a space environment, will probably have more far-reaching consequences than that of escape from high altitudes.

The next part of this paper concerns my thoughts on the protection of man in a space environment. In all respects, these thoughts do not reflect the present thoughts and plans of the Aerospace Medical Research Laboratory, the Aerospace Medical Division, or the Air Force Systems Command.

Today when we speak of men exiting a spacecraft for rendezvous, inspection and repair of vehicles, transfer of crews, and so forth, we place man in a very hostile environment. Research on the protection of a man in the hostile regions of space actually started one hundred years ago. On September 5, 1862, two Englishmen, Glaisher and Coxwell, made a balloon ascent to between 36,000 and 37,000 feet; lacking the proper protection these men were very fortunate to return safely to Earth.

The first pressure-suit research was started to provide an emergency means of pressurization for aircrew members, in the event that cabin pressurization was lost at altitudes in excess of 50,000 feet. Hence, the pressure suit was designed to conform to the sitting position of a man in a flying altitude, so that flight duties could be performed during the descent to a lower safe altitude in the event of a loss of cabin pressurization. All pressure suits, either the partial pressure or the full pressure suit, were designed to provide a means of pressurization for the aircrew member, if the need arose. The Excelsior tests were the first "real time" testing of a pressure suit, a pressure suit designed to be an emergency pressurization device rather than a space suit.

During May 1961, Comdrs. Malcolm Ross and Victor Prather, of the United States Navy made another "real time" test of a full pressure suit, this time ascending to an altitude in excess of 113,000 feet or a pressure of approximately 4 millimeters of mercury. However, in both the Excelsior and the Navy test the subjects were rather passive, and no useful work was accomplished other than making observations, manipulating switches, and so forth.

When a man exits from a spacecraft it will be to perform useful work, not to observe. For many years, divers have been descending into the seas in a modified full pressure suit and performing useful work. However, during the working cycle, the men are in a state of negative buoyancy and they do have positive orientation. A man outside the space ship will be in a state of weightlessness, with all the problems attendant to this.

There are two basic ways that men might be protected during extraneous trips from the basic spacecraft: one with a pressure suit designed to allow the man the freedom of movement needed and so forth, and the

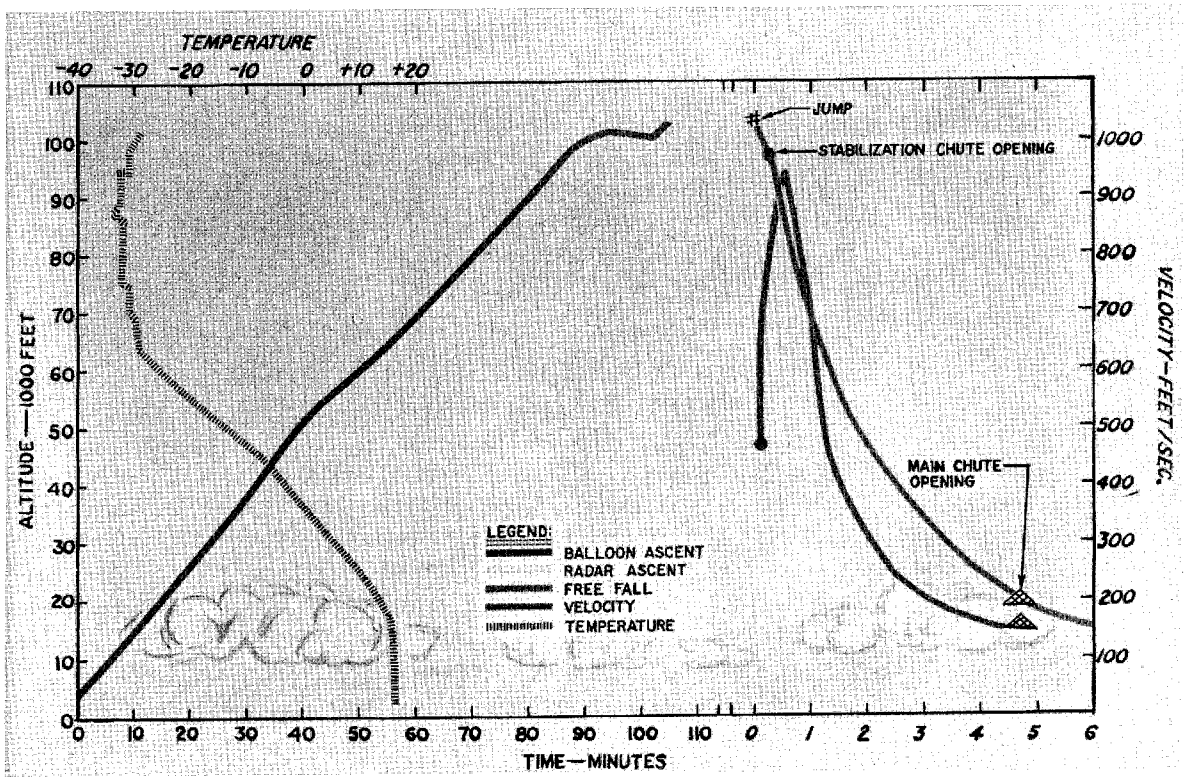


FIGURE 19–3. Excelsior III balloon flight and parachute jump.

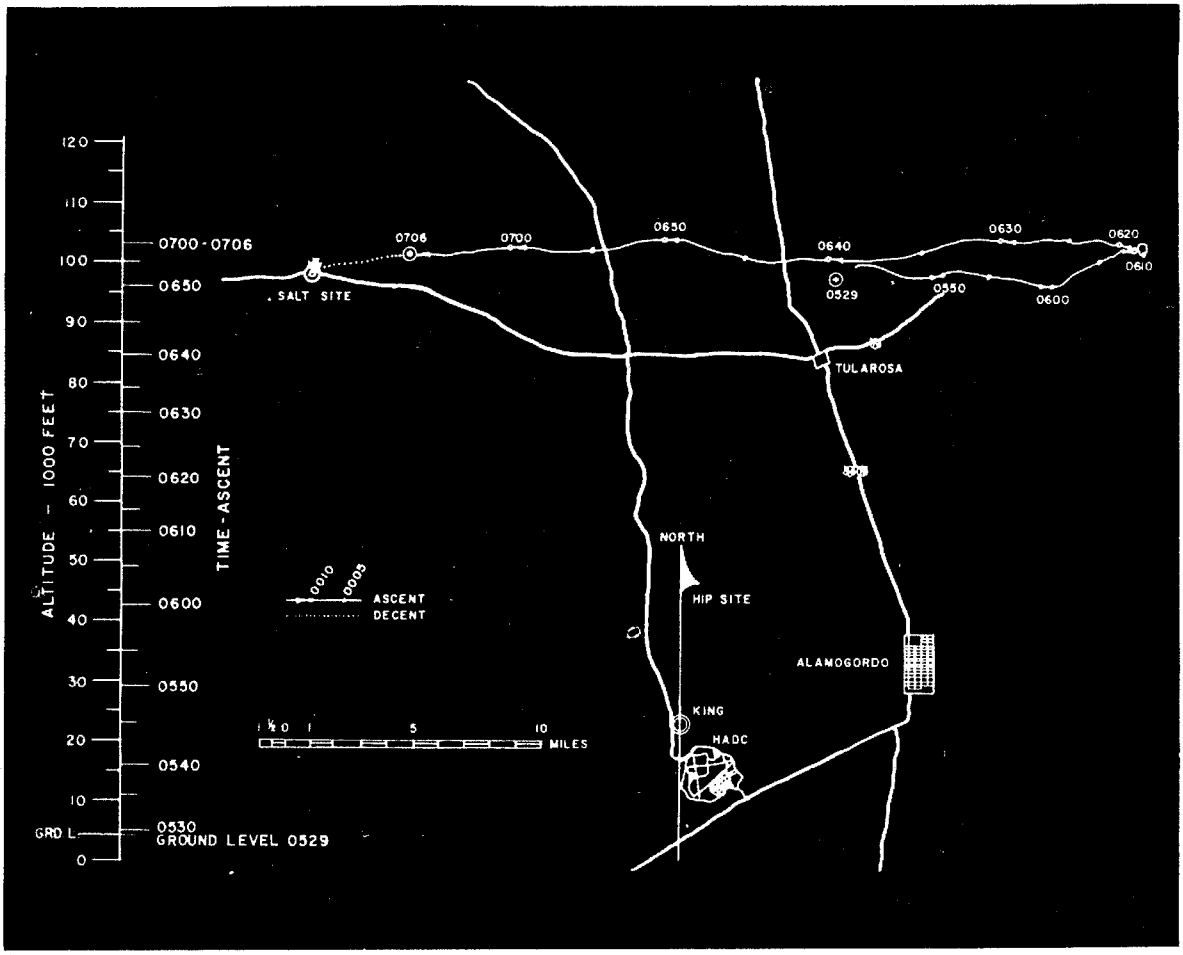


FIGURE 19–4. Radar plot of horizontal travel during Excelsior III flight.

FIGURE 19–5. Capt. Kittinger waves to automatic camera before making record 102,800-foot drop.

FIGURE 19–6. Capt. Kittinger leaping from gondola at 102,800 feet.

FIGURE 19–7. Pictures taken by automatic camera attached to the balloon's gondola immediately after Capt. Kittinger started his 102,800-foot drop.

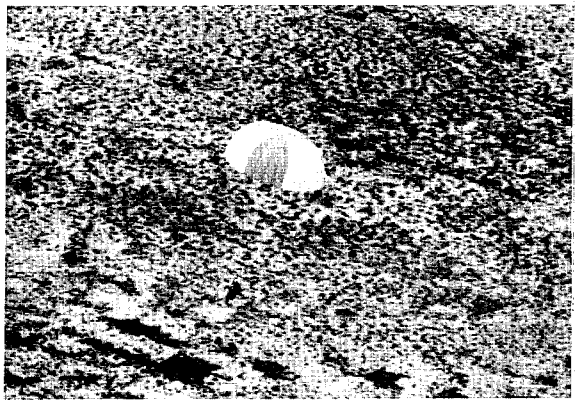


FIGURE 19–8. Capt. Kittinger preparing to land in New Mexico desert.

other, with the man in a powered capsule.

The first requirement of either approach is safety for the man. The next is task performance. I will briefly describe my thoughts on the merits of a capsule rather than a pressure-suit approach. A man in a capsule could have the capsule pressurized at the same pressure as the spacecraft. Pressure suits, even pressurized to 30,000 feet, are at present, very rigid. Astronauts Glenn's pressure suit would have protected him in the even of loss of cabin pressurization in the Mercury capsule; but it was designed for the reclining position, and work other than flying the spacecraft could not be easily accomplished.

