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CONFERENCE ON SPACE-AGE PLANNING

CHICAGO, ILLINOIS

MAY 6-9, 1963

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SPONSORS: National Aeronautics and Space Administration; The Mayor's Committee for Economic and Cultural Development of Chicago; University of Chicago; Argonne National Laboratory; Museum of Science and Industry; Chicago Association of Commerce and Industry; Illinois State Chamber of Commerce; State of Illinois Board of Economic Development; Chicago Convention Bureau; Northwestern University; Illinois Institute of Technology and Armour Research Foundation; Chicago Area Research and Development Council; Illinois Manufacturers' Association; Adler Planetarium and Astronomical Museum; University of Illinois; Chicago Board of Education; Catholic School Board; Chicago Natural History Museum; Illinois Bankers Association.

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PROCEEDINGS OF THE

CONFERENCE ON SPACE-AGE PLANNING

A Part of the Third National Conference on the
Peaceful Uses of Space, Chicago, May 1-9, 1963

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PRESIDENT'S GREETING

JOHN F. KENNEDY

President of the United States

The opportunity to lead the way into space has been thrust upon this generation of Americans, just as 2 decades ago in Chicago another generation unlocked the power of the atom. We have accepted the opportunity as well as the challenge of space exploration. But we can succeed in carrying out the tasks ahead only to the degree that our people understand what our aims are, and what the difficulties are, in our quest to master space and to gain all the benefits of scientific knowledge and technology which will come with that mastery.

We shall need to call upon some of our finest minds in science, engineering, and management. We must lay our plans wisely remembering that the costly and complicated tools of space exploration have to be designed and developed years before they can be put to use. The building and testing of rocket engines and spacecraft and the training of crews for manned space flight must progress with a minimum of wasteful stops and starts.

Adequate funds and resources must be available when they are needed. We must make the requirements of our national space program known to every American. But we must also make sure that every American understands all that this program can contribute to our economy and to our future well-being.

We know we cannot hold back tomorrow. The tomorrow of the space age is inevitable. For our nation there can only be a determination that it will be a free tomorrow. We are outward bound. I am convinced that our broad and accelerating exploration of space will help bring this nation to a destiny more splendid than any dreamed by our predecessors.

WELCOME AND OPENING REMARKS

HALE NELSON

General Chairman, Midwest Space Month

The Space-Age Planning sessions of the Third National Conference on the Peaceful Uses of Space have been planned by its principal sponsors—the National Aeronautics and Space Administration and the Mayor's Committee for Economic and Cultural Development of Chicago—and the 17 regional participating agencies to meet varied interests and contribute to future planning and profit. Its objectives are as follow:

(1) To develop widespread local and regional interest in every phase of man's relationship to outer space
(2) To bring about maximum utilization of regional industrial and educational resources in the Nation's space program
(3) To obtain full utilization by regional industries and universities of the spin-off research that the Space Age is generating.

The papers presented herein are concerned with exploration of space, man in space, the university-industry partnership in space programs, how space activities are changing the economy, business opportunities from space research, the placement and management of research and development projects, and the opportunities and challenges in space procurement.

The Nation's space program needs us—and we need it. The so-called "Sleeping Giant" of the Space Age (Chicago and the Midwest)—if it is asleep—must awaken! The Third National Conference on the Peaceful Uses of Space can be a resounding alarm!

* * * * * * * * * * * *

OTTO KERNER

Governor of Illinois

The State of Illinois is proud of the efforts of the leaders in industry, in academic life, and government which have made Space Month possible. This is a major achievement and a happy beginning of our full participation in the great voyage of scientific discovery on which our nation, and indeed our world, has embarked.

It is fitting that Chicago and Illinois, whose scientific talent pioneered our entrance into the atomic age, should play a major role in the age of space. Though we have been slow in mobilizing the tremendous scientific and industrial resources of this area in the Nation's space effort, that mobilization is now underway.

I am confident that Illinois and the whole Midwest will attain a proud place in the already brillant record of our country's space achievement. We can be satisfied with no less.

The officials and scientists of the National Aeronautics and Space Administration have gone to great lengths to present their first team, and we are grateful to them for taking time from their arduous duties to come and share with us their knowledge, their dreams, and their hopes for the Nation's role in space. A glance at the program will reveal that the city of Chicago, its industry leaders, and its great universities have done a magnificent job of providing a rich and varied fare for all those whose minds are challenged by the many facets of the great new age of exploration on which we and the whole world are embarked.

As we reflect on this new age of discovery, a rebirth of the venturesome quest that brought the discovery of America, and the settlement of this land on which we stand, we realize that the mariners and geographers of the heavens of today are the lineal descendants of an illustrious line.

The history books of our children and our children's children will place their names with Columbus, Magellan, La Salle, Lewis and Clark, and the storied host whose names mark the conquest of every corner of the globe. It is natural that we in Illinois and in the Middle West should wish our sons and daughters to form a conspicuous part in the unending line of those whose lives have extended the knowledge of mankind. Our desire for a full share and a major role in man's thrust to the stars is borne of no mere concern with the dollars of government contracts.

Our state, the city of Chicago, and the whole Midwest have had an illustrious place in the scientific and intellectual development of our country. We cannot stand aside as mere spectators while others push the craft of space toward the conquest of immensity. To be a mere backwater in this thrilling age of discovery is to risk the loss of the most precious asset of our future—the trained, generous minds of our youth. They seek, as such minds have always sought, not the dull havens of security, but the challenge of high adventure.

If we, their elders—in Chicago, in Illinois and in the Middle West—fail to provide our talented youth with the means to join the greatest challenge of their time, they will leave us for ports whose vessels consider discovery, as well as trade, to be their business. The future is to those who meet challenges and take risks, not to those who complacently abandon this to others and console themselves with the safe yields of security.

I am happy to see in this Month of Space a heartening sign that we in the Midwest do not intend to let the flood tide of national adventure pass us by and leave us in the shallows. I am happy to see the promising new and strengthening cooperation between our universities and our industries, and I am happy to see that the top officials of the Space Agency fully recognize that our capacity is matched by our will to play a major role in space.

* * * * * * * * * * * *

RICHARD J. DALEY

Mayor of Chicago

Our city has been extremely active in recent weeks learning about the exciting world of space. Beginning with the civic dinner honoring Astronaut John

Glenn, the people of Chicago have had an opportunity to participate in a variety of civic and educational experiences at our universities and museums.

As the Space Month draws to a close, it is a fitting climax that Chicago should host the Third National Conference on the Peaceful Uses of Space.

We are proud that Chicago was selected by the National Aeronautics and Space Administration as evidence of our interest in the national space program and our capabilities to participate in the achievements of our national goals. We can all be proud that our city—operating through the Committee for Economic and Cultural Development—responded to this opportunity to focus attention on Chicago by appointing a steering committee of leading industrial, civic, and educational figures to direct the events of Space Month.

Mr. David Kennedy, Mr. Kenneth Zweiner, Mr. Hale Nelson and his fine staff, and all those who actively participated are to be congratulated for their excellent leadership in this great series of events.

Space technology affects all of us as citizens—and also as businessmen, educators, professional people, and students. All of us cannot become experts in the technical aspects of the space program—but we should all become better informed to function effectively in our changing world. This conference is a notable step forward in this educational effort.

The great concentration of human and material resources in Chicago makes it a natural site to hold this National Conference which is concerned with research and development aimed at the peaceful uses of space. There is no question that our area has not assumed the role of leadership which it should have in the Nation's program to explore space. There may be many reasons for that. One of the prime reasons is that research and industry in Chicago and the Midwest have been concerned primarily with fulfilling their role as the Nation's leader in providing basic consumer goods and capital equipment. This leadership was earned because for generations this area has led in technological advancement and industrial "know-how."

The Midwest—with 20 percent of the Nation's population—produces more than 25 percent of the Ph. D.'s in science and engineering; our universities have contributed more than their share of Nobel prize winners and are renowned for their academic excellence. There are few cities in the Nation which can compare with Chicago in educational institutions and research centers.

We can be highly confident that when the capital facilities and energies of Chicago and the Midwest are directed into the field of space research we will emerge as a leader—just as we have maintained our dominance in the consumer-oriented economy.

Unlike many other areas, industry here has the mass production know-how, the skilled workers, the physical resources, the unmatched transportation facilities, and the capital to convert the scientific discoveries developed by the space program into improving the standards of living. This is a challenge that no other area can meet as successfully as we can.

There are some who are uneasy about the tremendous allocation of national wealth in placing a man on the Moon. There are some who are concerned about the growing reliance of our economy on the production of armaments in defense—but there has been and there will always be universal and enthusiastic support for the utilization of scientific discovery arising from space exploration in such fields as medicine, weather, communications, transportation, new products—and the promise of a new, bright world for mankind.

Certainly, the National Aeronautics and Space Administration—which is dedicated toward the peaceful uses of science—will recognize that there is no other region which can better achieve its objective.

The first step that was needed in bringing our resources to bear in serving space research is taking place at this meeting—for all of us are receiving first-hand information on how the combination of our fine educational institutions, research facilities, industrial skill, and capital can be used for greater participation in the space program.

Certainly, the space effort is one of the greatest and most challenging projects in history. It deserves and will receive the support of Chicago. Be assured that the city government and the Committee on Economic and Cultural Development will continue to explore every avenue in which our great resources can be used—to provide for the best kind of environment for industry and for workers, and to maintain the great tradition of accomplishment that has made Chicago a great city.

The "I will" spirit which exists here is already evident in the high quality of this conference and in the interest that Space Month has created in all of the people living in Chicago and the metropolitan area.

The National Space Program

KEYNOTE ADDRESS—NATIONAL GOALS IN THE SPACE AGE

JAMES E. WEBB
Administrator, NASA

Participants in this Third National Conference on the Peaceful Uses of Space will hear a most impressive array of speakers representing government, industry, and the universities, including some of the foremost authorities in virtually all fields of space science and space engineering.

The sponsors of Midwest Space Month and of this Conference have endeavored to provide a most comprehensive and detailed account of our National Space Program—one surpassed, perhaps, only in the annual hearings before the appropriate committees of Congress. It is a great tribute to your Steering Committee and its chairman, Hale Nelson, that one must look to the exhaustive effort of the Aeronautical and Space Sciences Committee of the U.S. Senate, and the Committee on Science and Astronautics of the House of Representatives, for an adequate standard of comparison.

Since the initial study and debate which led to enactment of the National Aeronautics and Space Act of 1958, these committees have conducted a continuing reexamination and public discussion of our goals in space and the level of effort required to achieve them. Rarely, if ever, has a program of government been presented in such detail, and subjected to such searching examination by the people's representatives.

In 1962, for example, more than 3,000 printed pages of testimony were taken in the House Committee on Science and Astronautics alone, and in 1963 the total will probably exceed 4,000 pages. The depth of this study, and the confidence inspired by such attention to detail, undoubtedly contributed significantly to the unanimous support given in the NASA Authorization Bill for Fiscal Year 1963 in the House of Representatives.

Congress, in two successive sessions, has carefully considered and affirmed the determination to undertake, as a national goal in Project Apollo, manned exploration of the Moon in this decade, rather than at some uncertain date beyond 1970.

The reasons for a major American effort in space in this decade have been articulated and debated since 1958, and have repeatedly withstood close and careful examination, to earn broad bipartisan support. Thoughtful consideration has made clear the urgent need for superior competence in space, but the degree of support which has resulted is effective evidence that those responsible for our security as a nation are determined that we must lead in space—that the United States is not prepared to accept the role of second best.

The Russians have no black magic in their space program or even any red magic for that matter. What they achieve depends on the level of scientific and engineering effort they elect to make, and the resources they are willing and able to commit to this effort. We have the skills, the industrial plant, the creative scientific and technical brains, the managerial efficiency, the national vitality, and the other resources needed to excel in space as in any other major field of endeavor. The Soviet Union has sharply challenged us in space, and has the advantage of an early start. This Chicago and Midwest Space Month is further evidence of our intention to meet that challenge in an area of competition which has captured the interest of people everywhere, and one in which we have the resources, the will and the determination to be preeminent.

The factors which lead this nation to undertake an active American space program remain unchanged. Time and experience have served to underscore their validity. A statement prepared by the President's Science Advisory Committee in 1958 which President Eisenhower found so compelling that he chose to share with all the people of America and indeed with all the people of the Earth, identified four points which, in his words

> . . . give importance, urgency, and inevitability to the advancement of space technology.
>
> The first of these factors is the compelling urge of man to explore and to discover, the thrust of curiosity that leads men to try to go where no one has gone before. Most of the surface of the earth has now been explored and men now turn to the exploration of outer space as their next objective.
>
> Second, there is the defense objective for the development of space technology. We wish to be sure that space is not used to endanger our security. If space is to be used for military purposes, we must be prepared to use space to defend ourselves.
>
> Third, there is the factor of national prestige. To be strong and bold in space technology will enhance the prestige of the United States among the peoples of the world and create added confidence in our scientific, technological, industrial, and military strength.
>
> Fourth, space technology affords new opportunities for scientific observation and experiment which will add to our knowledge and understanding of the earth, the solar system, and the universe.
>
> The determination of what our space program should be must take into consideration all four of these objectives.

It is evident that these reasons for an active and urgent space program, advocated by President Eisenhower and reiterated by the Congress when it enacted the National Aeronautics and Space Act of 1958, demand nothing less than leadership in space.

Certainly, the very idea of "exploration" implies a pioneering venture into territory where man has not gone before. To explore, and gain the benefit of that exploration, we must mobilize our resources in order to lead, not follow. Similarly, we cannot expect to guarantee our own national security, and that of the Free World by surrendering first place in space technology to the power which constitutes the greatest threat to our welfare.

There is little use talking about being strong and bold and creating added confidence in our scientific, technological, industrial, and military strength if we content ourselves with a role short of preeminence in space. With a billion people already allied against us, and the uncommitted and emerging nations concerned with their own future welfare, the United States must present the image of a can-do nation, to which they can confidently aline their futures.

Finally, consider the factor of opportunities for scientific observation and experiment. Even in this field, where international rivalries may appear to be less important, the significant advances will not be made in fields that have already been well plowed by others.

To sum up, the basic reasons put forward for an active and urgent space program in 1958 have not only proved thoroughly valid, but lead inescapably to the conclusion that the American goal in exploration and use of space in this decade and this century must be, as President Kennedy has said, preeminence.

The accelerated space program recommended in May of 1961 by Vice President Johnson and President Kennedy was much more than the result of a new look at an old problem by a new Administration. It was the result of a careful examination of a rapidly changing situation, and the evidence which this gave of our own expanding capability, and increasing Soviet activity.

In the early years of the Space Age, we were limited in what we could do by the lack of launch vehicles to put substantial payloads into space, the existing level of technology, and inadequate knowledge of the space environment. As progress was made on all these fronts our understanding of the potential of space grew, and it became possible to raise our sights and identify more clearly our long-range national goals.

This was the position when President Kennedy took office early in 1961. Between February 4 and April 12 of that year the Soviet Union put four satellites into orbit, each weighing more than 10,000 pounds. One of these was the Vostok spacecraft that carried Yuri Gagarin, the first man to orbit the Earth. The Soviet exploits made it clear that the U.S. space efforts then underway or planned were inadequate to meet the Soviet challenge, or give our nation a leading role in what promised to become one of the greatest undertakings in all human history.

The need for an accelerated program was apparent not only to President Kennedy, but to the leaders of both parties in Congress, and to all Americans who studied the evidence carefully.

It was also apparent that the promise of economic and social improvement inherent in the vast space research and development program gave added merit to acceleration of the program as a whole. It was clear, for example, from our work with experimental weather and communications satellites, that the national investment in space technology could be put to use and pay very practical dividends. Most thoughtful observers also are confident that technological advances made in space research and space engineering will prove of value in our general economy.

No one can say now how much of the cost of space research will be repaid in the form of new products and improved industrial processes. This contribution could be substantial, and optimism on this score is well grounded in technological and economic history, but it is impossible to establish a firm dollar value at this early stage.