It is not a simple matter to design a protective pressure suit to conform to the anthropomorphic shape of a man, and the prob-

FIGURE 19–9. Capt. Kittinger assisted out of his pressurized suit shortly after landing.

lem is magnified as the effective altitude of the pressure-suit system is reduced. A capsule could have a simple system of gyrostabilization and, in essence, the man could fly the capsule to any limited mission required, rather than having the propulsion system attached directly to the man in the pressure-suit approach. Safety of the man would be greatly enhanced by the capsule approach, since the man could wear an uninflated lightweight pressure suit in the capsule, so that in the event of failure of the capsule pressurization system the pressure suit would provide an emergency means of pressurization for the man. A man performing work outside the space ship, protected only by a pressure suit, with no safety device, would not have any means of escape from the hostile environment in the event of a failure of his one and only protective device.

Then, too, there are the problems of micrometeorite impact, radiation, temperature control, and, last but not least, the psychological benefit of the powered capsule approach with its inherent safety advantages. The additional weight penalty, caused by using the powered capsule, appears to be the main disadvantage of such system. However, this should not be the determining factor in relation to continuing research on this technique, as it appears to be technically feasible. It appears that both means should be explored and research conducted so that a system will be developed when the need arises, which will not be too far in the future.

The Excelsior flights and the United States Navy test should be the beginning of a test technique, a "real time" test technique for these types of protective environments. During balloon tests there are three basic problem areas that cannot be tested. These are weightlessness, radiation, and positive temperature control. In respect to temperature control, however, it could be stated that if the system being tested cannot afford a comfortable temperature environment at a pressure of 4 to 5 millimeters of mercury, the system would not provide a comfortable environment in space. Of course, both the day and night temperature effects could be tested. Thus, even today, in this modern space age, the balloon, man's oldest aerial vehicle, offers a means of inexpensive testing in our near-space regions, not only of manned protective devices, but in other sciences, such as manned balloon-borne observatories, life-support-systems evaluators, and so forth.

20. A Consideration of the U. S. Navy Strato-Lab Balloon Program and Its Contributions to Manned Space Flight

By MALCOLM D. ROSS, *Head, Environmental Sciences Section, Biological Sciences and Systems Department, General Motors Defense Research Laboratories; Lt. Comdr., USNR*

Mr. Ross was born November 15, 1919, in Momence, Illinois. He received his B.S. degree from Purdue University in 1941, attended various Navy schools between 1950 and 1955, attended George Washington Graduate School of Engineering Administration, 1954 to 1955.

As a naval officer his duties included: instructor in radiological defense at the Naval Damage Control Training Center; the plastic balloon research program; Project Skyhook liaison officer for the Office of Naval Research, where he administered the program as Field Representative, Navy Balloon Projects, for ONR; Balloon Projects Officer of the Air Branch, ONR; and technical director of Project CHURCHY, an expedition to the Galapagos Islands to obtain cosmic-ray and meteorological data from the balloon flights. He arranged for balloon launchings at Goodfellow Air Force Base and participated in that project in 1954 and 1955. He was a member of the scientific group which launched balloons for the Office of Naval Research at Saskatoon, Canada, and photographed, for the first time, the 1954 eclipse of the Sun from a Skyhook balloon over Minneapolis.

As Balloon Project Officer, Commander Ross initiated the Strato-Lab program of utilizing high-altitude manned plastic balloons for upper atmosphere research. On May 4, 1961, Mr. Ross established a new, official altitude record for balloon-borne flight when he piloted a balloon to an altitude of 113,500 feet with Lt. Comdr. Victor Prather as a passenger.

During 1957, Mr. Ross received the Navy League's Rear Admiral William S. Parsons Award for Scientific and Technical Progress and also the Navy's Meritorious Civilian Service Award. Jointly with Lt. Comdr. Lewis he received the Harmon International Trophy (Aeronaut) for 1957. Mr. Ross is also the recipient of the Distinguished Flying Cross. He is a member of the American Meteorological Society, the American Astronautical Society, and Wingfoot Lighter-Than-Air Society (honorary).

REVIEW AND SUMMARY

As the coined name Strato-Lab implies, it is a program which provides a stratospheric laboratory utilizing a plastic balloon platform for manned research investigations. The project was originated in 1954; actual work began early in 1955 and the first manned stratospheric flights were made in 1956. It was conceived and has been continued with the following three objectives:

(1) Provide a high-altitude research system, a scientific laboratory, permitting man's active scientific participation

(2) Provide an opportunity for studies of man's reactions to an actual environment of physiological and psychological stress

(3) Allow an opportunity for man to conduct tests and evaluate specific components and/or techniques in an extremely high altitude environment

It was initially reasoned that system development should focus on a two-man system. This implied that the two-man crew would be comprised of a balloonist, as pilot, and a flight scientist who would conduct his own scientific research. Thus, all important

Strato-Lab ascents have included a two-man crew.

Previous reports list pertinent details relating to each of the more significant Strato-Lab ascents. Briefly, there have been a total of five open-basket flights into the lower stratosphere at altitudes around 40,000 feet and five "high" flights at altitudes up to 113,740 feet. In this latter category four ascents utilized a sealed cabin system and one was conducted with an open-basket pressure-suit system. In all, ten Strato-Lab flights with two-man crews have been made into the stratosphere. The time aloft totals about 5 days, or an exposure of 10 man days to stratospheric conditions.

Figure 20–1 shows one of the four typical sealed cabin systems with the gondola (cabin) and balloon prior to launch.

Figure 20–2 shows the open-basket personnel gondola utilized on May 4, 1961, for carrying a flight crew of two in Mercury-type Navy full pressure suits.

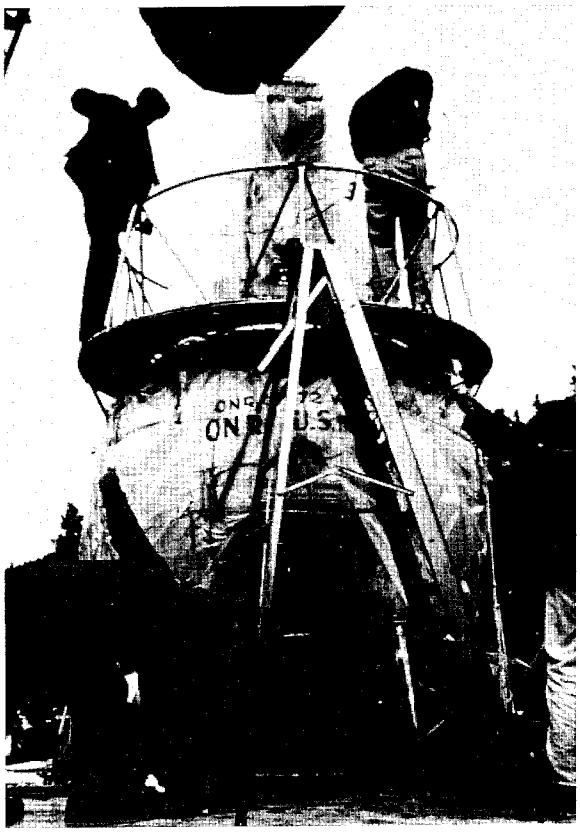


FIGURE 20–1. Typical sealed cabin system with gondola and balloon prior to launch.

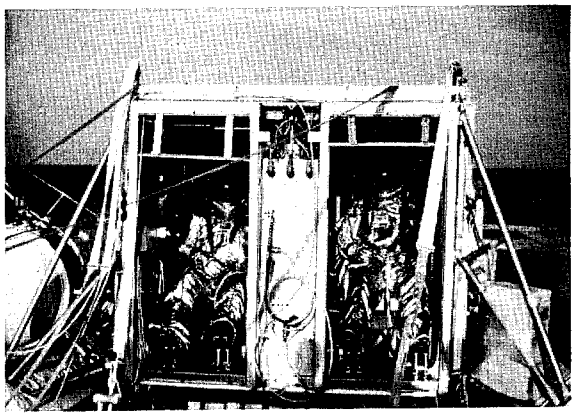


FIGURE 20–2. Open-basket personnel gondola.

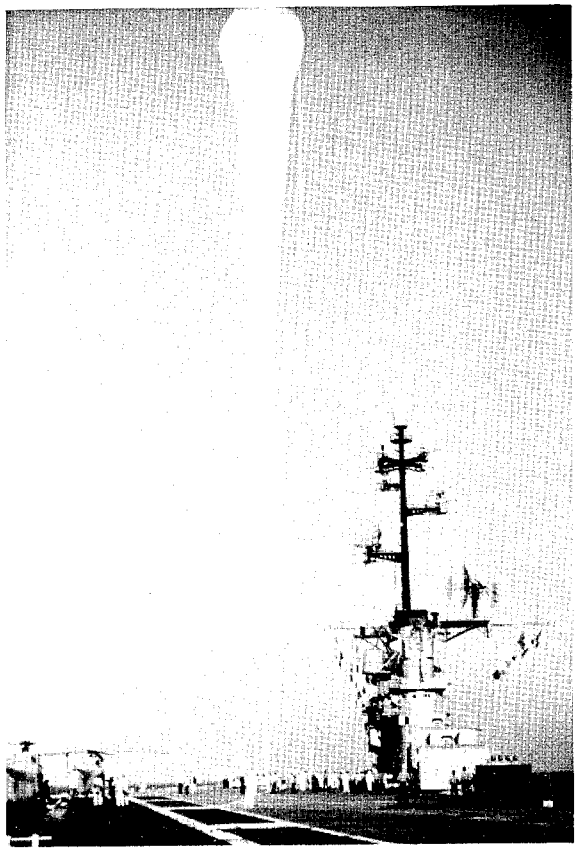


FIGURE 20–3. Aerostat inflated aboard carrier prior to launch of Strato-Lab High 5.

Figure 20–3 shows the aerostat inflated aboard the carrier *U.S.S. Antietam* prior to the launch of Strato-Lab High 5 to its record altitude last year. The carrier was in the Gulf of Mexico and steaming downwind at the time this photograph was made.

AREAS OF CONTRIBUTIONS

Contributions include three major areas of importance. The first two are technological accomplishments and scientific results. These will be reviewed briefly. The third has been Strato-Lab's unheralded role as an analog for manned scientific research. It deserves more attention.

Technologic

The technology category includes the learning and experience related to environmental subsystems, such as the use of sea-level-type pressures and atmospheric compositions aloft. Human factors, including system engineering and experience in the use of various pressure suits and techniques aloft, are also of interest. Heavy load balloon developments, in other scientific balloon research programs, can also be traced to Strato-Lab. These, and many many more, are technological advances assisted by the program.

Scientific

Measurements in cloud physics and observations of atmospheric phenomena, such as stratospheric particulate matter, have been of scientific interest; so have the first-hand observations of a sharp weather front with massive thunderstorms viewed from above. Another interesting aspect has been the visual observation of temperature inversions in the stratosphere indicating inhomogeneity. The human eye has been able to resolve quite easily the horizontal striations or bands of concentrated reflecting material revealing the presence of temperature inversions which do not appear in photographs and are not measured by normal temperature sounding instrumentation.

On one ascent the flight scientist was an astronomer. He was the first astronomer to observe the stars and planets from the stratosphere to note the absence of stellar scintillation. On another occasion a flight scientist, this time a physicist, made observations of the atmosphere of Venus which indicated the possibility of water vapor in that planet's atmosphere. The contribution made in the telescope-spectrograph instrumentation development alone will serve as invaluable assistance for future efforts from true space platforms.

Efforts in the medical sciences also have been of value to a better understanding of man and his relationship to a strange environment.

MANNED SCIENTIFIC SPACE ANALOG

It is in the third general area, however, where Strato-Lab has made its most important contribution. We might call this "An Analog for Manned Scientific Space Research." It is more important, I believe, than any of the specific items or identifiable positive contributions that can be described. Unlike any other known program, Strato-Lab has been an analog for our long-range national scientific man-in-space program.

Since early 1955 its potential availability has made it a catalyst to crystallize manned space science efforts. It helped focus early thinking by some of the best scientific minds in America on a fundamental question before our nation actually had a formal space program. The key question, of course, is whether man—as a scientist—should participate in space research utilizing unmanned automated instrumented vehicles. I am talking about man *as a scientist.* I am not aware of any important debates about the participation of other kinds of individuals in space exploration, whether they be aviators, astronauts, or aeronauts. There has been a sufficient pool of available personnel with appropriate qualifications to fill the latter categories.

It is assumed, of course, that the contributions of present programs to technology will result in the utilization of future space vehicle systems for the scientific exploration of space by man. The assumption is implicit in our national space program, but there are many questions. When will our manned space systems be ready and available for use by scientists? Who are the individuals who will want to use space systems or the surface of our nearby Moon as a base for scientific investigations? What specific research will they want to carry out? Will the systems be designed properly so that they and their equipment can be accommodated? When will the scientists start de-

veloping their instrumentation? And there are a host of other questions.

In my opinion we, as a nation, have not firmly addressed ourselves to answering these questions for our man-in-space program. This is the area where Strato-Lab has made an important contribution to our future national manned scientific space efforts because it has been a potentially realistic space-type vehicle system which could be considered as an available research laboratory for scientists. It has thus either allowed, "forced," or motivated a substantial percentage of U.S. scientists to consider its use for their investigations.

It is this catalytic effort which summarizes, to the greatest extent, the real, almost anonymous, contribution that has been made by Strato-Lab to our future national man-in-space program. My own personal involvement in the program while with the Office of Naval Research was as manager, planner, the seeker of funds, operational organizer, project engineer, then finally and anticlimatically, pilot, medical subject, and sometimes semiscientist. As an individual with an opportunity for such a unique involvement it seems incumbent to bring some of this background and experience into focus for long-range thinking as it may be applied to our true national scientific man-in-space program. This synthesis of the past has been occurring during my past year with General Motors.

Some of the questions raised earlier can be debated vigorously. The one most certain to find proponents and opponents is the question which simply asks, "Should scientific man himself go into space for scientific investigations, or can his work be done solely by instruments?" This is a completely unfair question with a wide spectrum of complexity. In my opinion we should not attempt to resolve that question until there is some hard factual information contributing to a full evaluation of the alternatives so that a proper assessment can be made at a future time. Scientific man *must* go into space. And scientists, indeed, in the not-too-distant future will be conducting research on the surface of the Moon, from Earth-orbiting space vehicles, from our neighbor planets, and maybe some day, beyond. Since it seems evident that this will come about, it is also apparent that we must provide adequately for the future space scientists. Where will they come from? Who will they be? How will they be encouraged? How will they be motivated? How will they acquire the proper educational background, training, and be provided with opportunities which will lead them directly into our national program as space scientists? This implies, to me, a very important area which is not being vigorously supported with adequate focus.

I have a sincere fear that when our technology of manned space flight is sufficiently advanced to permit a "seat open" we may have plenty of astronauts, but not enough "astroscientists." I use the term "astroscientist" merely to indicate a true scientist who will be participating physically in extraterrestrial scientific research.

After cogitating for a considerable period of time, it seems that wider identification and recognition of this potential problem area should be made so that appropriate thought, discussion, and problem analysis can be made.

In order to stimulate the kind of thinking that I believe should be addressed to the problem, I have developed a plan which is very simple, but, I believe, could be made workable and would certainly aim us in the right direction to provide the people we will need, not now but later during this decade and certainly afterwards.

A PLAN FOR ACQUIRING FUTURE SPACE SCIENTISTS

It is recommended that professorships in astroscience (merely areas of extraterrestrial physical scientific investigations utilizing man as a scientist) be established at three of our leading universities. These might be geographically located with one on each coast and one in the central portion of the United States. It would be hoped that the "chairs" would attract three of our nation's most scholarly, eminent, and mature scientists. Each professor would head up a staff with a graduate program of learning, aimed generally at providing an opportunity for the students to conduct their own creative

and imaginative research as scientists in future manned scientific space missions. The plan would be implemented on a trial basis, but should be established with an initial 5-year longevity so it will have a reasonable opportunity to demonstrate its value.

It is anticipated that liberal funding would be provided each of the three universities for unique laboratory facilities which might be required. It is also presumed that the Government, as part of its long-range national space program, would be most generous in providing support for special research activities of the young space scientists. This would allow them to develop specific instrumentation for semi-space-research platforms, such as very high altitude aircraft and balloon systems. These kinds of special tools also would be made available so that their graduate-school investigations would produce creative efforts with useful results. This type of effort would allow them to become deeply involved in the field of space exploration. The studies, experiments, and associated activities would be controlled only by the university and professor in charge of the program at each institution. Complete scientific freedom thus would be available for the type of scientific expression and accomplishment which can be developed best in the university atmosphere. Appropriate degrees, of course, would be conferred upon the candidates in accordance with standards now in effect for graduate students in universities. A variation of the three-university approach might possibly be the formation of a separate "Space Academy" for scientists. Other variations are also possible.

It is my belief that implementation of this simple plan would serve as a real catalyst in providing motivation for universty undergraduates to pursue studies and select careers which would point them toward space sciences and give them opportunities in a graduate-school environment to develop themselves into a new scientific discipline for the future. We cannot possibly predict the results of their activities. We merely must be convinced that their efforts will pay off in major discoveries and greater knowledge of benefit to man. If we are firm in this conviction we must be certain that the opportunities will exist. The plan suggested is a way in which we can discharge our responsibilities to future generations by taking action now.

As indicated previously I have used Strato-Lab as the analog, with my own deep involvement and full participation, to recognize a long-range need. This has resulted in the plan just suggested. In order to determine a cross section of impersonal scientific reaction to this plan, I have sent a form letter, a copy of this plan, and a simple questionnaire squeezed onto a postcard to a list of 200 scientists, research administrators, and engineers. In less than a month replies have been received from 102, over 50 percent of the addressees. The response has been most gratifying and the preliminary results may be of interest: 86 percent of those replying believe manned space flight will contribute to our national prestige; 93 percent believe that manned space flight will make significant scientific contributions; and 97 individuals, 95 percent of the replies received, indicated that there would be a need for scientists to participate in manned space flight. Of these 97 individuals, in indicating whether they agreed in the general approach of the plan which has been presented here, 79 individuals said yes, 15 said no, 3 were undecided. When considering that the 79 individuals represent over 77 percent of the 102 replies, it is almost startling that this large percentage agrees in general with the educational plan proposed.

CONCLUDING REMARKS

In summary, the preliminary results of this survey indicate to me that the thinking about a long-range need for our scientific manned space program is sound. It is also of tremendous importance and I hope will receive serious study and consideration in the future. This, in my opinion, is a *real* contribution resulting from the Strato-Lab program that overshadows, by far, any specific flight accomplishments of personnel, system development, or true identifiable technological or scientific contributions made to date.

21. The X-15 Flight Program

By NEIL A. ARMSTRONG, *Test Pilot, Flight Research Center, NASA;* JOSEPH A. WALKER, *Chief Test Pilot, Flight Research Center, NASA;* FORREST S. PETERSEN, *Comdr., USN, Commander of Fighter Squadron 154, Miramar NAS; and* ROBERT M. WHITE, *Maj., USAF, principal Air Force X-15 pilot, Assistant Chief of Flight Test Operations, Air Force Flight Test Center*

One of five active pilots assigned to the X–15 research program, Neil A. Armstrong joined the National Advisory Comittee for Aeronautics (predecessor of NASA) at the Lewis Research Center in 1955. Later that year, he transferred to the Flight Research Center as an aeronautical research pilot.

Mr. Armstrong has been actively engaged in both piloting and engineering aspects of the X–15 program since its inception. He made the first flight in the aircraft equipped with a new flow-direction sensor and the initial flight in an X–15 equipped with a self-adaptive flight control system. During an X–15 flight on January 17, 1962, he reached a speed of 3,715 miles per hour and an altitude of 133,000 feet, both high marks of his career.

Mr. Armstrong received a B.S. degree in aeronautical engineering from Purdue University in 1955. During the Korean conflict he flew 78 combat missions in F9F–2 jet fighters.

Since joining the NASA, Mr. Armstrong has served as project pilot on the F–100A and C aircraft, F–101, F4H, and F–104A. He also has flown the X–1B and X–5 of the research airplane series. He has accumulated 2,400 flying hours in over 50 aircraft types.

He has been a member of the USAF-NASA Dyna-Soar Pilot Group since November 1960. Mr. Armstrong is a member of the Society of Experimental Test Pilots, the American Rocket Society, and the Institute of the Aerospace Sciences.

Joseph A. Walker is widely recognized for his participation in research programs using research and advanced tactical aircraft as test vehicles.

Since joining the National Advisory Committee for Aeronautics (predecessor of NASA) in March 1945, Mr. Walker has served as project pilot on the X–1E, F–104, X–3, X–5, and the B–47. He has participated in the X–15 research program from its preliminary stages, providing valuable assistance in solving design problems based on his flight test experience and participation in centrifuge tests.

Mr. Walker flew the X–15 initially on March 25, 1960. On April 30, 1962, he attained an altitude of 246,000 feet. During a flight on October 17, 1961, he reached a speed of 3,920 miles per hour.

Mr. Walker graduated from Washington and Jefferson College in 1942 with a B.A. degree in physics. During World War II he flew P–38 fighters for the Air Force.

Prior to coming to the Flight Research Center in 1951, Mr. Walker was at the NACA Lewis Aeronautical Laboratory, Cleveland, Ohio, where his NACA career began as a physicist in 1945.

Among Mr. Walker's awards are the NACA Exceptional Service Medal, awarded in 1956 for action following an explosion in the X–1A research aircraft; the 1961 Harmon International Trophy for Aviators, which he shares with Major Robert M. White, USAF, and Scott Crossfield of North American Aviation; and the Air Force Association's Schilling Trophy, awarded in 1961 to the same trio; the 1961 Kincheloe Award; the 1961 Octave Chanute Award, sponsored by the Institute of the Aerospace Sciences; and the Air Force Exceptional Civilian Service Medal.