Predicting the ultimate benefits likely to flow from a given scientific discovery or technological innovation has proved a hazardous business, at best. One recalls Thomas A. Edison, who commented that the Wright brothers' airplane had no practical value, and would never be anything more than "the toy of wealthy sportsmen."

It would be interesting to know the extent to which the failure of even great minds to comprehend fully the potential of how knowledge has affected our national decisions, and in some important areas injured the Nation in years gone by. It is a fact that although the airplane was first flown in America, American pilots in World War I had to fly chiefly in foreign planes because we had developed no aeronautical manufacturing or design competence of our own. In 1914, France had 1,800 aircraft, and the U.S. Army 23.

Today, with the entire Free World looking to us for leadership in space technology, and indeed the fate of the world dependent on our achieving that leadership, we can no longer afford the miscalculation of the past.

Not everyone agrees on the potential technological benefits which may arise from our space program.

History indicates, however, that where the potential of scientific and technological breakthroughs are concerned, the tendency is to err on the conservative side.

The following view was expressed by an eminent scientist who has given a great deal of thought to this matter—Dr. Lloyd V. Berkner, President of the Graduate Research Center of the Southwest and until recently Chairman of the Space Science Board of the National Academy of Sciences, one of the many positions of trust and honor he holds, or has held, in the scientific community:

> We live in a dynamic civilization in which some aspects of technology must always lead the others. Failure to press these technological differentials will bring technology to a halt, and our space program is the greatest spur to technology today. Moreover, we cannot ignore the broad technological fall-out that is creating altogether new industry, employment, and broadening the national tax base.
>
> Beyond this, in satisfying man's primitive aspirations to conquer the unconquered, we spur him to greater effort. Only one percent added effort will pay for the whole space program, and there is no doubt that the program exercises a mighty influence in advance of both education and industry.

Now turn for a moment from the reasons for a space program to the reasons why we have given high priority to Project Apollo:

(1) The goal of lunar exploration is feasible from an engineering standpoint. No great new technological breakthroughs are required. The timetable set by the President gave us 9 years to carry out the project in a prudent, step-by-step manner.

(2) By planning ahead, and adopting a realistic schedule, we avoid the wastefulness of indecision, and stop-and-go financing.

(3) We have set ourselves a clear goal which the entire world can understand, and one in which we have a good chance of being first.

As President Kennedy put it in 1961, "No single space project in this period will be more impressive to mankind."

(4) We have set a goal which will focus our efforts, and at the same time enable us to build up a broad base of space power.

The lunar landing will be but the culmination of a tremendous effort that includes: development of the Saturn I and Saturn V rockets, which we need for many uses besides the lunar flight; construction of the facilities for building, testing, and launching these mighty new rockets; development of a three-man spacecraft that can remain in orbit 3 weeks or more and which will have many uses besides the Moon expedition; and perfection of the techniques of rendezvous in space and the joining of two or more spacecraft in orbit.

(5) In Project Apollo we are opening the way to future space activities which may be in our national interest—the establishment of a scientific base on the Moon, and of staging areas which can be used to great advantage in further exploration of the solar system, if future years show a need to proceed with these projects.

(6) It is not clear what the advantages of bases on the Moon might be. But in Project Apollo we protect ourselves against the great psychological advantage the Soviet Union would have if it alone could occupy and use the Moon.

There is a tendency in some quarters today to belittle the psychological value of Project Apollo. But think, for a moment, what the reaction would be in this country if the Soviets made a successful landing on the Moon and we had no plans and no potential for getting there. Certainly such a situation would be very damaging to our position throughout the world. The uproar after the first Sputnik would be mild indeed compared with the storm that would follow.

(7) We are stressing Project Apollo because it gives us a good chance of overcoming the lead in manned space exploration which the Soviets now hold.

It is geared to a vigorous effort on our part which gives us a chance to be first and assurance that in any event we will not be outdistanced. Being second would be serious. Not being in the competition at all would be a severe defeat for America and for the cause of democracy and freedom.

The schedule we have set for Apollo provides time for proving out our new rockets and new spacecraft, and for crew training. We are making a substantial investment in assuring the reliability of our boosters, our spacecraft, and our procedures. Project Apollo is not a spectacular do-or-die attempt. It is a painstaking scientific and engineering effort in which we still have 5 years or more of work ahead of us.

Our ability to get to the Moon and back safely will be developed and demonstrated in a series of careful steps. The completion of Project Mercury is a first step. Then come the 2-week flights and the rendezvous maneuvers in Project Gemini; then the unmanned tests of the Saturn boosters and the Apollo spacecraft; then flights of 3 weeks or more in the Apollo spacecraft in Earth orbit; then the first flight to the vicinity of the Moon, without an attempt at landing. Finally, there will be the lunar landing attempt. But even at the last moment before touchdown this can be broken off if the astronauts perceive an unexpected danger.

Furthermore, the lunar landing will be preceded by careful and detailed study of the Moon's surface and environment from unmanned spacecraft of the Ranger and Explorer type.

It is not a question of whether we should stress manned or instrumented exploration of the Moon. We are doing both, and in proper sequence so that the unmanned scientific studies will be available to help assure the safety and success of our astronauts.

A few remarks about scientific aspects of the United States space program, particularly as they relate to the Apollo project, may be appropriate.

As is well known, there is not complete agreement among scientists regarding the extent to which manned scientific exploration of the Moon will offer advantages over the use of automatic equipment. There is also concern, among the apparently substantial majority of scientists who recognize the importance of manned exploration, that unless thoroughly trained scientists are included as astronauts in the Apollo program, the maximum scientific value from these flights cannot be obtained.

Scientists would not be scientists if they did not question the conclusions of others, and disagree among themselves until a conclusive experiment has been made, for these attitudes are the very essence of the scientific process.

It appears clear, however, that there is agreement in principle, on the part of most scientists, that if the United States is going to explore the Moon with men, results will be obtained which will surpass those which automatic equipment would yield.

This is indicated in the report of a group of the Nation's leading scientists who met for almost 2 months last summer at the State University of Iowa under the sponsorship of the Space Science Board of the National Academy of Sciences. Their report made these statements:

> It is recognized that a man in a sensing and control loop can provide judgment, adaptability, improvisation, and selectivity to a degree which cannot be matched now or in the forseeable future by adaptive machines which only report the results of their observations, experiments, and actions to man . . .
>
> Manned exploration of space promises great scientific return and Apollo can be a fruitful first step in this effort . . . Although the mission itself is first an engineering enterprise aimed at ensuring that man reach the Moon and return safely, it is also the first step in manned scientific study of the Moon and the planets. . . .
>
> Man's opportunities for scientific exploration of the Moon are practically unlimited.

Other scientists have pointed out that the presence of man is essential for the detection of unexpected phenomena, and that the existence of anything that can be measured automatically is essentially already known before the instrument can be designed. And, in fact, President Kennedy's recommendation that the United States undertake manned lunar exploration as a national goal within this decade was based in part on a 1961 report of the Space Science Board of the National Academy of Sciences which said:

> Scientific exploration of the Moon and the planets should be clearly stated as the ultimate objective of the U.S. space program. From a scientific standpoint, there seems little room for dissent that man's participation in the explorations of the Moon and the planets will be essential. Man can contribute critical elements of scientific judgment and discrimination in conducting the scientific exploration of those bodies which can never be fully supplied by his instruments, however complex and sophisticated they may become.

Lunar exploration is appealing to many scientific disciplines because the uneroded surface of the Moon may reveal information about the origins of the universe which has long since been erased from the surface of the Earth. It offers unique opportunities for research in geology, geophysics, astronomy, and space biology. The back side of the Moon may provide an ideal antenna site for large low-frequency structures for use in radio astronomy. Such installations would be shielded from Earth noise background and capable of investigating the theoretically crucial long-wavelength region obscured by the Earth's ionosphere.

While acknowledging the value of manned exploration of the lunar surface, the scientists who participated in the Iowa Summer Study also forcefully expressed their conviction that one or more trained scientists should be included in the Apollo team. This view has been given careful consideration within the NASA organization.

Obviously, given the overriding national defense and foreign policy considerations involved in the space program, and a difficult and challenging national goal to achieve in the Apollo program *within this decade*, NASA's first concern has been, and must be, to develop and organize the resources to do the job. To those who have the responsibility for success in reaching the Moon, it has appeared that the nature of the Apollo effort requires the training of astronauts who have substantial experience as test pilots in high-speed jet aircraft, and to the extent possible, engineering training as well.

Meanwhile, it is apparent that the view of the scientists that trained scientific personnel should participate is valid, and that at the earliest appropriate stage in the program scientists will be included on Apollo missions. So far as we can now tell, we are obligated to utilize astronauts with the maximum of test flight experience and highly conditioned reflexes on the first flight of the most difficult of all undertakings. Should training and experience in intermediate flights indicate otherwise, we will, of course, take this into consideration in determining the stage of development in manned space flight at which a scientist-astronaut will directly participate.

In its effort to insure the maximum scientific benefit from the manned space flight program, NASA is doing several things:

First, manned flights are being used to take scientific measurements, in order that they will provide results beyond crew training and technological experience.

Second, efforts have already begun to provide scientific training for the present group of astronauts, including geological field trips, to enhance their capacity for scientific observation.

Third, a manned space science working group has been established, with Dr. Eugene Shoemaker, a geologist, as chairman, and a membership drawn from the NASA Office of Space Sciences and the Office of Manned Space Flight. This group is already at work in the planning of a program for training scientists for space flight.

Although the extended manned flights are some years in the future, this working group has begun to consider the methods through which the selection of such scientific personnel should be made, and how and when they should begin training. They are studying the extent to which these scientist-astronauts should be given technical and physical training related to the flight itself, how their scientific qualifications should be determined, what scientific disciplines should be represented on the initial flights, and whether the candidates should be exposed to a broad multidisciplinary training program outside their principal specialty, in order that their ability to observe a variety of scientific phenomena may be enhanced.

We do not know the answers to these questions, nor to many others which will rise. Obviously, many aspects of the problem will have to be decided within NASA itself. In answering most of the questions, however, NASA will require the advice and counsel of the scientific community.

At present NASA enjoys close relationships with the National Academy of Sciences, and our reliance on the wisdom available in the Academy has been and is of vital importance to the success of our effort. The Space Sciences Board of the Academy, in fact, provides NASA with counsel and advice in much the manner that the General Advisory Committee works with the Atomic Energy Commission. This guidance is an important element in the work of the Office of Space Sciences and of other NASA program offices as well.

It is our intention, therefore, in considering the role of scientist in the manned space flight program, to turn once again to the scientific community for assistance and guidance, utilizing the continuing close relationships which NASA has with the Space Science Board.

In the earliest scientific investigations, man relied only on his own senses and intellect to make observations of the solar system. Subsequently, he devised simple instruments to enhance these observational powers. Today, we have learned to send these instruments into the far reaches of space to improve further the quality and detail of the results obtained. And, finally, we are arriving at the point where man can be sent out with his instruments, to refine the investigative process further. It is our hope, through the efforts of the National Academy of Sciences and NASA, working closely on the problem, that we can arrive at a means of providing scientific representation on manned space flights which will maximize the scientific benefits which are obtained.

Here, I believe, is the main point of this discussion: The real value of Project Apollo, to the American people, lies not so much in exploring the Moon, but in acquiring the ability to get there, and get back, and perform whatever scientific observations are needed.

A boy or girl who wants a college education could put it off until age 40, but would be losing much of the potential benefit. The same is true of Project Apollo. Exploring the Moon will have scientific, psychological, and strategic value. But developing the space power to get there—building the new spacecraft and rockets and spaceyards and spaceports—is what we must do to lead in this new field, to make America the world's leading spacefaring nation, to assure that space, as the oceans and the atmosphere, will be used for the benefit of all mankind and not as a theater for Communist aggression or Communist propaganda.

1 The National Program for the Exploration of Space

DeMARQUIS D. WYATT
Director, Office of Programs, NASA

Only 5 years ago, the Congress of the United States was still deliberating the role that the U.S. should take in the newest extranational arena, the arena of space. It was to be as a result of those deliberations that NASA would be created.

Five years ago there was little positive basis for forecasting the future in space. The Soviet Union had launched two satellites; the U.S., three. Both Russian satellites had already gone to a fiery grave on reentry. The three U.S. satellites were all that remained aloft.

Nothing better illustrates the dynamic rapidity with which space has come of age than the fact that only 60 months after this uncertain status of space no one finds it incongruous that the nation's second city should be host to a Midwest Space Month and that NASA, which did not exist 5 years ago, should devote a solid day and a half to a brief and fragmentary review of some of the highlight elements of the national space program.

The NASA presentation to the Third National Conference on the Peaceful Uses of Space, when completed, will give a fair appreciation of some of the U.S. accomplishments, hopes, and aspirations in the space arena. In this introductory survey an attempt will be made to convey an understanding of the framework on which the NASA program is built and which ties it together.

In its broadest context the NASA program can be classified into three complementary parts. First, we have those phases of the program which are aimed at the exploration of the very nature of space. This part of our program is founded on the concept that space, as an operating arena, is here to stay and that as a mature, responsible, capable nation we can do no less than provide a secure foundation for future space activities, whatever they may be, by a careful, thoughtful, and comprehensive determination of the properties of space itself.

The second major element of our program is aimed at the earliest practical utilization of space for the benefit of mankind. At the moment the most immediately useful systems appear to consist of unmanned spacecraft. However, a large share of our program is aimed at a rapid determination of man's capabilities in the space environment based upon the firm conviction that future developments will involve men in a dominant role, whether as operators of near-Earth spacecraft or as explorers of our solar system.

Complementing our programs to understand and define space and our programs to utilize space is a third major program element aimed at developing and improving the highly complex technologies which will enhance our future capabilities in space. Although our efforts in this category are directly aimed at the enlargement of our space capabilities, we are acutely aware that the concepts and devices emerging from this effort may well, in themselves, become the basis for new industrial and commercial applications totally dissociated from the space environment.

Our fundamental knowledge about the nature of space, which is a necessary foundation to future activities, is acquired by a broad spectrum of missions. Figure 1–1 summarizes these. Our basic approach is through the use of sounding rockets, which may be defined as relatively small, relatively inexpensive vehicles for lofting simple payloads from a few score to a few thousand miles above the Earth's surface. Payload instruments measure selected properties of space near the Earth in the few minutes of flight before the rocket plunges back to the Earth's surface. This sounding rocket technique was highly developed in the decade following World War II and was our only technique for on-site measurement of space properties until Earth satellite flight was achieved in 1957. In spite of the more extensive and more dramatic capabilities of satellites the sounding rocket remains a basic tool, both for acquiring local instantaneous measurements of space properties and for providing a relatively inexpensive flying test bed to evaluate instruments contemplated for more complex payloads.

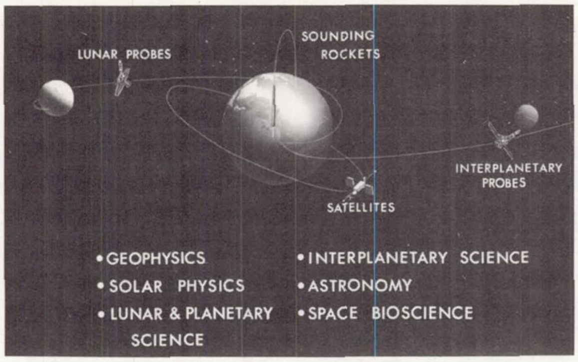


FIGURE 1–1.—Space sciences.

The Earth satellite is, however, our major tool for acquiring long-term measurements of properties of space near the Earth. By varying the orbital inclination and the ellipticity of the satellite paths it is possible to acquire gradually a basic understanding of space properties in all directions at distances up to several hundred thousand miles from the Earth's surface.

For measurements of spatial properties at greater distances from the Earth we cease to use the Earth as a focal point and escape from its gravitational attraction with vehicles that we call "probes." When exploring the Moon or the regions of space near the Moon we subclassify our spacecraft as "lunar probes." In flying to or near other planets of the solar system, we designate our flights as "planetary probes" and in those instances where we are measuring the remote properties of space at distances very far from any planetary bodies, we simply refer to our "interplanetary probes."