He is a charter member and Fellow of the Society of Experimental Test Pilots.

Comdr. Forrest S. Petersen was previously assigned to the Joint Air Force-NASA-Navy X–15 research program for 3½ years. He is a 19-year veteran with the U. S. Navy and a 1958 graduate of the Naval Test Pilot School. Comdr. Petersen attended the University of Nebraska and received a bachelor of science degree from the U. S. Naval Academy in 1944. He was awarded a masters degree in engineering at Princeton University.

As an aeronautical research pilot, Comdr. Petersen has specialized in stability, control, and performance. He has presented a number of technical papers on piloting techniques and aircraft performance.

Comdr. Petersen has completed five flights in the X–15 research airplane.

Major Robert M. White graduated from New York University in 1951 with a degree in electrical engineering.

During World War II and the Korean War Major White was a fighter pilot. In 1955, he graduated from the Air Force Experimental Test Pilot School (renamed Air Force Aerospace Research Pilot School). Aircraft he has tested since graduation include the F–86K, F–89H, F–102, and F–105B, all fighter aircraft.

He first flew the experimental X–15, then equipped with the two small interim engines, on April 15, 1960. On August 12, 1960 he took the research craft up to 136,500 feet, its highest altitude with the temporary engines which developed 16,000 pounds of thrust. After installation of the more powerful (58,000-pound-thrust) engine at the end of 1960, Major White flew the X–15 to a then new high altitude of 217,000 feet on October 11, 1961. On November 9, 1961, he flew the research craft 4,093 miles per hours, 93 more than its designed speed.

His work with the X–15 has earned him aviation's Harmon Trophy and the Society of Experimental Test Pilots' Kincheloe Award.

Major White is a member of the Aerospace Primus Club, recently formed to honor Air Force research and development personnel for outstanding contributions to the advancement of U.S. aerospace programs; the Mach 5 Club; and Mach 6 Club.

It is not the intention of this paper to describe the details of the X–15 research airplane and the many tests it performs. We would prefer, rather, to review its philosophy, to describe its concept in operation, and prophecy its future.

The concept is not at all new. Wilbur Wright in an address to the Western Society of Engineers on September 18, 1901, explained:

> Now there are two ways to ride a fractious horse: one is to get on him and learn by actual trial how each motion and trick may best be met; the other is to sit on a fence and watch the beast a while, and then retire to the house and at leisure figure out the best ways of overcoming his jumps and kicks. The latter is the safest; but the former, on the whole, turns out the larger proportion of good riders. It is much the same in learning to ride a flying machine: if you are looking for perfect safety, you will do well to sit on a fence and watch the birds; but if you really wish to learn, you must mount a machine and become acquainted with its tricks by actual trial.

This thesis is just as true to those of us in flight research now as it was to that original American research pilot 61 years ago. It was obviously true also to those men of foresight who were responsible for the genesis of modern flight research, the research airplane. These research airplanes, whose only purpose is the investigation of flight, have been uncovering problems and solutions for the past 15 years. Each faltering step as well as each giant stride brought us closer to space flight.

After World War II, the National Advisory Committee for Aeronautics, the predecessor of NASA, established joint research programs with the Air Force and Navy programs which have continued through the years.

The bullet-shaped X-1, of which two were originally built, was the first to reach the stage of flight testing (fig. 21–1). Initial glide tests of the X-1, conducted in Florida, proved successful. It was then decided to conduct powered flights in an area where an extended landing site was available, since

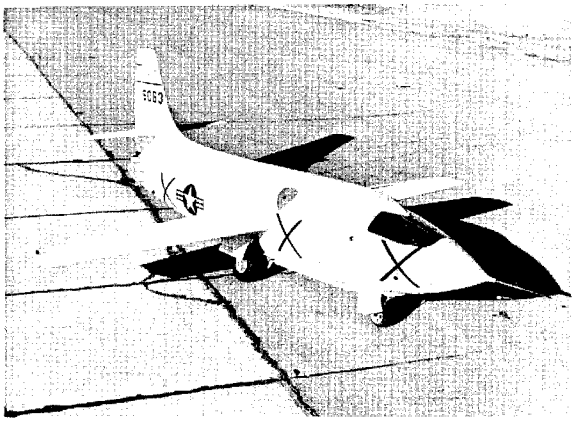


FIGURE 21–1. X–1 aircraft.

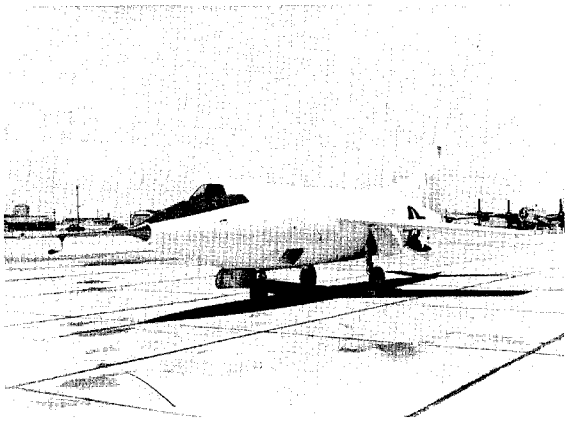


FIGURE 21–3. D–558–II.

the short powered phase of rocket flight necessitated a dead-stick or glide landing.

Edwards Air Force Base, California, then known as Muroc AFB, was selected because of a 64-square-mile natural dry lake, which provided an ideal landing surface. In late 1946 the X-1 and a crew of engineers and technicians came to the desert location, marking not only the start of rocket aircraft testing at Edwards but the origin of the NASA Flight Research Center (fig. 21–2). In 1947 the X-1 became the first airplane to attain supersonic flight.

Other types of research aircraft, designed to study various flight conditions, began to play prominent roles in the research aircraft program. After undergoing contractor trials by Northrop Corporation in 1949, the X-4, a tailless swept-wing jet propelled airplane, was assigned to the NACA in late 1950. This unusual aircraft was flown by the NACA to investigate flight characteristics of aircraft without a horizontal stabilizer.

The D–558–II "Skyrocket" rocket-powered successor to the earlier "Skystreak" was delivered to NACA at Muroc (Edwards) in 1949 (fig. 21–3). It became the first Mach 2 airplane.

From 1950 to 1953, a variety of projects was undertaken by the NACA. The X-5, a unique aircraft capable of varying its wing sweep during flight, provided considerable data about a configuration concept which has recently received serious consideration for some of our future aircraft design studies (fig. 21–4).

The problem of inertia coupling was first discovered during flight testing of the X-3, a stiletto-shaped research aircraft built by Douglas Aircraft Company, Inc. (fig. 21–5). Even before the NACA analysis of the prob-

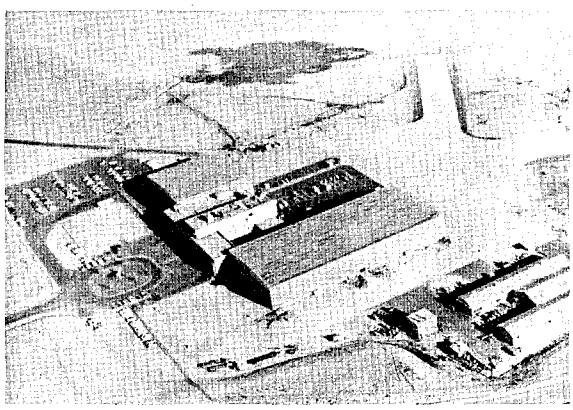


FIGURE 21–2. Aerial view of Flight Research Center.

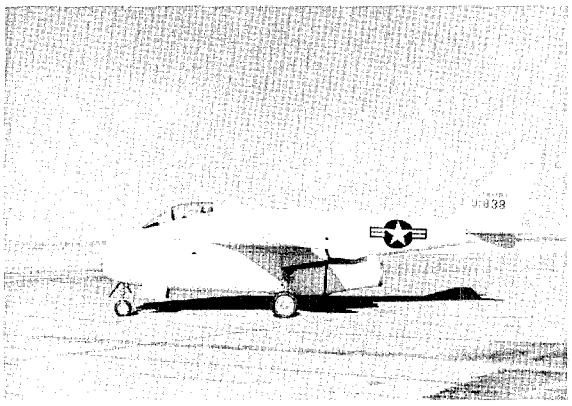


FIGURE 21–4. X–5 aircraft.

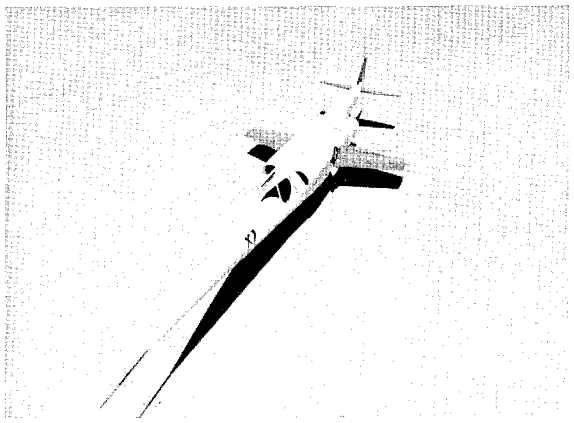


FIGURE 21–5. X–3 aircraft.

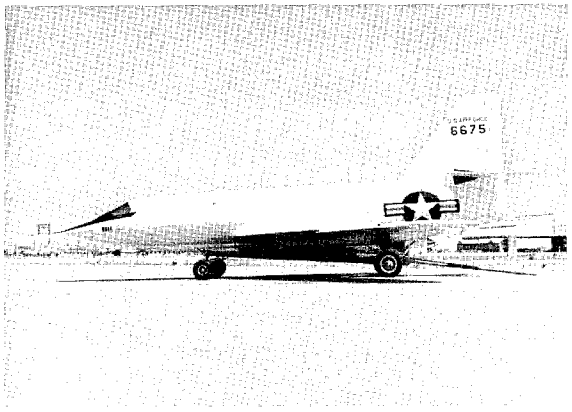


FIGURE 21–6. X–2 aircraft.

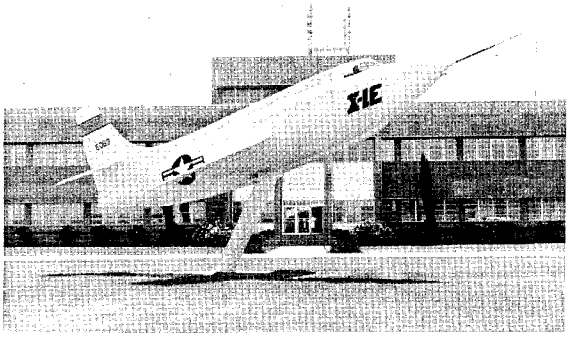


FIGURE 21–7. X–1E aircraft.

lem was completed, similar problems were uncovered in the F-100, then becoming operational with the Air Force. An intensive program sponsored jointly by the NACA, Air Force, and North American Aviation, Inc., resulted in an understanding and subsequent remedy of the problem.