Although trajectories and spacecraft differ for the various missions they are unified by common scientific objectives. We are interested in understanding the nature of space whether influenced by the presence of a planetary body (i.e., what is known as Geophysics); whether relatively uninfluenced by the presence of planets as in Interplanetary Science; whether concerned with the special properties emanating from or primarily influenced by the Sun as in Solar Physics; the properties of the larger universe as in Astronomy, the peculiar properties of the Moon and planets; or in the effects of space on living matter. In all of these areas our objective is to know more about space itself.

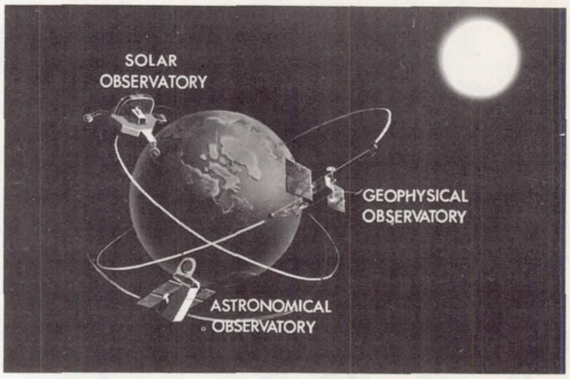


FIGURE 1–2.—Observatory satellites.

Figure 1–2 indicates, in a general fashion, the kinds of uses to which we put Earth satellites in this process of acquiring a fundamental understanding of the properties of space. In March 1962, we launched our first Solar Observatory. A 450-pound spacecraft with about a dozen correlated experiments aboard to make long-term observations, it is still functioning and is still yielding useful scientific observations 14 months after it was launched. Somewhat contrary to the concept shown in figure 1–2, the spacecraft is stabilized in flight so that the instruments are focused on the Sun whenever the Sun is in view.

A second kind of observatory which will be making its first flights near the end of this year is the Geophysical Observatory. In this spacecraft a score or more of related experiments will examine the properties of space up to a distance of about 60,000 miles from the Earth's surface. It will be oriented and stabilized so that the same face always points to the Earth. Thus, the interrelated properties of the energies and particles streaming from the Sun and the magnetic, gravitational, and electrical fields from the Earth can be determined.

The third spacecraft, the Astronomical Observatory will be flying in a few years. Whereas the Solar Observatory points at the Sun and the Geophysical Observatory at the Earth, the Astronomical Observatory will point to the universe outside our solar system. On command from the ground it will map our universe in energy wavelengths that cannot penetrate to the surface of the Earth.

These three spacecraft have been selected for general discussion in this paper because they illustrate our developing desires and capabilities for understanding the nature of space. Our scientific explorations up to this time have largely been conducted with single purpose spacecraft and while such devices will continue to be flown in the future for special purposes, the great volume of data will be derived from these observatories. We have deliberately chosen to call the spacecraft illustrated here "observatories" because each will have the interdisciplinary scope and capacity that one associates with ground observatories. Successive and continuous use of these observatories through at least the next decade should give us a fundamental understanding of space for whatever purposes space may hold for us.

The Moon as our nearest heavenly neighbor holds a special attraction for scientists, adventurers, and romanticists alike. The unmanned spacecraft that we will be using in this decade as a forerunner to, and in preparation for, manned exploration of the Moon are shown in figure 1–3. Although the Moon is our closest neighbor, it is at the same time so remote from our earthbound scientific devices that our knowledge is indeed meager. We do not now have the data to understand its origin, its composition, or its detailed surface features. On the latter point, for example, we do not know how flat are its surfaces, nor indeed whether flat surfaces truly exist, nor do we know whether it is rock-hard or dust-soft in its surface composition. Our best optical observations from the surface of the Earth cannot discriminate terrain features less than several thousand feet across and hence we have no way of knowing whether landing sites for manned spacecraft will be as flat as an ordinary floor, strewn with huge boulders, or laced with Sun-baked crevasses. To acquire this information we must extend our sensory perceptions to the vicinity of the Moon and this we shall do with the spacecraft shown here.

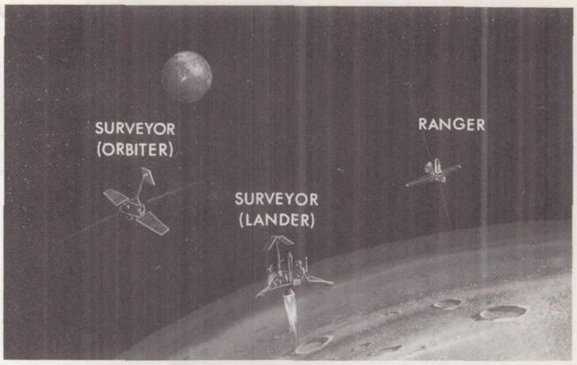


FIGURE 1–3.—Unmanned lunar spacecraft.

Project Ranger will, in the few moments before its destructive impact upon the Moon's surface, give us our first closeup look at the Moon. As it plunges downward on a collision course the spacecraft will orient itself about 1,000 miles above the Moon and take a succession of photographs. On a successful flight we can expect an excess of 3,000 photographs to be transmitted back to the Earth prior to impact. Each photograph will yield successively greater detail until we should be able to detect surface objects no more than a few feet across from the final photographs.

The Surveyor Lander spacecraft shown in the center of figure 1–3 will be our second generation lunar exploration vehicle and will yield correspondingly greater information. Instead of plunging into the Moon at thousands of miles an hour as will Ranger, the Surveyor will be decelerated upon approach by a large retrorocket and will be landed gently on the Moon's surface. Stabilized by its outrigger legs it will yield continuing surface data about the Moon. In addition to numerous instruments for determining lunar surface properties, it will contain real-time television cameras that will transmit panoramic pictures of the vicinity of the landing site back to Earth.

Project Ranger has already begun, although we have not performed successful missions up to this time. The Surveyor Lander flights will start within the next 2 years. We are currently evaluating the possibilities of yet a third lunar unmanned spacecraft that is here labeled a Surveyor Orbiter. We have not yet made a final determination as to how we should proceed or if we should proceed at all with such a mission. The concept we are studying, however, is to place a spacecraft in orbit around the Moon to acquire reconnaissance photographs of large segments of the lunar surface. There is a strong motivation to obtain this overall reconnaissance view to complement the local terrain photographs from Ranger and the Surveyor Lander. There are major technical considerations to be evaluated, however, before a final project determination can be made.

The last part of our current program for understanding space relates to the nearby planets. Figure 1–4 indicates our present concepts. The launch energies required to reach either Venus or Mars are so great that the resultant payloads using current launch vehicles are limited. Consequently, the kinds of missions we can fly are limited. On the left is illustrated the kind of spacecraft that we flew by Venus in 1962. Although the actual instrumentation was limited, we acquired a tremendous wealth of information about Venus. So successful was this flight, as a matter of fact, that we canceled our plans to make a second similar flight in 1964 because we felt that there would be little more to learn within our present payload capabilities. We will, however, make a similar fly-by of the planet Mars in 1964.

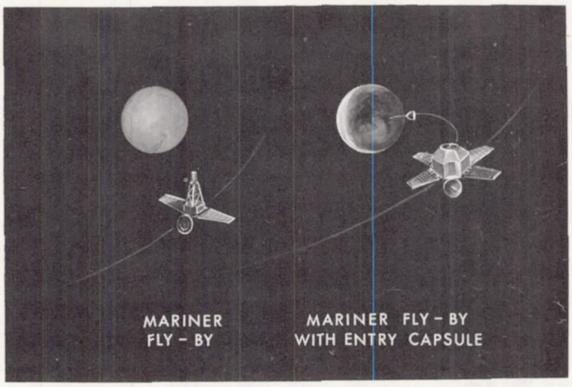


Figure 1–4.—Planetary exploration.

With the current limitations of propulsion systems, it is not possible to investigate the planets at the convenience of the scientists. Rather, it is necessary to leave the Earth within a 1 to 2 month launch period every several years when the Earth and the target planet have favorable relative positions. In the case of Venus, this only occurs about every 19 months and in the case of Mars, every 25 months. At the present time the other planets in the solar system are beyond our energy capabilities for useful spacecraft. Although our present capabilities are limited, they will become enhanced as new launch vehicles become operational. We, therefore, anticipate that our next step in planetary exploration will be with a spacecraft something like that shown on the right in figure 1–4. In addition to flying by the planet and acquiring data in transit, we will detach a capsule or pod to enter the planetary atmosphere. Certain artistic liberties have been taken in this sketch. We would not fling the pod overboard as we go by the planet but would, instead, detach it while some millions of miles from the intercept point.

We are beginning to study even more advanced missions than those shown here. When the very large launch vehicles being developed in support of our manned lunar program become operational, it will be possible to send large enough spacecraft to Venus and Mars to permit us to enter a satellite orbit around the planets and to make long-time observations of the planetary features. The energies required to reach the planets with sizable spacecraft are so great, however, that these unmanned investigations will probably constitute our only means of planetary exploration for several decades to come.

Although the prospects for manned flight to the planets are now remote, just the opposite is the case for lunar exploration. In May of 1961, President Kennedy established a goal for the Nation of landing men on and returning them from the Moon before this decade is out. The overall program to achieve this result is firmly underway. A discussion of the many detailed steps in this overall program will be given in subsequent papers and are reviewed briefly as follows.

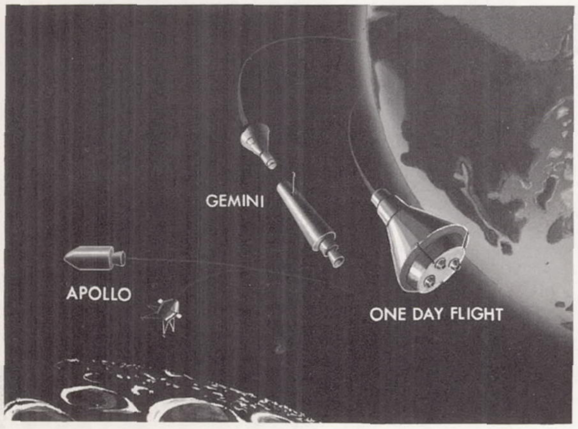


FIGURE 1–5.—Manned space flight.

The three major projects involving men are summarized in figure 1–5. Project Mercury, our first attempt at manned space flight may conclude with the projected flight of Astronaut Gordon Cooper for 1 day or more. We will then move into Project Gemini, in which two astronauts will fly together for extended periods of time. In this project we will begin to perform technological projects during orbital flight to complement the observation of man's behavior which has been the prime objective of Project Mercury. The third project now underway is Apollo. Three men will participate in these flights and as a final phase the three will fly in satellite orbit around the Moon and two of the astronauts will descend to the Moon's surface.

The spacecraft to be flown by Astronaut Cooper, shown in figure 1–6, is the now familiar one-man Mercury configuration. His flight will give us additional valuable data on the actions and reactions of astronauts when exposed to the unnatural condition of zero gravity associated with space flights. Although enough data have now been accumulated from our own and Russian flights to indicate that no incapacitation appears to result from flights of several days duration, the Cooper flight will give us valuable physiological and psychological data on the details of human behavior during the weightless condition.

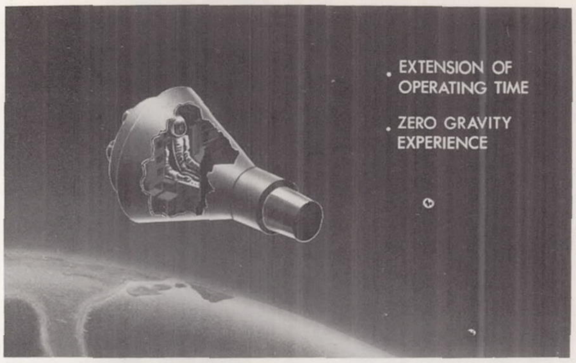


FIGURE 1–6.—One-day manned flight.

We will follow the one-man Mercury program with flights of the two-man Gemini capsule illustrated in figure 1–7. Aerodynamically similar to the Mercury capsule, the Gemini will also be limited to Earth orbital flight. It will have system capabilities, however, that will permit flight durations of a week or more and thus will provide us with behavioral data over the periods of time required for flights to the Moon and return. As an important addition, moreover, Gemini will give us the capability for developing the art of rendezvous and docking in space flight. "Rendezvous" is here defined as the art of placing two separately launched objects into close proximity in space, and "docking", as the art or technique of cou-

FIGURE 1–7.—Gemini spacecraft.

pling these two objects together to form a single composite spacecraft.

In Project Gemini we will initially place a modified Agena stage into Earth orbit using an Atlas launch vehicle. After the ephemeris, or orbital trajectory, is accurately determined the two astronauts in the Gemini capsule will be launched by a Titan II rocket into a closely proximate path, thus accomplishing the rendezvous. The astronauts will then control both their own spacecraft and the Agena target vehicle to accomplish a docking maneuver. As part of the Gemini program, provision is being made for one astronaut to climb outside the capsule to evaluate his capacity to perform simple construction or repair procedures during space flight.

The technologies acquired in the Gemini program will be directly applied in the Apollo program. Figure 1–8 illustrates the several missions which now make up the Apollo program and shows the total spacecraft configuration for the final lunar landing mission. At launch, three astronauts will be housed in a reentry capsule known as the command module. This is the only section of the spacecraft that will be recovered after reentry to the Earth's surface. The command module will sit atop a service module which will contain expendable supplies and auxiliary equipment, including a rocket stage suitable for slowing down the overall spacecraft configuration as it approaches the Moon and accelerating the command module from lunar orbit on a trajectory back to the Earth. The actual descent to the lunar surface will be made by two of the astronauts using the lunar excursion module at the bottom of the payload package.

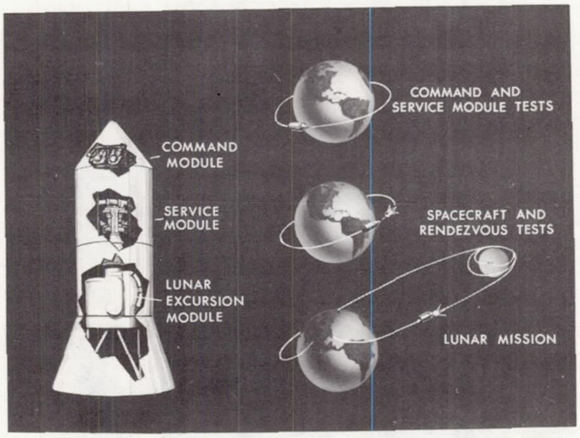


FIGURE 1–8.—Apollo spacecraft.

The mission profiles will be described in detail in subsequent papers. Here it may be pointed out that in the accomplishment of the final lunar mission it will be necessary to separate the command and service modules from the lunar excursion module during transit to the Moon, to turn them end for end, and to dock them so that the command and lunar excursion modules are connected face to face. After the lunar excursion module descends to the lunar surface it will have to be launched back into a lunar orbit rendezvous with the orbiting modules and will have to dock with the command module to permit retransfer of the two lunar surface explorers back to the command module. This illustrates the importance of the early development of the rendezvous and docking technologies.

In the conduct of the Apollo program it will be necessary to proceed with an orderly development of our flight techniques. The earliest flights will be Earth orbital missions using only the command and service modules. These flights will permit an extension of our zero gravity observations of astronauts to time periods on the order of a month; they will provide us a technological checkout of the configuration and will, very importantly, provide us with a crew training device for pilot familiarization of the three-man crews.

Subsequent to these flights we will launch the entire lunar configuration into Earth orbit and will, in that orbit, practice the docking maneuvers ultimately to be required for the lunar mission. Then and only then will we be ready to undertake the terminal mission.

Our program for evaluating and extending the capability of men in space flight missions embraces much more than the spacecraft developments just discussed. A whole new series of launch vehicles is also being developed. All of our space activities to date have been accomplished using launch vehicles based upon military missile boosters, except for some small spacecraft launched with the Vanguard and the Scout vehicles. New launch vehicles, shown in figure 1–9, are now under development to

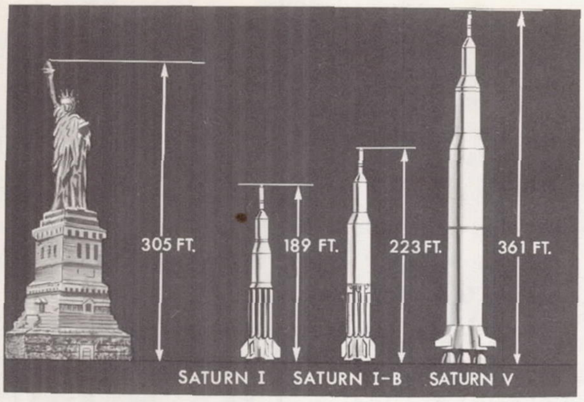


FIGURE 1-9.—Large launch vehicles.

accomplish the Apollo objectives and to give us the potential for a broad spectrum of future missions.

As a standard of comparison let us use the capabilities of the Atlas booster used in Project Mercury. It has a takeoff thrust of less than 400,000 pounds and will place a payload of about 3,000 pounds in a low Earth orbit. The Saturn I vehicle, which has undergone four highly successful first-stage flight tests, will develop 1½ million pounds of thrust at takeoff and will place about 20,000 pounds in Earth orbit. This is the launch vehicle that will be used for the initial flights of the command and service modules. By using an improved second stage we will achieve about a 30,000-pound Earth orbit capability with the Saturn IB and this vehicle will be used for the Earth orbital tests of the entire Apollo configuration including the docking experiments with the lunar excursion module.

In order to perform the lunar landing mission we are developing the Saturn V vehicle. The 7½ million pounds of thrust it develops at takeoff together with the 1-million-pound second-stage thrust will enable us to place over 200,000 pounds of payload in Earth orbit. This will be about 70 times the payload capability of the Atlas. With a 200,000-pound payload in Earth orbit we will be able to launch approximately 90,000 pounds of Apollo spacecraft to the Moon.

In addition to being the necessary tools for the accomplishment of the Apollo missions, these three launch vehicles will give the United States unparalleled capacity for the accomplishment of other space missions of the future.

Our immediate goals for the utilization of space will not in themselves require this tremendous power. In two technological areas the applications of small, unmanned spacecraft promise early beneficial returns from our space efforts. We are beginning the examination of other attractive possibilities.

Meteorological satellites hold promise for providing a valuable data supplement to our conventional weather observational techniques. Up to this time we have flown six of the exploratory Tiros spacecraft shown on the left in figure 1-10. Though of limited utility because of the space orientation, which only allows the cameras to record cloud cover over a portion of the Earth on each revolution, the more than 200,000 cloud pictures transmitted by Tiros have clearly indicated the value to be achieved from overhead observations.

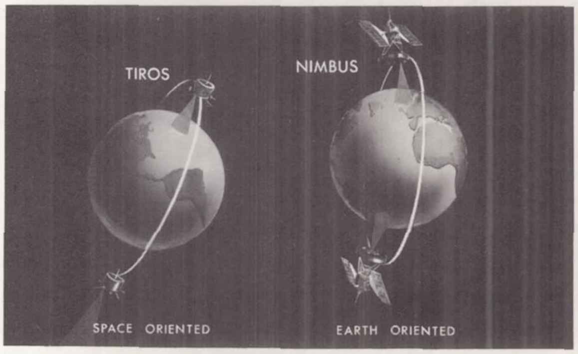


FIGURE 1-10.—Meteorological satellites.

The Tiros experimental spacecraft will soon be replaced by the more advanced Nimbus, which will be stabilized to provide Earth orientation of the cloud cover cameras at all times. (See right side, fig. 1-10.) By flying Nimbus in a near polar orbit it will be possible to have daily observations of cloud cover over most of the Earth's surface. Although Nimbus will only fly for the first time late this year, it is already conceived of as having a preprototype potential for an eventual, and not too distant, weather observational system.

The startling possibilities of communication satellites have been dramatically impressed upon the peoples of the world by the performance of Telstar and Relay within the last year.

These are but two of the communication satellites being investigated. The overall content of the current NASA program is shown in figure 1–11.

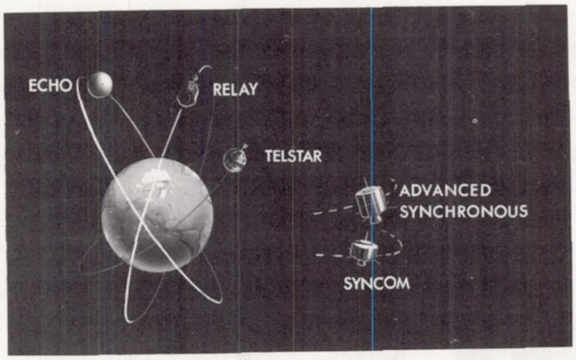


FIGURE 1–11.—Communications satellites.

NASA launched an Echo satellite in 1960. This was a large, inflated, balloonlike reflecting sphere from which radio signals could be bounced over transoceanic distances. We will launch another passive sphere of improved rigidity characteristics in the near future.

At the present time the attractive reliability characteristics of the passive sphere seem to be outweighed for commercial purposes by the ground station simplifications possible with the so-called active satellites. Relay and Telstar are representative of possible active communications satellites to be flown at low orbital altitudes where a system of several score satellites would be required to insure uninterrupted communication. Additional flights of these kinds of satellites will be required to establish the technological base for the extension of lifetimes that are now inhibited by particle damage from the great radiation belts.

We are now undertaking our first exploratory steps with communication satellites launched to the synchronous altitude of 23,000 miles where the dual advantages of small numbers of satellites and lower exposure to energetic particles may be realized. Our first Syncom satellite early this year failed for as yet unexplained reasons, although the actual launching appears to have been successful. We will continue with further launchings of this satellite, and are looking ahead to a consideration of a more advanced Syncom satellite configuration that would have greater channel capacity and antenna stabilization to reduce necessary power levels. Although the final configuration for an operational communication satellite is not yet clear, the eventual utilization of such satellites appears obvious.

As indicated previously the NASA program is not just represented by our many and varied flight projects for exploring and utilizing space. A less evident, less spectacular, but nonetheless equally important effort is underway to expand our technological capabilities for space activities of the future. Figure 1–12 suggests the scope of this effort.

In the area of propulsion we are developing the concepts and principles that will yield much more efficient propulsion systems for future space flights. We are not only looking to the improvement of chemical rocket propellants but, most importantly, are carrying out projects in cooperation with the Atomic Energy Commission that will give us nuclear propulsion in the future. We expect to utilize nuclear power for direct thermal cycles as well as for electric power sources for use with the more efficient electric propulsion system. In addition to searching for improved propulsion devices we are also seeking improved auxiliary power units for the generation of on-board power required in space flight.

Our space vehicle research covers the gamut of technologies for the improvement of future spacecraft. Structures, materials, electronics, and the multitude of disciplines to sustain, support, and enhance the capabilities of man are under investigation.

Finally, it should be noted that we are an aeronautics as well as a space agency. A vigorous well-rounded program continues to give this country an improved technological base for better, slow-speed aircraft having short takeoff and landing field characteristics, through the next generation supersonic transports, and on to possible hypersonic aircraft configurations of the future.

The world has already moved a long way into the space arena. It will move farther—much farther. The program of NASA described briefly herein, and which will be presented in greater detail in subsequent papers, is designed to forge a national capability that will achieve and insure a preeminent position for the United States in that arena.

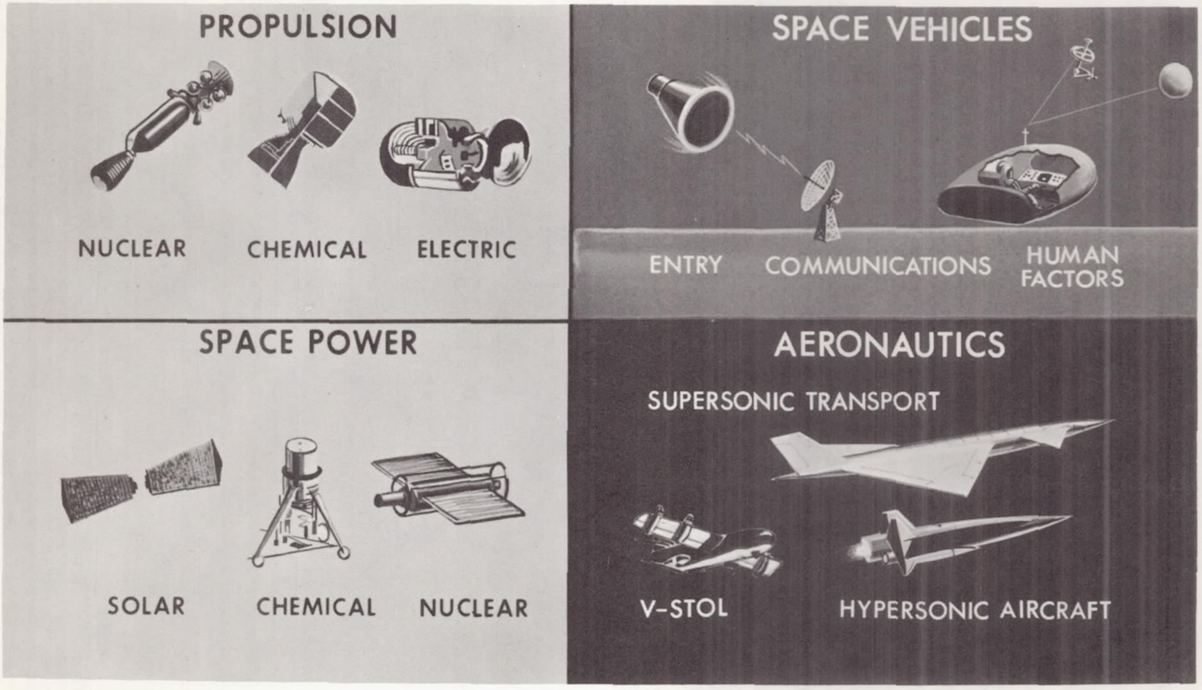


FIGURE 1–12.—Advanced research and technology.

2 Results of Scientific Research in Space

JOHN E. NAUGLE
Director, Geophysics and Astronomy Programs,
Office of Space Sciences, NASA

The National Aeronautics and Space Administration (NASA) was formed and given the mission of conducting this nation's space program on October 1, 1958. From October 1958 to the beginning of 1962, NASA successfully launched 14 scientific satellites and about 200 sounding rockets. Scientific experiments which increase our knowledge of nature are my definition of success. Note that I did not say our "knowledge of space." In many instances, the measurements did increase our knowledge of the region of space surrounding the Earth; however, in many other instances we learned more about the Earth itself, we learned more about the Sun, and in some cases we even learned some very new and some very fundamental facts about the distant stars. The scientific programs of NASA are a logical extension of the research work which has been underway in laboratories on the Earth since the time of Galileo. Just as astronomers once carried their telescopes to the top of a mountain to see better, now we carry telescopes beyond the Earth on rockets and satellites. By this method entirely new phenomena are observed and scientists are enabled to broaden their studies in certain scientific disciplines.

Since early 1962, NASA has successfully launched six scientific satellites in six attempts. This paper is a report on the results that are being received from these satellites. The following paper, by Oran W. Nicks, reports on the very interesting results from spacecraft which escape from the Earth and visit other bodies in the solar system. Details of future scientific spacecraft, are discussed in a subsequent paper by Edgar M. Cortright. Figure 2–1 shows some of the phenomena which can be studied with spacecraft which remain attached to the Earth. The use of satellites and sounding rockets to study the stars has already been mentioned. NASA is flying a solar observatory to study the solar radiation and the kind of light emitted during solar flares and how the intensity of that light varies

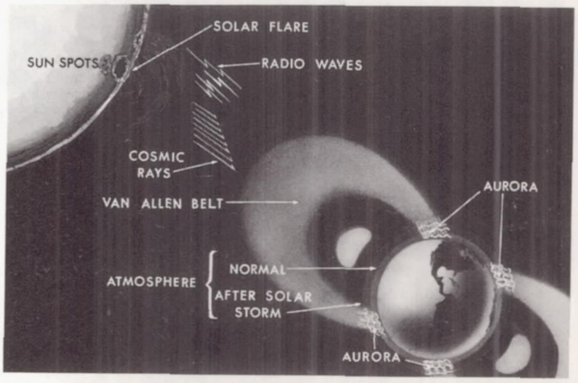


FIGURE 2–1.—Phenomena under study in the geophysics and astronomy program.

with time during a flare. Explorer satellites have been placed in highly eccentric orbits to study the magnetic field of the Earth, the radiation trapped in this field, and cosmic rays outside the influence of this field. Other Explorers have been placed in low-altitude orbits to study the atmosphere and the ionosphere of the Earth. The ionosphere is a layer of positively charged atoms and electrons which begins about 60 km above the surface of the Earth. This layer reflects radio waves and makes possible long-distance communications. The aurora is believed to be caused by trapped particles leaving the radiation belts and entering the atmosphere. Measurements of such electrons have been made on low-altitude polar-orbiting satellites and compared with simultaneous measurements out in the belt to determine whether this is indeed the mechanism. The propagation of plasmas outward from the Sun has also been studied by comparing measurements made on Explorers near the Earth but outside the influence of the Earth's magnetic field with similar measurements made on the Mariner spacecraft.

An attempt will be made to give a coherent picture here by first discussing the measurements that were made on the Sun, then moving from the Sun closer to the Earth to discuss the significant results on the magnetosphere, and finally discussing the measurements made on the atmosphere and ionosphere of the Earth.

TABLE 2–I.—*Successful Scientific Satellites Launched by NASA Since 1962*

Name	Purpose	Launch date
OSO I	Solar physics	Mar. 7, 1962
Ariel	Ionospheric physics.	Apr. 26, 1962
Alouette	Ionospheric physics.	Sept. 29, 1962
Explorer XIV.	Energetic particles and fields.	Oct. 2, 1962
Explorer XV.	Artificial belt	Oct. 27, 1962
Explorer XVII.	Atmospheric physics.	Apr. 2, 1963

Table 2–I shows the six scientific satellites that have been launched by NASA since the beginning of 1962. All six were successful, and we are very proud of this record. Much of it is due to the reliability of the Delta rocket, which was used to launch five of the six. Explorer XVII was the sixteenth straight success of the Delta. All of these satellites were under the overall management of the Goddard Space Flight Center. Two were a part of our international program. Alouette was designed and built in Canada, at their Defence Research and Telecommunications Establishment in Ottawa. Ariel is also a part of our international program. In this case, the experiments were provided by the United Kingdom and integrated into a spacecraft designed and built at the Goddard Space Flight Center. Both Ariel and Alouette were designed primarily to study ionospheric physics. The Orbiting Solar Observatory (OSO) is the first observatory-class satellite NASA has launched and was designed primarily for the study of solar physics.

Explorer XIV was placed in a highly eccentric orbit with an apogee of about 100,000 km. It is designed to continue the work of the highly successful Explorer XII launched in August 1961. Explorer XV is a special satellite which was launched just 60 days after work was started. It was designed specifically to study the artificial radiation belt. Explorer XVII was launched in April 1963 and is designed for the difficult job of measuring the properties of the very tenuous atmosphere above 250 km.

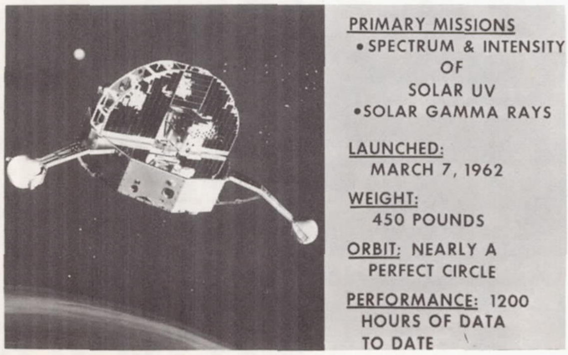
The objectives and significant results from each of these satellites will now be discussed. The Sun is the major source of energy in the solar system. It controls the environment in space as well as the weather on the Earth. Therefore, a discussion of solar physics and the results from OSO I will be given first, and then we will move into the magnetosphere of the Earth and look at the results from Explorers XIV and XV. We will see the effects of solar activity on the radiation belts and the geomagnetic field. Then we will return to the Earth to see what we have learned about the ionosphere from Alouette and Ariel. Finally, a brief discussion of atmospheric physics and Explorer XVII will be given.