The X-2, highest performing aircraft of the early series, was the first airplane to exceed Mach 3 and 100,000 feet (fig. 21–6).

Ironically, the airplane of the series last to be retired was one which had been among the first to fly. The X-1-2, sporting a new advanced wing and incorporating a variety of structural and system changes, became the X-1E (fig. 21–7). Flights were continued until 1958.

Solutions of problems in a research airplane program are of four types:

(1) The requirement for the industry actually to produce a piece of hardware to meet a set of realistic specifications precipitates a number of new approaches in the art of prediction, the science of configuration engineering, and the art of fabrication

(2) Solutions of the in-flight problems for which the airplane was built

(3) Insight into phenomena revealed in flight which have not been predicted, or for which the craft was not specifically designed. In the case of the airplanes just discussed, this category was a large one. Major contributions in the area of tracking, edge surface effectiveness, inertia coupling, transonic turns, pitchup, buffet, and gust studies were subscribed

(4) The understanding gained from the actual flight operation of these airplanes, with a whole new series of operating constraints.

The Air Force, Navy, and National Advisory Committee for Aeronautics, convinced of the value of these research tools, were in the early 1950's performing separate studies to determine the problems to be solved by a second-generation research airplane and the range of performance and configurations required. In 1954, the three agencies established mutual objectives and jointly initiated a competition for the design and construction of a manned research airplane that could explore the new flight regime. The upper

limit of the new aircraft's performance was established by the projected availability of structural materials and power plants. Use of a new nickel-chromium alloy, Inconel X, would permit structural temperatures to go as high as 1,200° F — some 1,000° beyond the capability of conventional aluminum-alloy airplanes. The new alloy would permit a research airplane to penetrate the "thermal barrier" imposed by supersonic aerodynamic heating, up to a speed six times that of sound for short periods of time.

Estimated best attainable engine efficiency for a new man-rated, pilot-controlled, rocket engine was a specific impulse of 265 pound-seconds per pound of propellant. This dictated, then, the amount of fuel required and hence the thrust of 60,000 pounds.

In retrospect, a most significant specification was one which permitted a period of only 3 years for the design and fabrication, in order to provide the maximum possible time for the application of research results to future aerospace vehicles. This requirement allowed little or no time for perfection of mill-run quantities of the laboratory super metal Inconel X, development of radical new methods of forming and fastening the metal, and for creation and refinement of a very large controlled-thrust liquid rocket engine safe enough for use in a manned aircraft. Such a schedule permitted the creation of the required vehicle but left no time to perfect its configuration or performance. Although some of the sophistication and well-tested solutions were thereby eliminated from the project, so also were unwarranted changes and hypothetical or "conjured" problem areas. The task both fired and staggered the imagination of all people concerned.

The contract which was awarded to the Los Angeles Division of North American Aviation, Inc., in December 1955, specified that the research aircraft, designated X-15, be capable of speeds of 6,600 feet per second, fly to altitudes of at least 47½ miles, and be capable of withstanding structural temperatures as high as 1,200° F. The operational envelope described for the X-15 was many times greater than that previously achieved with any research or operational aircraft and was intended to provide an airplane capable of exploring a wide variety of research objectives.

Perhaps most important, it was to be conceptually independent, with no guidance, data link, or other ground equipment to be required for the completion of a flight. Onboard command and onboard data collection would insure the highest probability of mission success. A measure of the value of that concept may be seen on any X-15 flight plan under "Emergency situations after launch": "In case of radio, radar, or telemetry malfunction: *proceed as planned.*"

Those who recall the struggling days of early pressure suits will appreciate the significance of commiting the X-15, in its design phase, to a new full pressure suit. Its requirements for mobility, vision, heat retardation, integrity under a wind blast of 2,500 pounds per square foot, and reliability presented a formidable problem. It is a significant advance, then, to have achieved such a suit, fabricated by the David Clark Company, which not only meets those specifications, but is moderately comfortable as well. The suit is an integral part of the escape system, an ejection seat capable of providing successful escape throughout nearly all foreseen situations necessitating its use. Our philosophy does not require the pilot to be able to eject throughout the airplane's performance envelope, but does provide alternatives for most predictable *emergency* situations.

A primary engineering problem was the expansion and contraction of the airplane structure due to extreme variations in temperature. At launch, the belly of the airplane is cooled to 300° below zero by the liquid-oxygen rocket-engine propellant carried inside the X-15. Later in the flight, this same metal on the belly is exposed to high air-friction temperatures. Thus, the metal that was contracted at —300° F must be able to expand when it is heated by air friction, or the airplane will tear itself apart from internal stress within the metal. The same problem is present to a lesser degree in the wing, where, during reentry, the lower surface is heated more than the upper surface. These problems of the thermal expansion were

overcome by using as few internal structural members as possible in the body and by using corrugated internal structure in the wing and tail. The body skin is, therefore, free to shrink and stretch as it will, and the corrugated structure can flex enough to keep wing and tail skin stresses within tolerable limits.

Laboratory tests on the new super metal, Inconel X, indicated that it would retain enough strength at 1,200° F to be useful as an aircraft structural material. Another space-age metal, titanium, was just beginning to be produced in sufficient quantities to be considered as a high-temperature material. This metal proved to be less heat-resistant and less efficient than Inconel X at the higher temperatures, but it is used in many areas where it is not exposed directly to the 1,200° heat. Neither of these metals had been used previously in wholesale quantities to build an airplane. In solving the problems of how to heat-treat, form, machine, and join together pieces of Inconel X, North American Aviation contributed very significantly to advancing airframe construction into the space age.

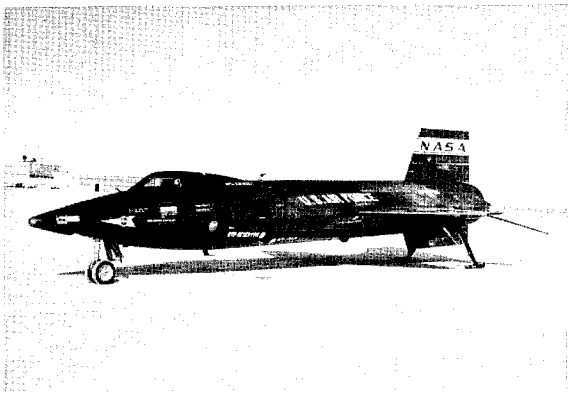


FIGURE 21–8. X–15 aircraft.

Although the X-15, as it flies today (fig. 21–8), looks surprisingly like NACA's proposed configuration of 1953, thousands of hours of wind-tunnel work were required to produce a configuration with satisfactory hypersonic stability and control. The most extensive use ever made of a closed-loop piloted ground simulator for design development provided confidence in satisfactory handling qualities for the unusual craft. Some question as to the adequacy of these results under the conditions of the high longitudinal and normal accelerations led to the first use of the U.S. Navy's Johnsville centrifuge as a flight simulator. Not only did the pilot, through an analog computer, control his simulated trajectory, aircraft dynamics, and instrument presentation, but also the magnitude and direction of the resulting acceleration vector. Variations and simplifications of this technique have been used many times since then on other aeronautical and space programs and are expected to continue for many years to come.

A unique requirement in the control of the X-15 concerns that part of its flight at extreme altitudes where conventional aerodynamic controls become ineffective. For that portion of the flight, some other means of control had to be found that would enable the pilot to turn the airplane in the desired direction. The solution was found in one of man's oldest harnessed energy forms—steam. Remarkable as it may seem, this ancient form of bottled energy is being used to control all of the nation's most advanced research vehicles.

The X-15 was the first design to require rocket reaction control within its design envelope, but was not the first to use it. The X-1B research airplane (fig. 21–9) was fitted with hydrogen peroxide control rockets in 1957. A similar but more advanced version was installed in an F-104 in 1959. Four H_2O_2 rockets, two for pitch and two for yaw, with a propellant tank and associated plumbing, are installed in the aircraft nose. Roll rockets are installed in each wing-tip pod

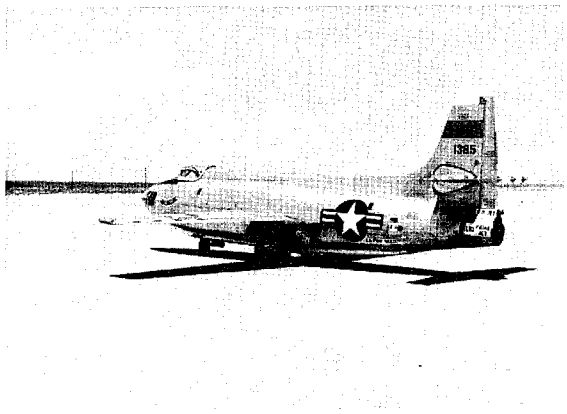


FIGURE 21–9. X–1B aircraft.

with individual fuel tanks. This configuration eliminated the requirement for pumping dangerous peroxide throughout the airplane. The rockets could be fired by a separate control stick, integrated with the aerodynamic controls on the pilot's conventional center stick, or operated by rate dampers for auxiliary damping. The airplane was controllable down to zero airspeed in zooms to an altitude of 90,000 feet. Similar systems are installed in the X-15, the Mercury capsule, and all known forthcoming manned spacecraft.

The X-15 is powered by an XLR-99 rocket engine, built by the Reaction Motors Division of Thiokol. The thrust can be throttled from 20,000 to 60,000 pounds with anhydrous ammonia and lox as propellants. The engine may be started, throttled, shutdown, and restarted by the pilot in flight. The complete operation of this rocket engine and its propellant system, approximately the size of a Redstone, is accepted as being one of many reasonable in-flight pilot chores.

Preparation of the X-15 for a particular flight usually requires several weeks. Aircraft subsystems are intimately inspected prior to each flight and instrumentation changes and calibrations to meet the particular research objectives of that flight are made during this period. Frequently, cockpit presentation changes which will enhance the pilot's ability to follow the profile dictated by the research objectives are also made during this period. These are usually brought out by the extensive practice which precedes any flight on the six-degree-of-freedom fixed-base simulator. However, only the last 24 hours prior to the flight are required to mate the X-15 to its parent B-52 and service both for their mission. Servicing equipment is minimal in nature and consists only of the necessary storage and plumbing to route the liquid oxygen, anhydrous ammonia, hydrogen peroxide, liquid nitrogen, and gaseous helium to X-15 and B-52 systems. Details of the servicing procedures are monitored by use of the actual systems in the X-15 and B-52. During the last few hours of the servicing period some of the aircraft systems which are important to a particular mission, such as the inertial platform and cabin and instrumentation section pressurization and cooling, are given final alinements and checks.