SOLAR PHYSICS

The solar physics program has two major objectives. The first of these is to study and understand the Sun itself. We do not understand why the Sun has an 11-year sunspot cycle; nor do we understand what causes a solar flare. We do not know how the energetic particles, which create a radiation problem for Apollo, are accelerated to their high energies. We do not understand the processes which take place in the chromosphere of the Sun. All of these are problems associated with the Sun itself.

The second objective is to monitor continuously the radiation from the Sun. These data are needed by other scientists to understand the measurements they make on the atmosphere and ionosphere of the Earth, in interplanetary space, and on other planets.

OSO I, the first Orbiting Solar Observatory, has taken data which are pertinent to both objectives. By making continuous measurements of the ultraviolet light and soft X-rays emitted by the Sun, it has given data on the processes happening on the Sun. The effect of these radiations on the atmosphere and ionosphere can be understood by observing the fluctuations in the intensity of the radiation and correlating with ground and satellite observations of terrestrial phenomena. Figure 2–2 is a picture of OSO I. OSO I was launched on March 7, 1962, and is still in partial operation. It continues to point at the Sun but gives data only when it is near a receiving station. The tape recorders no longer function.



PRIMARY MISSIONS
- SPECTRUM & INTENSITY OF SOLAR UV
- SOLAR GAMMA RAYS

LAUNCHED: MARCH 7, 1962

WEIGHT: 450 POUNDS

ORBIT: NEARLY A PERFECT CIRCLE

PERFORMANCE: 1200 HOURS OF DATA TO DATE

FIGURE 2–2.—The first solar observatory.

The upper portion of the satellite, called the sail, points continuously at the Sun and carries the solar cells which provide the energy for the satellite. The bottom section, known as the wheel, rotates to provide stability. The batteries, telemetry, and experiments which need not be pointed continuously at the Sun are housed in this section.

One of the major experiments in the pointed section of OSO I was a spectrometer to study the solar spectrum of the Sun in the wavelength region from 50 to 400 Å. At the short-wavelength end of this region, 50 Å, are the soft X-rays. At the other end, 400 Å, is the ultraviolet light. All of this light is absorbed at extremely high altitudes in the Earth's atmosphere and is that portion of the solar spectrum which controls the properties of the upper layers of the Earth's ionosphere. This is an extremely difficult kind of light to work with. In the laboratory, all the equipment must be in a good vacuum. No lenses can be used, only mirrors. Even a minute amount of air will absorb the light.

In this experiment, a grazing incidence spectrometer was flown. This is a device which separates the radiation of different wavelengths somewhat as a prism separates the visible light into its various wavelengths or colors. The intensities of the light in the various wavelengths are measured and, indeed, are continuously monitored. This experiment gives us many clues about the properties of the chromosphere and the corona of the Sun. Certain intense lines are observed. These lines enable the scientists to tell what atoms are present in the solar atmosphere. The intensities of these lines vary during a solar flare, the amount of variation depending upon the altitude in the solar atmosphere at which it originates. In general, the lines produced at the higher altitudes show the larger increase in intensity. There is a particularly intense and interesting line in the solar spectrum, known as the Lyman Alpha line, emitted by the hydrogen in the Sun. Measurements on OSO I showed that the line brightened by some 5 to 7 percent during a flare.

Another major experiment on OSO I was to measure the intensity of X-rays in the 1 to 8 Å region. It was possible to observe the X-ray emission from very weak flares and in some cases to observe X-rays from flares which were not observed visually on the ground. The X-ray flux was continuously monitored at all times the Sun was visible to the satellite. Thus, it was possible to observe the behavior of the X-ray flux from a flare during the entire lifetime of the flare.

Continuous monitoring of the X-ray flux on the Sun is very important. Figure 2–3 shows how fast a flare occurs on the Sun. Most of the X-rays occur in the very earliest phase of a flare. The only way we have found to study such X-rays in the past has been to fire a a rocket as soon as a flare is detected by an observer on the ground. This takes several minutes, and much of the phenomena of interest may be missed.

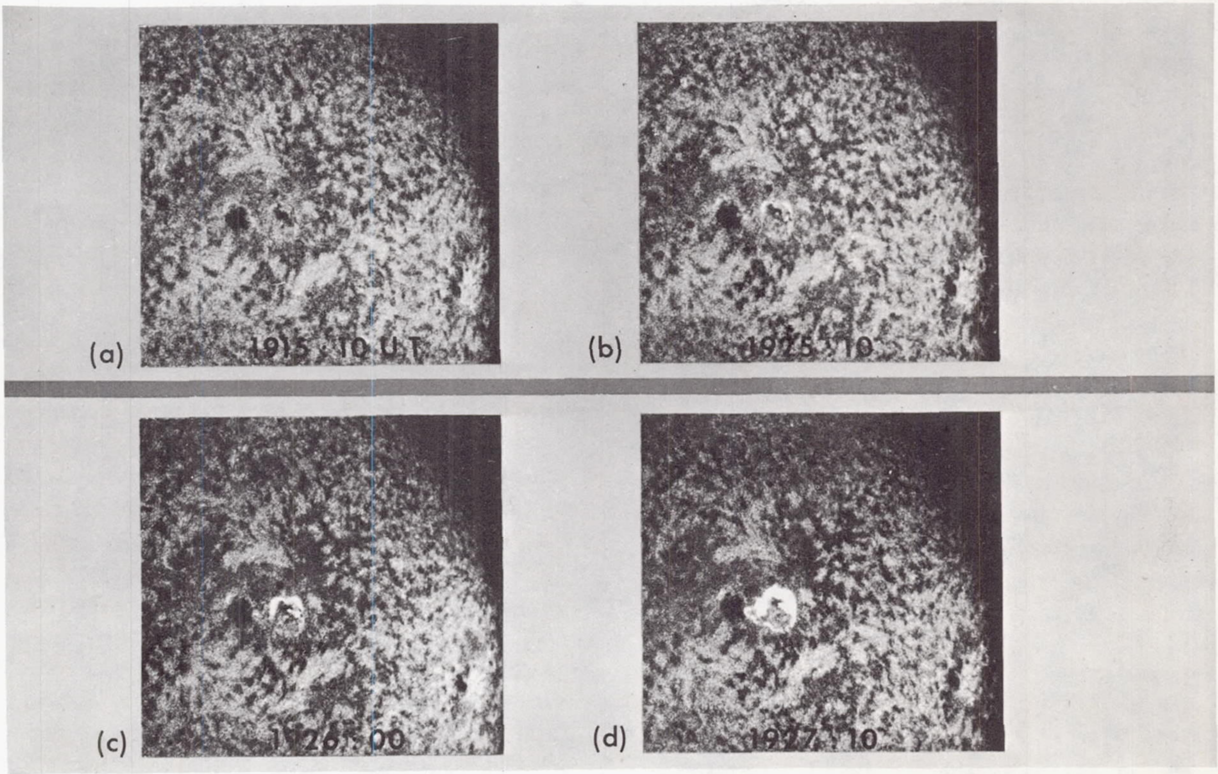


FIGURE 2–3.—Explosive flare, August 11, 1960. (a) 1915 : 10 U.T.; (b) 1925 : 10; (c) 1926 : 00; (d) 1927 : 10

The first OSO was designed to measure the radiation of the entire Sun over a broad wavelength region which is inaccessible to measurement by solar observatories on the Earth, and in this task it has been exceptionally successful. However, OSO I could not pick out a small region on the Sun, such as the flare seen in figure 2–3, and study the radiation coming from it. All the solar-flare measurements have been made by detecting the radiation coming from a small region, like this, against the background of radiation coming from the whole Sun.

The next OSO will not remain pointed at the center of the Sun as OSO I did. It will scan back and forth across the Sun, thereby making it possible to measure the radiation which comes from a particular region such as a flare.

MAGNETOSPHERE PHYSICS

The region of space around the Earth which is controlled by the magnetic field of the Earth—the so-called magnetosphere—will be discussed next. This is the region of the Van Allen belt, magnetic storms, and the artificial radiation belt. The shape of the magnetosphere is determined by a plasma which streams out continuously from the Sun—the "solar wind." Figure 2–4 shows a theoretical physicist's conception of the shape of the magnetosphere of the Earth. It is compressed on the side facing the Sun and pulled out on the back side of the Earth.

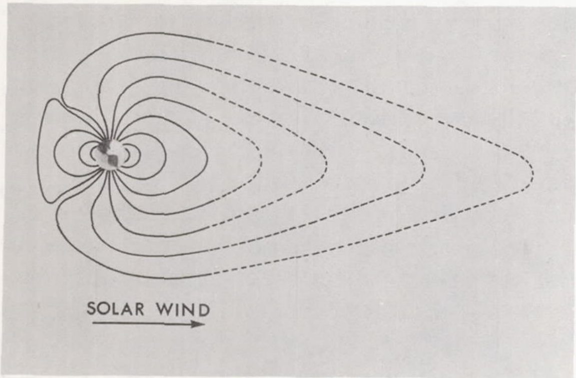
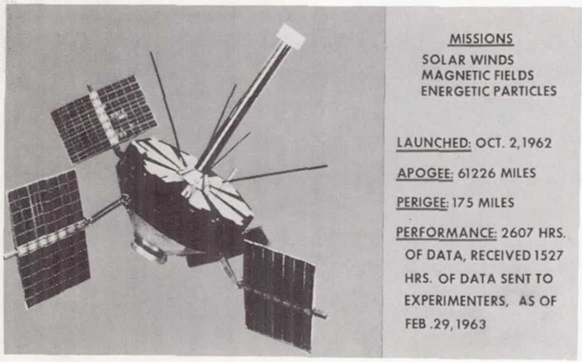


FIGURE 2–4.—Shape of magnetosphere.

NASA launched Explorer XIV during 1962 to study the magnetosphere in a continuation of the work of Explorer XII, which was launched in 1961. Explorer XIV (shown in fig. 2–5) was designed specifically to study the fields and particles in space. The long boom contains a magnetometer. In order to measure the weak magnetic fields in space, it is necessary to place the magnetometer as far as possible from the spacecraft to avoid the effect of stray magnetic fields produced by other equipment. In addition to a magnetometer, Explorer XIV carried a plasma probe and several experiments to measure the flux of energetic particles and cosmic rays. In order to obtain a clear picture of the magnetic field and the particular flux, it is necessary to measure on the same spacecraft and at the same time the plasma flux, the magnetic field, and the energetic particles.



MISSIONS
SOLAR WINDS
MAGNETIC FIELDS
ENERGETIC PARTICLES

LAUNCHED: OCT. 2,1962

APOGEE: 61226 MILES

PERIGEE: 175 MILES

PERFORMANCE: 2607 HRS. OF DATA, RECEIVED 1527 HRS. OF DATA SENT TO EXPERIMENTERS, AS OF FEB .29,1963

FIGURE 2–5.—Explorer XIV.

Figure 2–6 shows one of the reasons why it is necessary to launch two similar satellites in close succession. The dashed lines represent the boundary of the magnetosphere which was shown in figure 2–4. The solid ellipses represent the orbit of Explorer XIV. Its orientation remains fixed in space. As the Earth moves around the Sun, the solar wind blows the magnetosphere of the Earth radially outward from the Sun. Therefore, as time passes and the Earth moves about the Sun, the magnetosphere rotates about the trajectory of Explorer XIV and makes possible the plotting out of the magnetic field and particle fluxes in the entire magnetosphere, provided Explorer XIV lives for a year. Explorer XII lived only about 3 months and covered only the region from D to A.

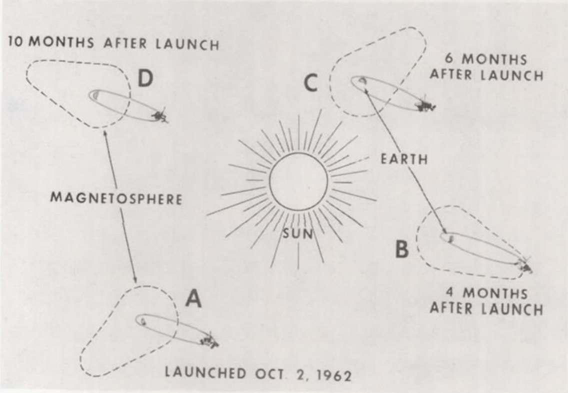


FIGURE 2–6.—Explorer XIV mission.

Figure 2–7 illustrates some of the results which have been obtained from the two Explorers XII and XIV. It has been shown that the magnetosphere has a sharp boundary on the sunlit side at about 10 Earth radii. This boundary, which is some tens of kilometers thick, moves in and out depending upon the density and velocity of the solar wind pressing on it. Inside the boundary there is a high density of trapped particles and the magnetic field is characteristic of a dipole field. Its strength and direction is consistent with that predicted by

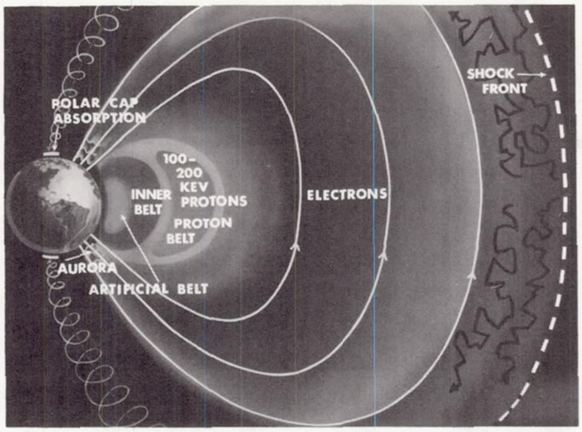


FIGURE 2–7.—Magnetosphere.

the strength and direction of the dipole field of the Earth as deduced from surface measurements. Beyond the boundary the trapped particles vanish and the direction and magnitude of the magnetic field change abruptly and fluctuate with time. Beyond the boundary, there appears to be a turbulent region where the low-energy particles of the solar wind are stopped. This region may actually be a kind of "shock front."

The apogees of Explorers XII and XIV were not high enough to insure that any measurements were actually made in true interplanetary space beyond this turbulent region. Therefore, we as yet do not know how thick it is.

Explorer XIV and Mariner II were both operative at the same time and both carried plasma probes, magnetometers, and energetic-particle detectors. This made possible simultaneous measurements of the solar plasma and magnetic fields in interplanetary space, together with measurements of the behavior of the Earth's field. Thus, it was possible to measure quantitatively the plasma flux and study its influence on the magnetic field of the Earth.

One of the most interesting results from Explorer XII was the detection of a belt of low-energy protons at about 3.5 Earth radii from the surface of the Earth. The population of this belt varies with time and is correlated with fluctuations in the solar plasma and in the geomagnetic field. The origin of these particles is a mystery. They are too numerous and of the wrong energy to be due to the neutron decay which produces the more energetic protons discovered by Van Allen.

Although the apogees of Explorers XII and XIV were not high enough to insure measurements of the true interplanetary environment, they were high enough to insure that all the particles emitted by the Sun during a flare could be measured. The flux, energy spectrum, and angular distribution of particles emitted during solar fluxes have been studied as a function of time. These measurements not only tell us what the radiation levels in space are during a flare, but also give us some indication about the configuration of the magnetic fields between the Earth and the Sun. Since these particles come from the Sun, they are used to tell us what the composition of the Sun is.

The combined data from satellites, sounding rockets, balloons, and ground instruments have shown that solar protons from a large solar flare could give an unprotected man in space, outside the magnetosphere, a lethal dose of radiation. Such a large solar flare occurs about once a year during periods of maximum solar activity. During periods of solar minimum, such as we are in now and will be in until about 1967 when solar activity begins to increase again, the frequency of such events is much lower. These same measurements have shown that the time dependence and energy spectrum are such that sufficient shielding can be carried on an Apollo spacecraft to reduce this dosage to a tolerable level. This information does not mean, however, that we can or will relax our efforts to understand solar flares or to know what the conditions are in interplanetary space during the time of an Apollo mission. There are times when the astronaut may be outside a spacecraft, on the Moon, with very little protection. At such times we will want to observe the activity on the Sun very closely and to know very precisely what the configuration of the interplanetary magnetic field is in order to warn the astronaut as early as possible of a potential increase in the radiation level.