During the last hours of servicing the pilot reports on station and is given a final check by bioastronautics personnel. After body sensors are attached, the pilot dons his full pressure suit which is, of course, a backup protective device to cover failures of the primary cabin pressurization system. He mans the X-15 about an hour before B-52 take-off and monitors the last minutes of servicing and checkouts.

Taxi is quite pleasant after the nylon in the B-52 tires warms up and the flat spots disappear. During taxi the launch-panel operator begins the process of keeping the X-15 topped off with liquid oxygen. Both he and the X-15 pilot will now be continously monitoring systems readouts in the X-15 cockpit and on the B-52 launch panel to catch any indications of malfunctions or abnormalities. A system malfunction during the period before drop, although delaying the flight, has no greater consequences than requiring the B-52 to land with the X-15 aboard—without propellants—to allow the malfunction or abnormality to be rectified. (See fig. 21–10.)

During the last few minutes prior to drop the workload on the pilot and launch operator increases until the final seconds of the drop are counted off by the B-52 pilot. During these last minutes the pilot must get the power units which will provide him with electrical and hydraulic power on the line and stabilized. Propellant tanks must be pres-

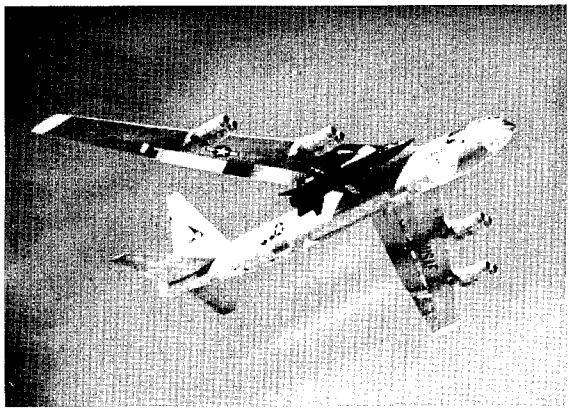


FIGURE 21–10. B–52 mother ship prior to launching of X–15.

surized. During the last minutes before the drop the pilot is increasingly occupied in priming the 58,000-pound-thrust XLR-99 engine and getting the first and second stages of the engine igniters on and stabilized.

Although the main chamber of the rocket engine is never ignited prior to drop, the procedure of having the first- and second-stage engine igniters on and stabilized prior to drop greatly enhances the reliability of obtaining normal thrust after drop. This procedure is wasteful of rocket propellants but the increased reliability is felt to warrant the loss of some propellants. These procedures are intentionally delayed as long as possible to minimize propellant losses and, of course, this increases the workload on the pilot as he reaches the drop point. This may be fortunate as it effectively precludes any pilot apprehension at this point. The X-15 pilot normally drops himself from the B-52 but may elect to have the B-52 plane commander perform this function for him.

After launch the pilot's objective is to start the main thrust chamber at specified power and rotate the aircraft to the climb-out attitude scheduled for the mission. The aircraft is controlled by the aerodynamic surfaces through the flight until engine shutdown 81 seconds after launch at about 150,000 feet. (See fig. 21–11.) From this point the altitude control rockets are utilized to damp some residual oscillations and then to maintain prescribed attitude.

Of course, every flight ends with a landing. We start about 50 miles from the dry lake at Edwards AFB, in the neighborhood

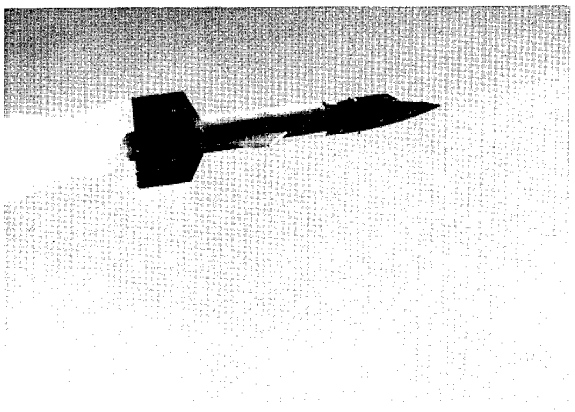


FIGURE 21–11. X–15 in flight.

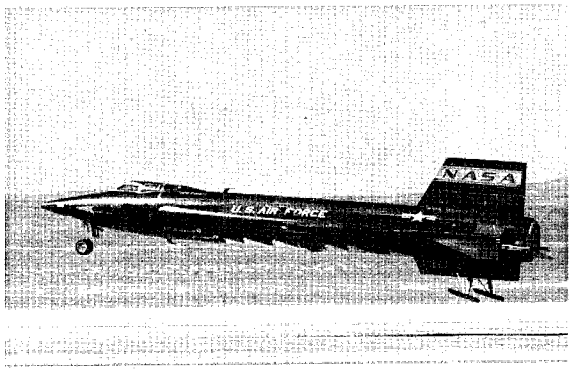


FIGURE 21–12. X–15 landing on dry lake.

of 60,000 feet and at about 2,000 miles per hour for our actual landing pattern. We utilize a glide speed of 300 knots and hold the landing flaps and gear until ready to land and close to the runway in order to reduce total drag in the glide. (See fig. 21–12.) The lower vertical tail is jettisoned prior to landing. We use a mark on the runway as an intended touchdown spot and have consistently landed with $\pm$ 1,500 feet. In about a mile the airplane slides to a stop, the canopy is opened, and the pilot gets out after completing some checks in the cockpit.

Questions in the minds of many people are: "How long are we going to continue testing with the X-15?" and "What follows the X-15 when it is finished with its work?" In general, these two questions can be answered in this way: As we see it now, by late fall or early winter of 1962, the original X-15 program will have gathered most of the data that were desired of this airplane. At that time, we expect the X-15 to become very useful as a flying laboratory, or testbed, for aerospace scientific experiments. The X-15 is considered by many to be a perfect vehicle for gathering scientific data in the little-explored region between altitudes of 50 and 100 miles. Balloons cannot go that high, and sounding rockets go through the region so fast that it is difficult to determine if the data gathered came from 50 miles or 100 miles up. The X-15 can deliberately be flown in this region for a sufficiently long time to obtain definite information. Some of the experiments planned for the X-15 in the near future are

very interesting and will provide much-needed data in particular fields.

In the final design and construction stage at North American Aviation now is a stellar camera modification to the X-15. This camera will be used to photograph the stars while the X-15 is above the Earth's atmosphere blanket. It will return the clearest pictures ever taken of the heavens. These pictures will be of utmost interest to astronomers all over the world.

Guidance instrument experiments are to be conducted in the X-15. These experiments are to develop navigational equipment for spacecraft. Consider the fact that future generations of space vehicles will have to travel enormous distances with pinpoint accuracy, and will have to do this without the aid of landmark, airspeed information, compass headings, or ground radar guidance. In the works now, ready for checkout on the X-15, is a new horizon scanner that will help solve this problem. Other guidance equipment can likewise be tested as it becomes available. Other tests that are waiting to be taken aboard the X-15 include precise determination of atmospheric density at extreme altitude, measurement of quantity and size of micrometeorites in near space, and determination of the intensity of ultraviolet and infrared rays in near space.

These are only a few of the possible follow-on uses for the X-15 airplanes. There are also many others, and unless something happens to change the scientific picture drastically, we feel that many scientists will strive to place experiments aboard this Blackbird of Space, the X-15.

22. Astronaut's Report on Project Mercury

By JOHN H. GLENN, JR., *Astronaut, Manned Spacecraft Center, NASA; Lt. Col., USMC*

Col. John H. Glenn, Jr. was born July 18, 1929, in Cambridge, Ohio. He considers New Concord, Ohio, his permanent home.

Col. Glenn attended Muskingum College in New Concord. He entered the Naval Aviation Cadet Program in March 1942. He was graduated from this program and commissioned in the Marine Corps a year later. After advanced training, he joined Marine Fighter Squadron 155 and spent a year flying F4U fighters in the Marshall Islands. During his World War II service he flew 59 combat missions. During the Korean War he flew combat missions in the F–86 Sabre-jets. Col. Glenn attended Test Pilot School at the Naval Air Test Center. After graduation, he was project officer on a number of aircraft. He was assigned to the Fighter Design Branch of the Navy Bureau of Aeronautics in Washington from November 1956 until April 1959, during which time he also attended the University of Maryland. In April 1959 he was selected as an astronaut for Project Mercury.

In July 1957, while project officer of the F8U, he set a transcontinental speed record from Los Angeles to New York, spanning the country in 3 hours 23 minutes. This was the first transcontinental flight to average supersonic speed. He has more than 5,100 hours of flying time, including 1,600 hours in jet aircraft.

On February 20, 1962, Colonel Glenn became the first American to experience orbital flight in a three-orbit mission (MA–6). He was awarded the NASA Distinguished Service Medal for this feat.

There has been so much recent information put out on the orbital flight and on Project Mercury that I thought that, rather than give details of the flight and Project, I would discuss briefly some of the general aspects of space flight.

I think one question asked repeatedly is why are we even trying to go to space. Perhaps this is so obvious to most people that we hardly need to comment on it. It seems to me if we go back a few million years to the time when the first caveman was starting out, probably the first time he was curious about what was over in the next valley, his wife thought he was crazy, because he had everything he wanted in his own valley and she could see no reason for him to want to visit a strange place when he did not know what was going to happen.

But he had learned, and learned the hard way probably, that when he was curious about things, when he tried to learn something new, it almost always benefited him in the future. Lightning had struck a tree one day maybe and set a fire; when he investigated this fire, perhaps his wife once again was unhappy with him because maybe he burned the new tiger skin that she was expecting to get, or maybe the children blistered their fingers, and she thought that this was sheer nonsense. On the other hand, by his continual curiosity about fire, he learned to cook food, he learned that fire could keep him warm, and he learned by experimenting that fire would probably keep the wild animals away at night, so his curiosity had stood him in good stead. When he did go over that next hill, probably he found some new fruit or berries that enabled him to have an easier life and a little more time to work on a new alphabet which furthered his education. So he was already beginning to make progress even from such simple things as these. When he took time to be curious about something

new or went exploring, it almost always resulted in new things or ideas that gave him better control over his present environment and his future. Man has repeatedly proven this, I think, and the time and effort spent on research or exploration have a way of paying far greater rewards than ever dreamed of at the outset.

Probably the biggest exploration that has ever been considered is the field of space exploration. The fact that it is the biggest and the toughest assignment that man has ever undertaken also probably means that in the future it will be one of the most rewarding. Our part in this has not, so far, been greatly concerned with the use of scientific information to benefit our lives. So far, most of us have been involved in just assembling the tools, the basic information, that we really need to go out and obtain the knowledge that awaits us from further space exploration. The sooner, we have felt, that man gets into this program, the better off we will be, because man can observe and can make so much more in the way of contributions per mission or endeavor than can be made just with instruments. There are many many bits of information needed: The balloon flights, cosmic-ray studies, high-altitude Strato-Lab flights, and the X-15 studies, discussed in the preceding papers, the control studies for departing and reentering the atmosphere, our suborbital Mercury flights, and then my orbital flight, with another one anticipated in a week or so. These investigations are not competitive programs, as is sometimes thought. So much information is needed to complete the big jigsaw pattern that makes the whole picture that contributions from all sources are essential. These are all complementary programs, not competitive.