The Starfish explosion on July 9, 1962, produced the artificial radiation belt shown in figure 2–7. At the time of that test, there were only three satellites in the air which could measure the radiation. These were Ariel, Injun, and Traac. Traac went dead very shortly and Ariel began to malfunction, in both cases because of radiation damage to their solar-cell power supplies. Telstar was launched the day after the test. None of these satellites carried instrumentation designed to study electrons of the energy produced in the Starfish test.

In order to obtain badly needed information on the flux, energy spectrum, and spatial distribution of the Starfish electrons, we decided to launch a satellite with experiments designed specifically to study them. The Goddard Space Flight Center started work on this project early in September 1962 and launched the Explorer XV 60 days later. This satellite was designed to be despun after injection into orbit. The despin mechanism failed. Although the high spin rate eliminated the measurements of the angular distributions of the particles, it was possible to get extremely accurate flux and spectrum measurements of the trapped radiations. These measurements, together with the early measurements made with Injun and Telstar, show that the heart of the artificial belt is at about 1.25 Earth radii and that at that altitude the belt will be detectable for a number of years. At both higher and lower altitudes the intensity is decreasing faster than it is at the heart of the belt. It decreases faster at low altitudes because the atmosphere is more dense there and absorbs the particles faster. The exact mechanism by which the particles are lost at the higher altitudes is not known.

IONOSPHERIC PHYSICS

Ariel and Alouette, the two satellites where objectives were primarily to study the ionosphere of the Earth, will be discussed next. Ionosphere physicists are interested in the density and temperature of the electrons and ions that make up the ionosphere. They are also interested in the radiation which produces this ionization.

Three main techniques are used to study the ionosphere. The electron density can be measured by placing a detector at a particular point in space to measure directly the number of electrons in a given volume. Such a detector can also be used to measure the temperature or energy of the electrons. In the second technique, the attenuation of a radio signal from a satellite is measured on the ground. This attenuation gives the total number of electrons between the satellite and the ground station. The third method involves "sounding" the topside of the ionosphere. Scientists have been sounding the bottom side of the ionosphere for years by sending a radio signal vertically upward and measuring the length of time required for the echo to return. Signals of a particular frequency will be reflected at an altitude where the electron density is a particular value. Therefore, if radio signals of various frequencies are sent up and the time delay for each frequency is measured, the variation of electron density with altitude can be plotted.

Figure 2–8 illustrates the sounding of the ionosphere from both top and bottom and also shows why we need a Topside Sounder satellite. The region of high electron density is represented by the darkest area on the graph. Radio signals of higher frequency are reflected at regions of higher electron density until at a certain critical frequency the ionosphere becomes transparent and the wave is no longer reflected by the ionosphere. Thus, with a ground-based sounder it is possible to study the nature of the bottom side of the ionosphere but nothing can be studied about the topside of the ionosphere.

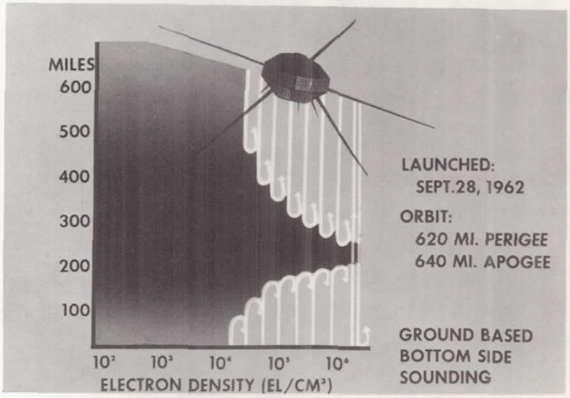


FIGURE 2–8.—Alouette (Canadian topside sounder).

The Canadian satellite Alouette was designed to study the topside of the ionosphere. This satellite has worked perfectly so far. It has already produced more than 200,000 ionograms or profiles of the electron density in the topside of the ionosphere. In addition to performing this function, the data from Alouette can also be used to measure the magnetic field at the position of the satellite; this is an unexpected dividend which may be valuable for magnetic surveys.

Figure 2–9 shows Ariel, the first international satellite. This satellite carried two experiments to measure the electron density of the satellite environment and experiments to measure the electron temperature, the mass of the ions in the ionosphere, the solar radiation responsible for producing the ionization in the atmosphere, and cosmic rays.

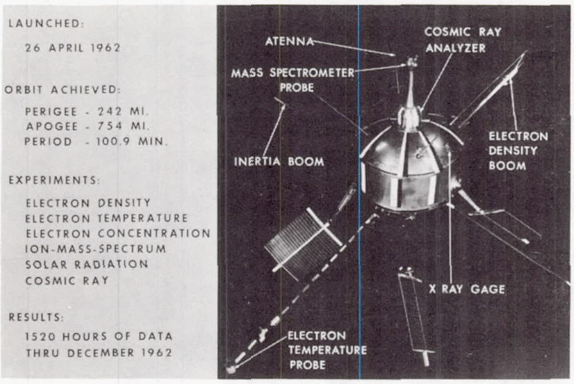


FIGURE 2–9.—Ariel (international ionosphere satellite, U.S.–U.K.).

Ariel has produced a number of significant results. The contributions which the cosmic-ray experiment made to the study of the artificial radiation belt have already been mentioned. Another interesting and significant result from Ariel has been the discovery that the picture of the ionosphere shown in figure 2–8 is really not too good. The electron density on the topside of the ionosphere does not decrease smoothly in going to higher altitudes. There is a further stratification of the electron density above the maximum. Furthermore, these layers appear to be alined along magnetic lines of force in a manner somewhat analogous to the higher energy trapped radiation.

ATMOSPHERIC PHYSICS

Explorer XVII, launched April 2, 1963, was the first satellite designed to study the temperature, pressure, density, and composition of the atmosphere. At this time all that can be reported is that Explorer XVII is working perfectly. Twenty hours of data have been collected already and the experimenters are analyzing it.

CONCLUDING REMARKS

It should be clear from this report that NASA has now evolved to the point where small explorer and monitor satellites can be launched with a high degree of success. The Delta rocket has performed successfully on the last 16 launch attempts. The last six scientific satellites have also been successful. A great deal of very interesting and very significant data is being obtained.

In addition, in the successful launch and performance of OSO I, we have entered a new phase of more complex spacecraft capable of precise orientation over long periods of time. These more complex spacecraft, the Orbiting Astronomical Observatory and the Orbiting Geophysical Observatory, will be discussed in the paper by Edgar M. Cortright. In addition to obtaining exploratory data from these small explorer satellites, scientists have obtained the data required to design instrumentation to make maximum use of these large stabilized spacecraft as they become available.

3 Space Sciences—Lunar and Planetary Exploration

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Office of Space Sciences, NASA

Flights to the Moon and neighboring planets are being discussed today on a relatively common-place basis. At times it appears to those of us engaged directly in these efforts that man has accepted this challenge without full realization of the exciting possibilities it affords for advancing our state of knowledge. There are also times when it appears that the magnitude of the tasks may have been underestimated, for there are some 9 planets, 31 moons, asteroids, comets, and a star (our Sun), which are obviously within our capabilities to explore in the near future. In the 6 brief years the United States has been engaged in space activities, space flights to explore three of these planets, the Sun, and one moon have already begun—some 10 percent of all the major bodies known to be in our solar system. Thus, statistics lead us to believe that our nation is not doing too badly.

As indicated in figure 3–1, initially the concentration is on the Earth, its Moon, the Sun, Venus, and Mars. Of course, NASA is placing major emphasis on our favorite planet, Earth, with an entire program devoted to its study, as indicated in the previous paper by John E. Naugle. It is therefore excluded from our lunar and planetary program and further consideration in this paper.

This presentation will outline briefly some of the early answers being sought in our exploration. It is almost a certainty, however, that the surprises encountered in this program will offer more rewarding returns than the answers sought. Scientific accomplishments are the major aims of the programs to be described, but emphasis is also being placed on advancing the technology essential to paving the way for greater events, including manned ventures to the Moon and planets.

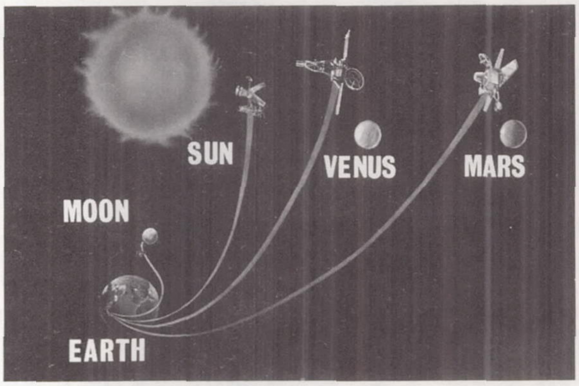

FIGURE 3–1.—Areas to be explored.

Figure 3–2 presents the names of the lunar and planetary projects which will be discussed in more detail and indicates the time-phasing of the current programs. Note that three projects comprise the current lunar program. The first of these is the Ranger project, which has resulted in three launches toward the Moon, two of which flew by the Moon, and one of which impacted on the lunar surface. Ranger flights are to be conducted through 1964 and are being considered for a later period.

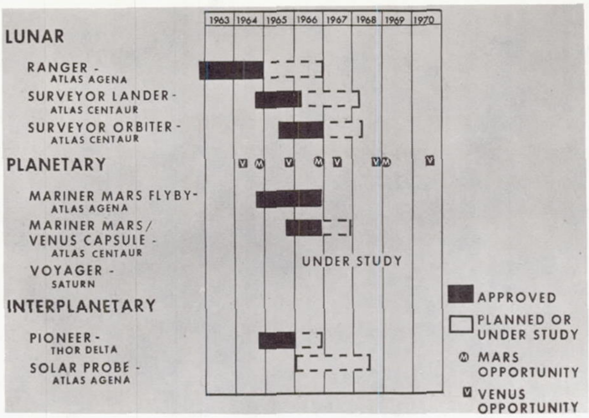

FIGURE 3–2.—Lunar and planetary flight schedule.

The surveyor project consists of complementary soft-landing spacecraft and orbiting spacecraft which will become lunar satellites. Early flights are scheduled to begin late in 1964 and are expected to continue for several years. Before the end of this decade, man will personally begin to explore the Moon. It is anticipated, however, that unmanned missions may be continued after initial manned landings in order to explore those regions of scientific interest that are not readily accessible to man.

Our first planetary mission was the Venus flyby of Mariner II on December 14, 1962. Mariner II performed exceedingly well and large quantities of significant scientific data were obtained. Similar spacecraft are being prepared for missions to Mars. The small letters "v" and "m" shown in figure 3–2 indicate the times when Venus and Mars are in the proper relationships with respect to the Earth and the Sun to make it feasible for launching spacecraft to those planets. The frequency of these opportunities for Venus and Mars are about 19 and 26 months, respectively. This constraint of nature figures importantly in planning planetary missions to Mars and Venus. First United States flights to Mars are scheduled for 1964 and are planned again for 1966.

The next evolutionary steps in planetary exploration are planned to begin in 1965 or 1966 with larger Mariner spacecraft. Mariner Mars and Venus spacecraft are planned for planetary missions extending at least through 1967. The Voyager project is being considered for possible orbiter and lander missions to both Mars and Venus using the Saturn-class of launch vehicles. It is not, however, an approved flight development project at this time.

The phenomena occurring within interplanetary space are of great interest to scientists and to engineers designing unmanned and manned spacecraft. Most planetary spacecraft, such as Mariner II, will be instrumented to measure scientific phenomena in interplanetary space on their long journeys to the planets. However, it is necessary to augment their interplanetary results with data from specially designed interplanetary monitoring spacecraft. The relatively simple Pioneer spacecraft is scheduled for flight at the beginning of 1964 during the International Quiet Sun Year.

Finally, studies are being conducted on a solar probe which might travel to within about 30 million miles of the Sun and other missions, which will be mentioned later, are also under study.

Some of the questions of major concern with respect to the Moon are indicated in figure 3–3. Looking ahead to the era of manned lunar missions, we are, of course, concerned with many of these questions from a practical standpoint. All the questions, however, are extremely significant from a scientific viewpoint and the answers will help to satisfy man's undying curiosity about the nature and origin of the Moon, perhaps the Earth, and maybe even the solar system. Also indicated in figure 3–3 are areas of the near side of the Moon where early Rangers may land, the design capability of early Surveyors, and a schematic illustration of the manner in which the lunar satellite may provide direct observations from lunar orbit.

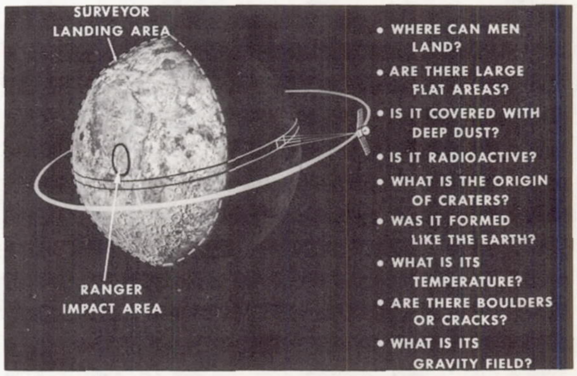

FIGURE 3–3.—Lunar exploration.

Advancing scientific capabilities have continually improved man's opportunity to further his knowledge of the Moon by Earth-based means, such as improved telescopes and large radars. The advancement of space science, although heavily dependent on space flights, would be trivial if man neglected to extend his knowledge of space science by every means possible. Early space flights have clearly proved that a small amount of flight data often opens the doors for a tremendous amount of Earth-based research. NASA is, therefore, supporting concurrently with its flight programs a proportionate program in Earth-based scientific studies. Two examples of Earth-based space science efforts are presented to illustrate these NASA-sponsored activities.

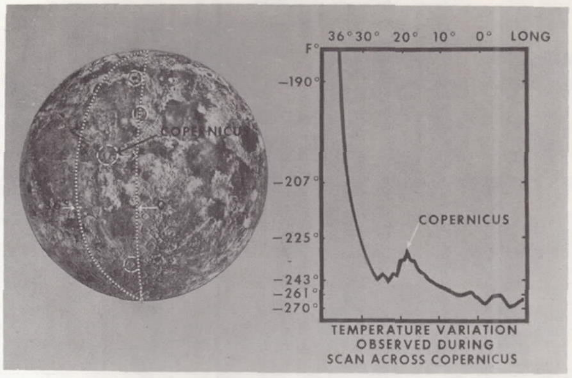

FIGURE 3–4.—Hot spots on the Moon.

Figure 3–4 shows a picture of the Moon and traces of scans made with a large telescope and an infrared sensor by Dr. Bruce Murray of California Institute of Technology. His observations noted that after the "Sun went down" on regions of the Moon, certain areas remained hotter than others for periods of time. These data provided the basis for speculation that the hotter areas must be composed of either rock formations with high heat capacity so that they cool slowly or of some other unusual material which emits heat at a much lower rate than most of the lunar material.

It has been possible by using pictures already available of the Moon's surface and by direct telescopic observations to make detailed geological studies of particular areas. An example of this type of work which is being sponsored by NASA and conducted at the United States Geological Survey is shown in figure 3–5. The up-

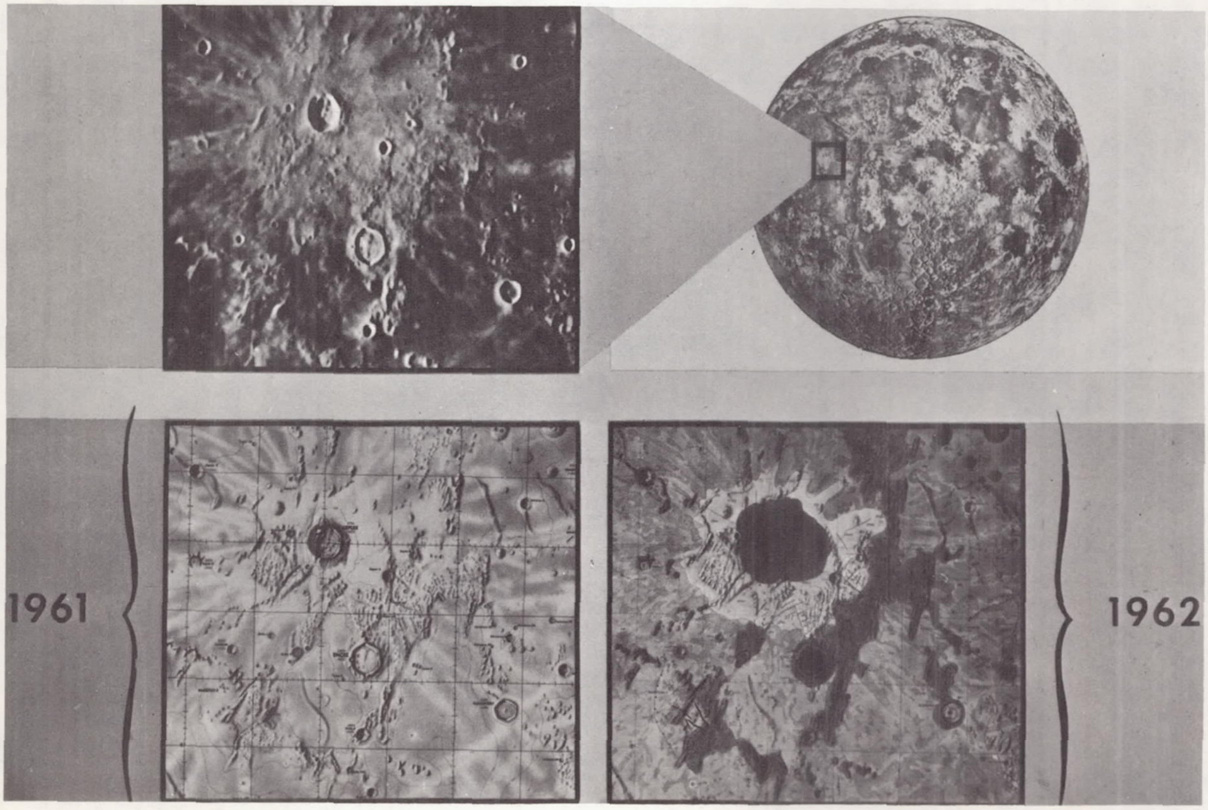

FIGURE 3–5.—Lunar geology.

per picture presents a photograph of a small area of the Moon, the lower lefthand picture is a topographic map made from such pictures, and the picture at the right is an example of a geological map giving not only contour information but also using colors to identify the different types of terrain on the lunar surface. This mapping program is being extended to cover a large portion of the Moon in a region of interest for early Apollo landings.

The best pictures available today from Earth-based telescopes provide a resolution of approximately two-thirds of a mile on the lunar surface. With spacecraft, it is planned that real closeup looks can be obtained. The United States' first spacecraft with this capability is the Ranger which has been designed to carry different mission payloads as indicated in figure 3–6. The interplanetary payload shown at the left was launched on the first two Ranger shots. The three lunar missions already carried out, but not entirely successfully, attempted to land lunar capsules of the type shown. The next series of Ranger flights, to begin late this year, will carry a payload of 6 television cameras intended to obtain a series of high-resolution photographs during the Ranger final approach to the Moon.

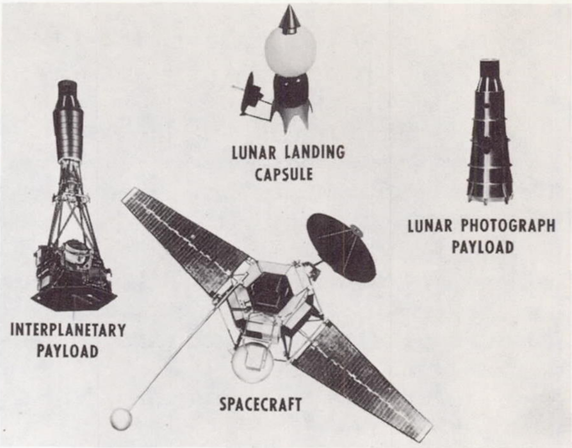

FIGURE 3–6.—Mission payloads of Ranger spacecraft.

Figure 3–7 illustrates the type of data expected from this series of Ranger missions. Approximately 3,250 pictures are to be transmitted to Earth during the final descent, the

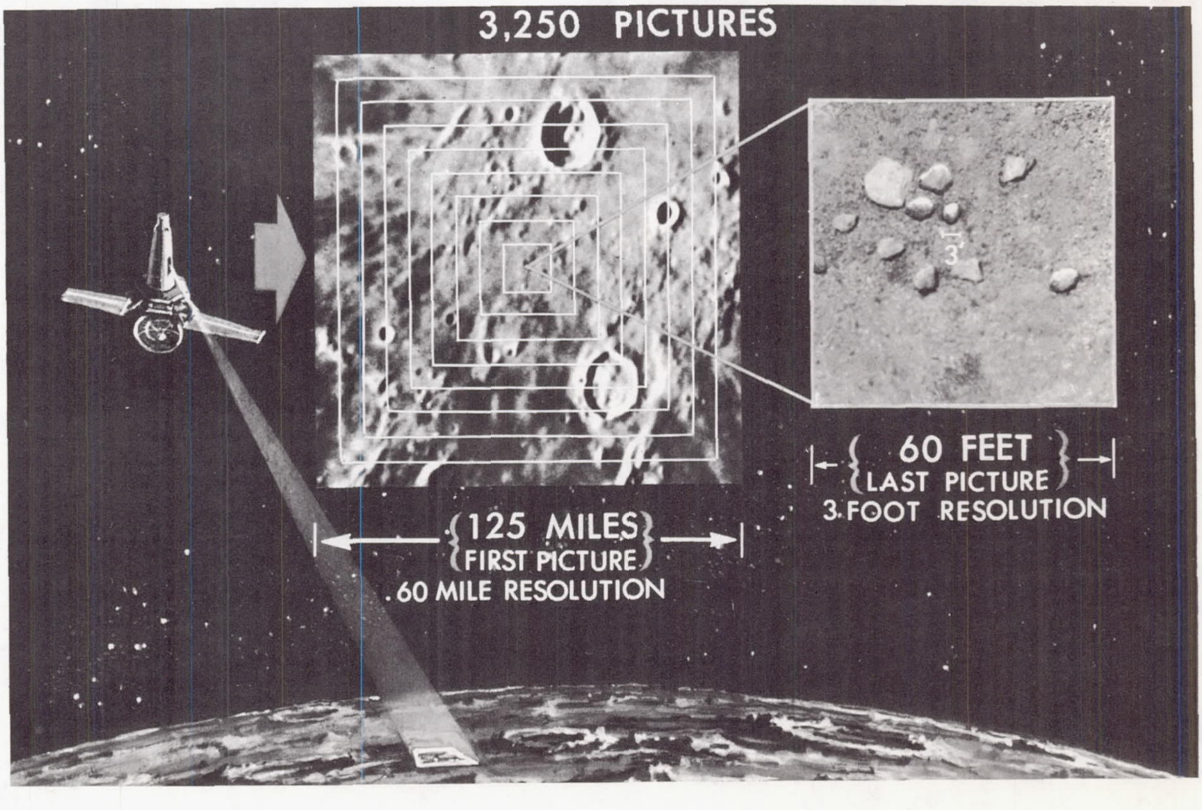

FIGURE 3–7.—Television photographs from Ranger.

first pictures covering an area of 125 miles on a side, the last picture providing high-resolution coverage of an area only 60 feet square. These closeup photographs are expected to greatly increase our knowledge of the surface detail and texture of the Moon.

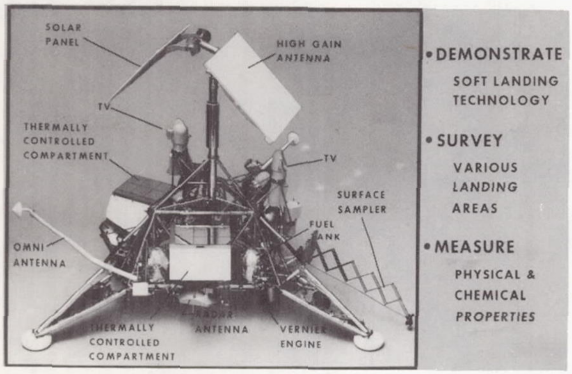

FIGURE 3–8.—Surveyor spacecraft.

The second evolutionary step in lunar exploration is to be carried out by the Surveyor landing spacecraft. (See fig. 3–8.) It is intended to demonstrate the soft-landing technology vital to future programs, is expected to survey various areas where it lands, and is to measure the physical and chemical properties in the vicinity of its landing. The Surveyor spacecraft has the capability of carrying various combinations of experiments, such as multiple cameras and the surface sampler indicated.

Some of the Surveyor instruments are shown in figure 3–9. The surface sampler is merely a pantograph on an extendable arm with a scoop on the end. This scoop will be actuated on commands from the Earth and can be watched on Earth with the television aboard the spacecraft. By scratching the surface of the Moon in much the same way a man might with his hand and by measuring the forces on the instrument, useful information can be obtained on the nature of the soil. This instrument also picks up soil samples and sets them aside for chemical analysis. The bevameter is an instrument to determine the compressive and shear strength of the surface, two important

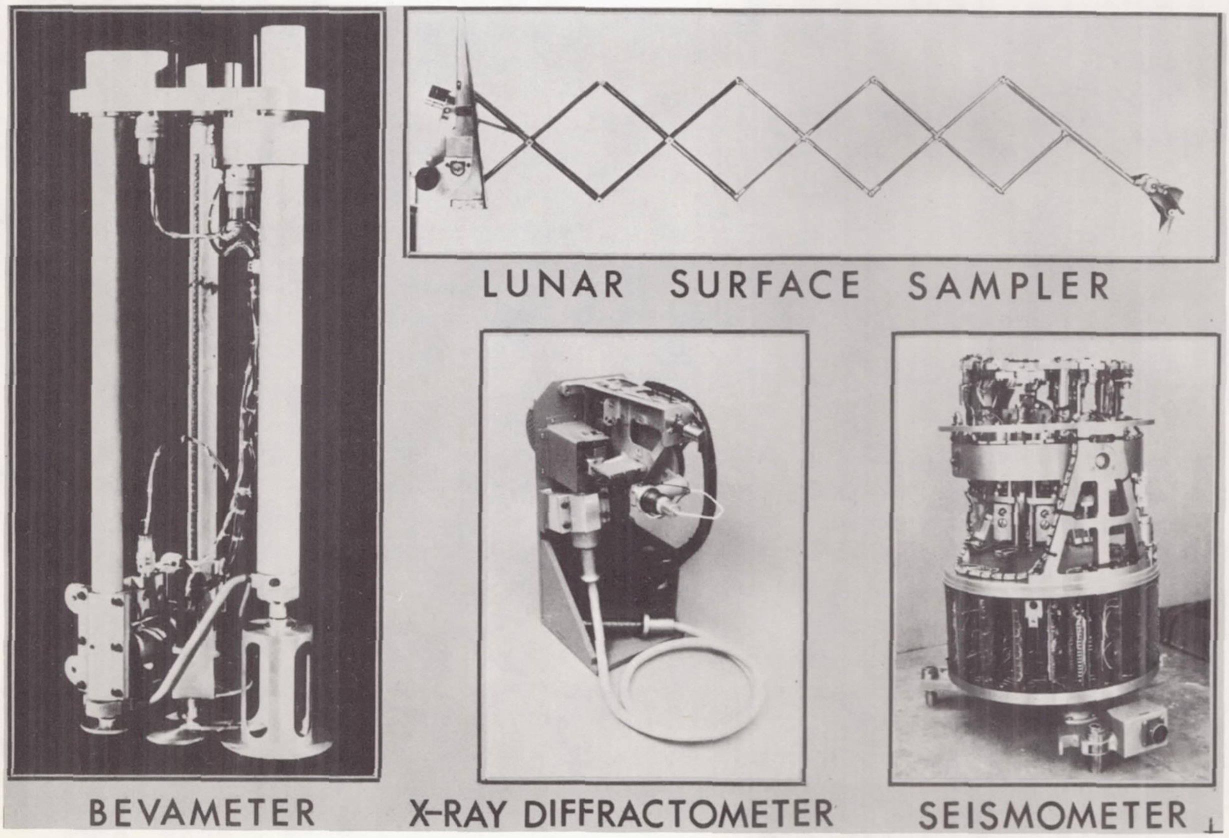

FIGURE 3–9.—Surveyor instruments.

factors in the design of landing gear. The X-ray diffractometer is an example of adapting a well-known laboratory technique used for performing chemical analysis. By extreme miniaturization, a large bulky set of equipment has been made into a lightweight spacecraft instrument. It will determine something about the structure and constituents of the lunar surface. The seismometer developed for the Surveyor is an extremely sensitive, lightweight "cousin" of instruments currently in use to record earthquakes or to aid in geological exploration on the Earth. These experiments are merely examples of several types under development for Surveyor landing missions.

In the same way that Earth satellites offer an excellent capability for study of the Earth, a lunar satellite will enable a gross examination of the Moon. (See fig. 3–10.) With photographic equipment, lunar orbiters should be able to survey large areas and complement the local terrain coverage of a Surveyor lander to permit further extrapolation of the data obtained at a single landing point. The orbiter can also carry monitoring equipment for surveying the environment in the vicinity of the Moon and, of course, affords the best opportunity for a good look at the Moon's mysterious backside. The complementary results of the orbiter and the Surveyor lander are expected to expand greatly the capabilities for scientific discoveries by unmanned spacecraft.

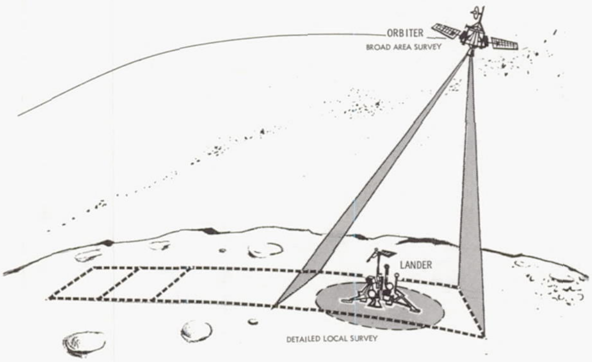

FIGURE 3–10.—Surveyor lander and orbiter team.

In regard to the planets, figure 3–11 indicates the evolutionary steps which are underway. The first type of mission, the close flyby and observation of a planet, was accomplished by the Mariner II when it approached Venus. This same technique is to be applied in 1964 to observe Mars at close range. The next step, when the larger Centaur launch vehicle is available in the 1965–66 time period, is to be accomplished with a spacecraft which will fly by and eject a capsule which will enter the planetary atmosphere and make measurements during its descent and after touchdown on the surface. The spacecraft which delivers the capsule will fly past the planet, make its observations, and continue on into orbit around the Sun, as did the Mariner II. The third step illustrated, which will be possible with the Saturn-class vehicle, will accommodate the landing of a capsule and will allow the spacecraft to contain a rocket of sufficient size to effect an orbit of the planet. This rocket will extend the operating lifetime and observational capabilities of a particular spacecraft in the vicinity of the planet and will enable the desired combination of orbiter and lander as described earlier for the lunar missions.

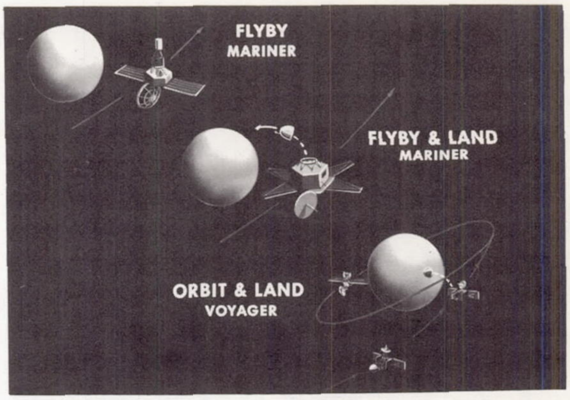

FIGURE 3–11.—Steps in planetary exploration.