The scope of the program is also interesting. I was surprised to learn, even working in this field, that as of March of 1962, the United States had orbited 68 different spacecraft. We had recovered from orbit 15 different spacecraft. In the Soviet program up to that time, as far as we know, 13 satellites had been orbited and 5 had been recovered. These numbers indicate that we have recovered more spacecraft than the total they have launched. They do apparently have the capability of putting up considerably more weight per mission than the U.S. launch vehicles. But I only bring this up to indicate the size of our program. Ours is not centered on just one little facet of space flight; it is centered on a broad across-the-board expansion of knowledge in this space era that will best enable us to carry out man's flight into the future.

At this point we have obtained enough information so that man can go into space safely and return. What was our mission? In the Mercury-Atlas 6 flight (the first U.S. orbital flight) we still were seeking the tools; we are still establishing the basic criteria that we need to go farther into space and make solid scientific contributions. Our test objectives on MA–6 were (1) to evaluate the performance of a manned spacecraft system in a three-orbit mission, (2) to evaluate the affect of a space mission on the astronaut, and (3) to obtain the astronaut's opinions on the operational suitability of the spacecraft and supporting systems for man's space flight. The results obtained in these opinion and performance areas enable engineers to design better vehicles and give us an idea of the directions our efforts should take for the future. We have not even begun to obtain scientific information from space study. We are still getting the tools. Even though the objectives of MA–6 were broad, I can say that we met most of these objectives on the flight.

Where do we stand now? What of man in the system? What does man contribute? We feel that man contributes in two big general areas. One is in the area of reliability and the other is in the area of adaptability. Of major significance is the probability that much more dependence can be placed on man as a reliably operating portion of the manned spacecraft system as a result of our efforts so far. In many areas his safe return can be made dependent on his own intelligent actions, and this was a concept not accepted for flights into such an unknown area. These areas, however, must be assessed carefully, that is, the areas where return depends completely on the man. They must be assessed carefully because man is not infallible, as we are all acutely aware. So, in some areas, some auto-

matic or semiautomatic systems may still be needed, but certainly not to the extent that they have been included in the past. Many things would be done differently if the MA–6 flight could be flown over again, but we learn from our mistakes. I do not think that any pilot ever flew a test flight on an airplane from which he did not return wishing that he had done some things a little bit differently than he had done them on that flight. Even where automatic systems are still necessary, mission reliability is tremendously increased by having the man as a backup. The MA–6 flight is a good example. This mission would almost certainly not have completed its three orbits and might not have come back at all if a man had not been aboard.

What of the adaptability, then? The flight of Friendship 7 (MA–6) proved also that man can adapt very rapidly to this new environment. His senses and capabilities are little changed in space; at least for the 4½-hour duration of this mission, this was no problem. Man's adaptability is most evident in his powers of observation. He can accomplish many more and varied experiments per mission that can be obtained from an unmanned vehicle. When the unexpected arises, as happened with luminous particles and layer observations from the flight of Friendship 7, man can make observations that will permit more rapid evaluation of these phenomena on future flights. I don't think any of us, though, have ever conceived of ourselves as being merely passengers on any of these flights for the future.

Most important, however, we are all looking to the future when man will not always be as power limited as we are now. We will progress to the point where missions will not be totally preplanned. There will be choices of action in space, and man's intelligence and decision-making capabilities will be mandatory. This can be likened to the first flight at Kitty Hawk. There were unmanned flights and these were followed by the first manned flight completely preplanned, such as ours are now, and of a few seconds in duration. They were again power limited. But they soon progressed beyond that point, as we will too. We are at that same stage of development today.

Question Period

QUESTION: Col. Glenn, do you think there is any chance that the Titov flight was faked?

COL. GLENN: I am in a very poor position to judge yes or no on that. I have nothing to prove either way. I have no information to prove that he did do it; I have no information to tell me that he didn't do it.

QUESTION: Col. Glenn, I am from Denver, and I have talked to Dr. Walter R. Roberts, of the National Center for Atmospheric Research; he is much interested in those layered luminous phenomena which you observed on the outer fringes of the atmosphere. He believes that you may be the first man to have observed the airglow in the ionosphere. Do you have anything to add to that, or could you back him up on that?

COL. GLENN: Since we had no instruments along to measure something of this type, I can only describe what I saw, and that is what I have done. Dr. O'Keefe of the Goddard Space Flight Center has been working almost continually on this problem since my flight. The nearest I can come to a description of these things is, at the very first light of Sun, and this occurred on all three orbits, all at once there were, coming by the capsule, little luminous particles of the same color. Here would be a good way to describe it: If you have been out in a pasture or in a field on a summer night and have seen fireflies all over the place, if you could turn their light on, that yellowish-green light of a firefly, at about that same intensity, and could just stop all the fireflies right where they were, then you turned and backed across the field about 3 to 5 miles per hour and they just came out from behind you, about 8 to 10 feet apart above, below, to the side, and all around as you moved through this big homogeneous field, that is exactly what it would look like, the same color and approximate intensity. I can not give a better description than this simile to the fireflies.

QUESTION: Col. Glenn, is it your belief, then, that the fireflies seemed close up and the flow far off?

COL. GLENN: This may well be what it is. I do not know. I have no theory on it, myself. I have talked with Dr. O'Keefe and many other people at some length on this. They thought at first that these things emanated from the spacecraft and were perhaps from our water evaporator system and were maybe little snowflakes that were reflecting light. I do not feel that this was the case because they didn't look white, for one thing; for another, they were a lot closer together the closer they were to the capsule. I don't think that they originated with the capsule. There was another theory that it might be paint flaking off. Well, this once again would mean that they originated at the capsule. I don't feel they originated at the capsule; they didn't look like they were coming from the capsule, and, when I turned around on the third orbit and looked in my direction of motion there were some coming toward me, which certainly wouldn't indicate that they came from the capsule.

That is about the extent of the information I have on it; I was interested in the particles observed on one of the X-15 flights, and I am sure we want to get together and talk this over.

QUESTION: Col. Glenn, if man is necessary for reliable flight in an orbital system, how in the world did you fellows ever train your predecessor, the monkey?

COL. GLENN: Oh, that's a loaded one. The monkey flight and the instrumented flights were by far the toughest ones in the program, we feel, because we didn't have this reliability that man provided in the program. As a result, the preceding chimpanzee shot was called down after two orbits before we lost complete control of the capsule. If a man had been aboard, as I was when we had worse troubles the next time, three orbits would have been completed with no problem.

QUESTION: Col. Glenn, on the reliability of man in space, what are your feelings on manned boosters to return the boosters to Earth, for economy. I have read something about this in the newspaper.

COL. GLENN: This has been proposed. I am certainly not opposed to this program if somebody can work it all out. It is a tremendously complicated program, as to what type booster you use, if you are going to use this to refuel and then launch it as we do from a mother ship, or something like that, or if you have the whole booster go into space and then reenter; there are many many fields like this, of course, that we want to explore for the future.

QUESTION: Maj. White, what are the factors used in stabilizing the ejection seat to eliminate the rotation over the center of gravity?

MAJ. WHITE: On that particular system, after a number of tests, of course, there were changes made and we had folding fins that extended on the ejection seat, a small set of wings, so to speak, to help give the airplane roll stability, and in addition to that there are telescoping booms that extend to the rear of seat, two telescoping booms that extend after the seat is ejected, to help give it directional stability. From a film taken during flight, it was noticed that the seat was quite stable, it rolled rather slowly and did the job nicely, we think, if you could have seen some of the earlier films of ejection seats. I hope that answers your question.

QUESTION: Col. Glenn, assuming that there is a satellite in an elliptical orbit, will this satellite when falling back to Earth maintain an elliptical orbit, or will it change its pattern to a different shape?

COL. GLENN: This trajectory analysis is a tremendously complicated thing. You have to pinpoint the speeds, where you want to land, and how far ahead you want to fire. I couldn't even begin to give you a definite answer on a question that complicated right here. Questions such as you proposed might take months of study and a whole bank of computers to work out, and has in the past, I might add.

QUESTION: Col. Glenn, why does a spacecraft go, say, north to south, and why is it at a certain height? What are the advantages?

COL. GLENN: Well, there were a number of reasons why a specific trajectory for MA-6 was chosen. One was to keep it over friendly territory in case we did have to reenter anywhere on the Earth, and if you will follow the Mercury trajectory you will find that the Mercury tracking network follows it through friendly countries all around the Earth. Consistent with that, you determine the inclination that you want to fire at, and keep it in as much of an east-west direction as possible so that you take advantage of the speed you already have on the surface of the Earth to help you in your orbital velocity. At the equator on the surface of the Earth you have about a thousand-mile-an-hour speed helping you out to orbital velocity, just by being on the surface of the Earth. We are traveling at this latitude probably some 600 or 800 miles an hour, something in that neighborhood right now. So you can take advantage of this. That is the reason for the easterly direction of travel. Then, the altitude, until more is known about radiation belts, you want to keep the spacecraft well out of the atmosphere but still below radiation belts, as we know them; these come down to somewhere, I think, around 325 or 350 miles. So we are sort of above atmosphere, below radiation, free of unfriendly territory, and east and west.

QUESTION: Col. Glenn, there has been some talk recently concerning the safety of the capsule and I want to know how the U.S. spacecraft compares with the Soviet spacecraft as far as safety is concerned?

COL. GLENN: Well, I can only speak for ours. I have no information to compare their efforts and ours, safetywise. We obviously felt that ours was to the point where it was safe, and it proved that it was. So for lack of information on theirs, I guess theirs was, too.

QUESTION: Capt. Kittinger, you told us the advantages of using a small capsule outside the spaceship for work. I was wondering if you would tell us the advantages of using a pressure suit for these same works?

CAPT. KITTINGER: Well, as I pointed out, my thoughts do not reflect the thoughts of the Air Force. These are my own thoughts, and they are based upon the fact that I was at 103,000 feet, and it was a rather uncomfortable feeling because of the lack of a backup system. Looking back on my altitude

ascents, I feel that a great advantage, psychological advantage, is having a comfortable environment. So I feel that a pressure-type device of this nature might make it safer for the man who would be operating the spacecraft.

QUESTION: Col. Glenn, I would like to know if the booster of the Atlas is fed off the second tank, off the second stage; it looks so small.

COL. GLENN: Well, there is no second stage on an Atlas. You have your lox and fuel in separate tanks. Then you have three engines. Two of those engines are booster engines on the outboard side. All three engines are fed out of both the lox and fuel tanks. Now when you get up to staging altitude (your two outboard engines stage and they are normally what we would call half a stage, for lack of anything better to call them), the two outboard engines detach and drop away; your center engine then, the sustainer engine, keeps on feeding out of these same two tanks that all three of them were previously feeding out of and drives you right on up into space.

QUESTION: Col. Glenn, after you completed your three orbits you said you would like to make some changes in the capsule to give it more freedom. I would like to know what those changes are.

COL. GLENN: Well, we have a number of minor changes going into the capsule. The thing you are referring to, I think, to have more freedom of movement and so on in orbit, free to maneuver; Scott Carpenter is going to have that on the next flight. He will be much more free to maneuver than I was, to do maneuvering flight and rolling flight; we plan quite a number of maneuvers like this, visibility experiments where a balloon will be released and trailed on a long line behind for visibility and for air-density-measurement experiments. The Earth path indicator has come out of the capsule and has been replaced; there are a number of small changes like this. But, in general, the missions, the orbits, the reentry, all this will remain the same.

QUESTION: In conversation with Major Titov and the members of his delegation, it was disclosed that the Russians are using the metal of which the first stage is made for fuel for the second stage. Is something similar being done within our program?

COL. GLENN: They are using what to do what, now?

QUESTION: They are using the metal from the first stage; the entire first stage is melted down to be used as fuel for the second stage of their vehicles. The first stage is crushed and melted, and through special injectors, fed to this second stage to provide fuel for the second stage.

COL. GLENN: Well, that is a breakthrough. I am sorry; I have to confess complete ignorance. I know nothing of this whatsoever.

QUESTION: Col. Glenn, if we were to lose a man in space, what effect would this have on the Mercury project? Would it set it back, and, if so, how far?

COL. GLENN: I don't know. This is something we have brought up numerous times. Eventually there will be people lost in space. if we could go back, 15 years, say, something like that, and list all of the colleagues that we felt were the leading pilots in squadrons and test work, and go back and see how many of them have been crossed off the list today, the number would be fantastic. The number of people who have been killed in this type of work, in aircraft, has been tremendous. We can expect some losses in space, of course. We are doing everything we can to keep this to a minimum. We don't feel that the program should be stopped or should diminish in any way if there are casualties. We are just working as hard as we can work to keep any of them from happening, that's all.

QUESTION: Col. Glenn, in an earlier Session, the possibility of reaching the stars was discussed. Do you think that man will ever reach the stars?

COL. GLENN: That is a long way out. Yes, of course, sometime they will. I don't know whether it will be in our lifetime. Right now, with the way progress has been made the last few years, I don't think any of us would be willing to sit here and predict what man can or can't do. I wouldn't. I think

sometime we will go to the stars; however, I think that the lunar mission we are talking about now, and the closer planets, are a little more worthwhile objectives for our first efforts.

QUESTION: Col. Glenn, you had trouble with your heat shield on the Mercury capsule. Could you tell me what actually caused that, or was it in the instruments on the base?

COL. GLENN: One correction. We did not have trouble with the heat shield, per se. We had an indication from telemetry segment 51 which gave a signal on the ground that the heat shield had been detached from the capsule, that it was loose. This, it turned out later, was a faulty signal, but at that time, not knowing whether it was a faulty signal, they recommended that I keep the retropackage, which sits over the top of the heat shield and is held onto the sides of the capsule by three straps, on. This, if it was still in place, of course, would keep the heat shield in place until reentry. So after firing the retrorockets we decided to leave the retropackage on so that if this segment 51 was right and if the heat shield was loose, at least until we got into a flow condition where there was some force holding the heat shield in place, we would have the retrorocket straps holding it on. So this whole thing was a result of a faulty telemetry signal. That switch, incidentally, has been replaced for the next flight.

QUESTION: Col. Glenn, will the method in which Scott Carpenter is put in orbit be the same method in which you were put in orbit, or will there be changes?

COL. GLENN: Yes, exactly the same trajectory and everything. Once he gets up there, as I said before, he will do some things differently, but the flight itself, the insertion, and recovery, will be identical.

QUESTION: Col. Glenn and the X-15 staff, I was curious after viewing a film on exobiology, which showed Dr. Lederman of the Stanford Institute doing some work on the possibility of life on other planets and in space, if the capsule and the X-15 had any canisters to collect foreign matter from outer space and the layers of air?

MR. ARMSTRONG: We do not in the X-15, at least. But we have in a number of other research flights in other aircraft carried such collectors, and I am not aware of the results of that particular research program. These will be carried in the future on the X-15, but not currently.

COL. GLENN: We are at the study stage on this, also.

QUESTION: Col. Glenn, I would like to know if we have any plans for a capsule similar to yours that will land on land, as the Russians claim they do?

COL. GLENN: Well, our capsule has the capability of landing on land, too. We have made a number of studies. We have made man drops on land, testing the capsule to see how it would work out. So if we had an abort off the pad, say, and came down on the Cape, we could tolerate this. Now the main reason for selecting a water landing when the program started was so that we would have a known surface to land on and could thus prepare for that surface; water is pretty much the same except for wave conditions. There are no really large land areas where you have enough of the same terrain that you could reliably come down without, say, hitting a boulder, or you might come down in high trees. Water gives you a nice even surface to work on. Now we are interested in getting back to landing on land just as much as everybody else is. We would much prefer to land on land and make controlled landings, of course, and we hope that comes in the future.

QUESTION: Col. Glenn, this conference has been on the peaceful uses of space; can you tell me what plans, if any, have been made for military tactical uses of space?

COL. GLENN: Well, I haven't been involved in any discussions of military uses of space at all; so I couldn't even comment on that.

QUESTION: Col. Glenn, from the discussion of these objects that you are uncertain about, and that have been photographed but you can't identify, do I understand correctly that you do take some credence, then, in unidentified flying objects?

COL. GLENN: Joe has the best answer; he says in the Navy they call them small unidentified flying objects. I accept what the

Air Force said on that one. I have never observed any unidentified flying objects.

QUESTION: The second part of my question is that I have a photograph of a real one. Would you like to look at it?

COL. GLENN: I have seen a number of pictures of flying saucers, but I have no more information than just what I read in the newspaper.

QUESTION: Col. Glenn, I saw films of your flight that the Government released a few weeks ago, and as you were reentering the atmosphere the inside of the cockpit of the capsule seemed to get extremely bright. I was wondering what the reason for that was. Did you have window of some kind in there?

COL. GLENN: Well, there were periods during reentry during which it was very bright and dark and very bright and dark. The reason for this is that we rotate constantly during reentry. A constant roll rate is set up. This is in case your center of pressure and your center of gravity alinement are not quite right; you would be reentering at a slight angle, and would tend more or less to fly; you would get a little more lift from the capsule and, instead of making a straight reentry, you would tend to skip off slightly to a farther landing point. This roll rate then neutralizes that tendency as you come in so that you still come down on the predicted landing point. Thus, you will notice in those films that there are bright areas when you turn to the Sun line, and then dark areas as you rotate around on the dark side.

QUESTION: Col. Glenn, in view of recent statements made by Titov in Seattle, what do you think of his statement that he would not care to go on a flight with an American astronaut, in view of our failures? Also, do you feel there is any documentation, or do you know of any documentation, of Russian losses of men in space?

COL. GLENN: Well, I think you have to think a little about the motives behind these statements, maybe. We conduct our program, of course, rather straightforwardly, we are reporting the projects as clearly as we can, and we don't try to get over into any other fields in which we are not qualified to comment, as much as possible. I think the motives behind some of their statements—I wouldn't say what their motives were—but I think when comments like that are made, I would be suspicious as to whether this is a technical analysis of our project or whether it is motivated by some other reason.

QUESTION: X-15 pilots, can you tell us who will pilot the next X-15 flight, and do you have any idea when that flight will occur?

MAJ. WHITE: The pilot of the next flight should be Maj. Rushworth; he will be looking at some flight control systems studies that we are doing, and it should occur next week.

QUESTION: Col. Glenn, I would like to know about the escape measures on your flight, and I would like to know if there is any difference between those and the flight of Scott Carpenter.

COL. GLENN: No, we have no ejection seat in there at all. We depend on the systems that are built into the craft to take care of us. We have the escape tower, of course, that would take us off on a low-altitude abort, or an off-the-pad abort. On the Redstone flights we did carry parachutes because we thought that there was a big enough percentage of the flight spent in the atmosphere that we might be able to use a parachute. We feel that such a big percentage of the flight now is outside the atmosphere, that we would just rather not take the weight along; so we carry nothing along that line.

One further comment on the previous question regarding Titov. I don't mean to dodge that one too much. I think a lot of his comments were politically oriented, obviously. That is what I was referring to before. He is entirely open to whatever opinion he may have of our spacecraft. I don't know how accurately he was quoted in the press; I assume his statements were quoted accurately. I thought it rather ridiculous for someone who knew so little about our program to be making an appraisal that our spacecraft were unsafe, especially in view of the fact that we just got one back in pretty good shape.

QUESTION: Mr. Ross, I would like to get from you straight information about the malfunction in the October 18, 1957, flight. Apparently there were many variations and I

would like to hear from you the facts of the case.

MR. ROSS: Well, I am just thinking. I do remember the flight; it was a daytime flight, launched from Crosby, Minnesota. I remember we got hot, very high; we had some problems about the heat. We had litter around the gondola. Then we landed in some trees, but there is nothing really abnormal about that when you are flying balloons. The only unusual thing was that part of the equipment was stolen after the landing.

QUESTION: The reason I asked the question was that at the time a major wire service reported that there was a malfunction of the balloon and it collapsed and you came down on a hugh emergency parachute. I just wanted that clarified.

MR. ROSS: No, that was incorrect. We landed the balloon quite properly.

QUESTION: Mr Ross, is there in the offing a publication which one can consult as to the types of vehicles available, in other words, balloon and high-altitude crafts such as the X-15; is there a central brochure to which some of us might go?

MR. ROSS: No, there is no central brochure, and I am afraid if there were, and certainly something like that could be prepared, it might not be in as much depth as you would like. The problem I am afraid would be the interrelating complexity of trying to arrive at one book, one pamphlet, that would answer everyones' questions, and I am afraid it just couldn't be done. But even on the surface, I know of no particular document that would go into reasonable depth on all of the kinds of research tools, such as the unmanned balloons, sounding rockets, manned rockets, X-15, and so forth.

QUESTION: So it amounts to going to the individual services as you hear about these devices?

COL. GLENN: This has been a big problem ever since I have been involved in technical research; this interchange of information is always woefully lacking, and there is no one spot to which people can go to get all the information that is available on a particular item or even find a listing of where such information may be obtained. I think that people recognize this as a problem, and I believe that NASA just very recently let a contract to establish a data center like this, where you could get all the information available from the Mercury, the X-15 flights, and the balloon flights; this would be readily available to contractors and scientists and everybody who wanted to get particular information on a particular subject. It is a step in the right direction, and you have touched on a field in which we are woefully lacking, I think, technically, right across the board.

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