The Mariner II, as man's first successful attempt to launch a spacecraft to the vicinity of a neighboring planet, is worthy of some discussion. As illustrated in figure 3–12, Mariner II was launched on August 27, 1962, and flew by Venus 109 days later on December 14. The spacecraft weighed only 447 pounds and carried 41 pounds of instruments. These instruments were roughly divided into two categories, those which made continuous measurements of the interplanetary medium during the flight and in the vicinity of the planet, and those specifically oriented to make direct observations of

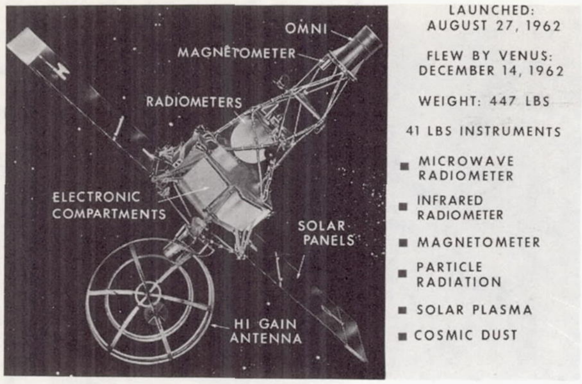

FIGURE 3–12.—Mariner II spacecraft.

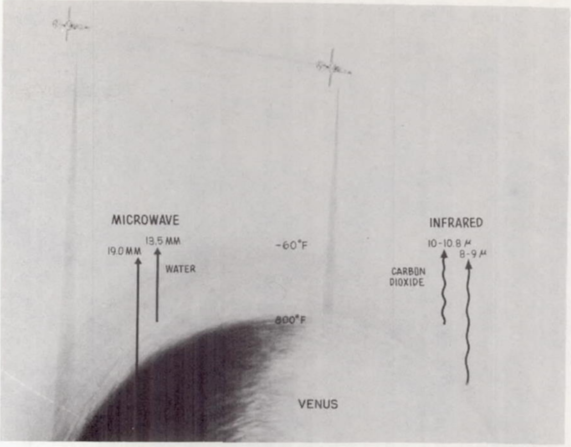

FIGURE 3–13.—Mariner II radiometric experiments.

the planet surface and atmosphere during the close approach. Some 65 million bits of data were received from the Mariner II during the course of its journey and, although much has already been learned from a study of the information returned, analysis will continue for an indeterminable period of time before the last shred of information is gleaned from the Mariner II measurements.

Mariner II results indicated that Venus is covered by cold dense clouds in the upper atmosphere. It has surface temperatures calculated to be 800° F. It has an unexplained cold spot in the Southern Hemisphere. The temperatures on the surface are essentially the same on both the dark and Sun-lighted portions of the planet. It does not have the high density electronic ionosphere that some scientists had speculated existed, and the amount of carbon dioxide in the atmosphere above the cloud layer is too small to be detected by the Mariner II instruments. This information was obtained from direct scans of the planet by microwave and infrared radiometers during a 35-minute period on December 14, 1962.

The mircowave radiometer scanned the surface of Venus at two wavelengths and detected emissions from Venus at 13.5 and 19 millimeters. Figure 3–13 illustrates these radiometric experiments. In the electromagnetic spectrum, 13.5 millimeters is the location of a microwave water-absorption band. If water were present in the atmosphere of Venus above certain minimal levels, the readings from this instrument would have been able to detect it. Although complete analysis has not been made of the 13.5 mm data, it does not appear that there is appreciable water vapor in the Venus atmosphere.

The 19-millimeter readings were of principal interest because they provided an indication of the surface temperature. It is on the basis of these data that it is believed that a fairly uniform temperature of about 800° F. exists all over the surface of the planet in the dark as well as in the Sun-lighted regions.

The infrared radiometer was designed to measure infrared radiations from Venus in two wavelength regions. One wavelength band was centered at a 10.4-micron carbon dioxide band, and the other at an infrared "window" of about 8.4 microns. Interpretation of the results from the infrared radiometers is that the thick clouds surroundng Venus are fairly contiguous and do not have breaks in them like the clouds on Earth. These measurements also indicated that there was not enough atmosphere above the clouds for appreciable absorption to occur by carbon dioxide. The cloud temperatures as measured appeared to be on the average of −30° F. at a level within the cloud layer.

Figure 3–14 illustrates the elements of interplanetary space which were sampled on the way to Venus and in its vicinity. Based largely on findings from satellites and probes, it has been determined that the magnetic fields and plasma in the vicinity of the Earth are as represented. Because of the known similarities between Earth and Venus, it was anticipated that similar indi-

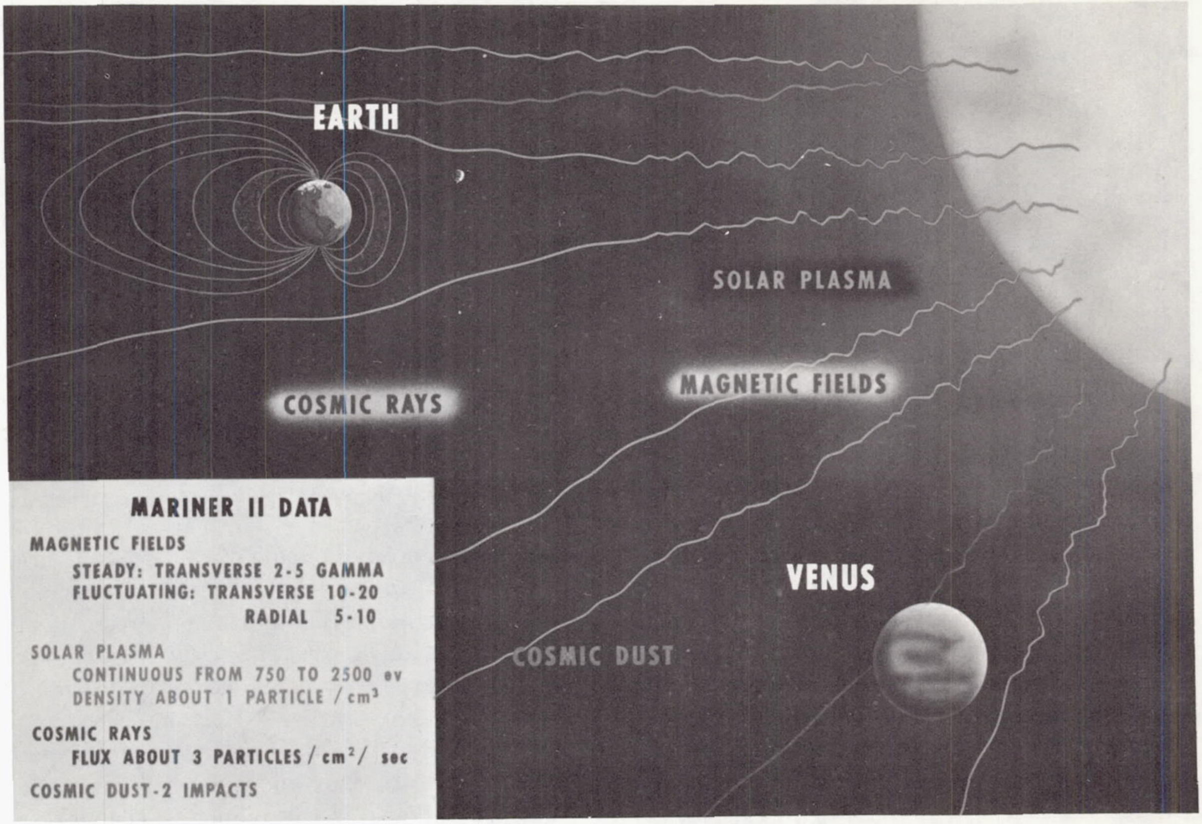

FIGURE 3–14.—Interplanetary findings.

cations might be found for the fields in the vicinity of Venus. However, no change in the interplanetary magnetic field was measured in the vicinity of Venus, and no detection of plasma-flow effects due to the planet was encountered.

Radiation experiments did not record any radiation belts in the vicinity of Venus such as exist around the Earth. The absence of trapped particles, an unmeasurable magnetic field, and the plasma conditions correlate to confirm some theories and to eliminate others. On the basis of data obtained by radar measurement and the Mariner II, it is believed that Venus may be rotating extremely slowly on its axis, if at all.

Much knowledge of the interplanetary environment between Earth and Venus was obtained by Mariner II. Several magnetic storms were recorded by Mariner and the data obtained were correlated with measurements on Earth. During these magnetic storms, plasma flow from the direction of the Sun was found to be variable and correlated with the magnetic-field changes. Micrometeorite detectors to sample the cosmic dust in interplanetary space recorded only two hits on the way to Venus. When compared with near Earth data, these measurements indicate that the number of particles in the vicinity of Earth is about 10,000 times greater than that found by Mariner II on its way to Venus.

The astronomical yardstick—the distance from the Earth to the Sun—was refined significantly from an analysis of Mariner radio tracking data. Tracking data also refined our knowledge of the mass of Venus to an accuracy of ±0.015 percent.

Some of our critics have belittled the Mariner II scientific accomplishments on the basis that the answers merely confirmed existing theories. This, in many ways, is true. However, these critics would appear to have overlooked the significance of eliminating the several other theories which prior to Mariner II were equally as plausible. It can be argued that confirming one of many theories is tantamount to the discovery of a new theory; this process of elimination is a normal occurrence in the evolution of scientific knowledge.

The next planetary mission will be conducted with a spacecraft (fig. 3–15) which is an outgrowth of the Mariner II. It will be launched to Mars in 1964 to fly close by the planet and make direct observations. Included in the payload will be a television camera to take pictures which will be transmitted back to Earth by radio.

The growth to larger spacecraft and the second step of injecting capsules directly onto the planet will be made possible by Mariners of the type indicated in figure 3–16. This configuration shows a spacecraft carrying a capsule which may contain instruments to observe firsthand the planetary atmosphere and surface features. A type of experiment being planned for early missions, which will be landed in a capsule, is intended to search for life of some form. This question of whether life exists on other planets is an exciting one scientifically, inasmuch as it may provide clues to our development on Earth and to the state of evolution of life in other planetary environments.

The Pioneer spacecraft (fig. 3–17) is being developed to provide continuous observations of the interplanetary space and the Sun near the orbit of the Earth as it moves slowly to positions ahead of or behind the Earth. This monitoring spacecraft is comparable to a weather station sending continuous data on the conditions in space. It will help to understand the effects of solar activities on interplanetary phenomena and may contribute to the safety of manned space flights.

Beyond today's projects, more extensive efforts for the continuing exploration of the solar system are being planned. In table 3–I, two major missions under study and others of a more general nature being considered are indicated. The Voyager missions using Saturn-class vehicles for launches to Mars and Venus have already been mentioned. A probe is being studied which will allow measurements in the vicinity of the Sun; and the outer planets are being considered and missions to other bodies

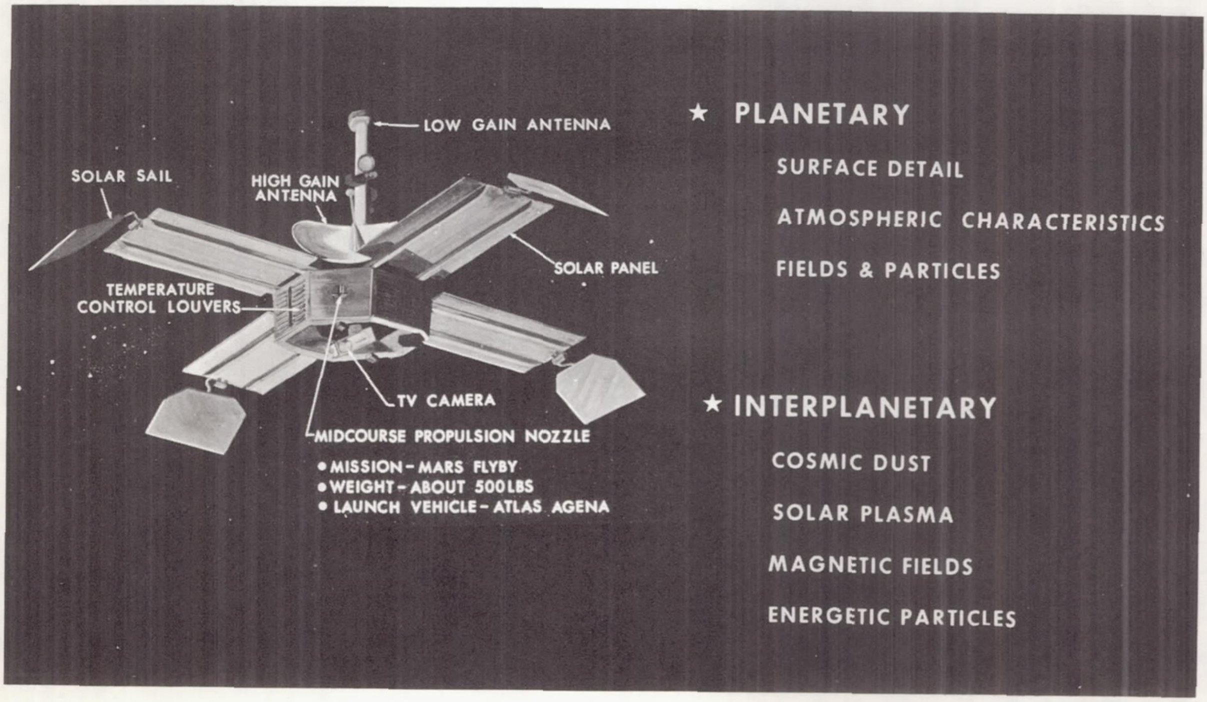

FIGURE 3–15.—Mariner Mars scientific mission.

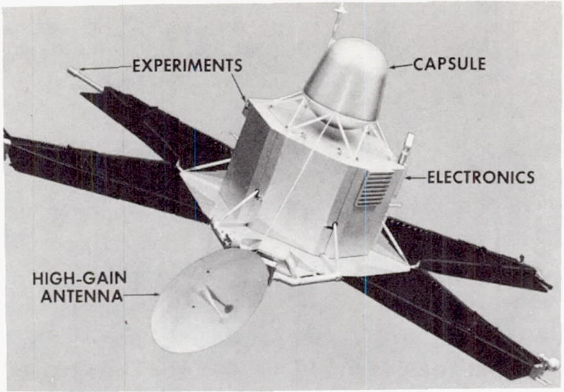

FIGURE 3–16.—Mariner flyby and landing capsule.

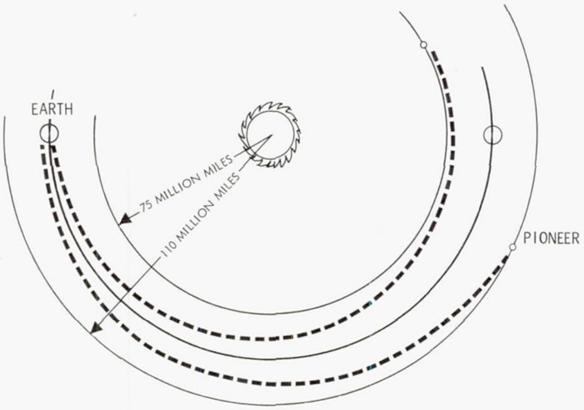

FIGURE 3–17.—Pioneer orbits. Earth-probe distance at 6 months, 50 million miles.

within the solar system are already being discussed. It is believed to be within the realm of existing technology to send probes completely out of our solar system.

TABLE 3–I.—*Missions Under Study*

Voyager:
- Mission—Mars and Venus orbit and land
- Weight—3,000 to 8,000 lb
- Launch vehicle—Saturn

Solar probe:
- Mission—Probe of Sun to about ⅓ astronomical unit
- Weight—About 300 lb
- Launch vehicle—Atlas Agena

Other missions:
- Outer planets
- Out of the plane of the ecliptic
- Comets
- Asteroids
- Escape from solar system

The vistas opening to the people of the world as a result of the efforts being sponsored by the citizens of the U.S.A. appear to be limitless. No one of us can say, knowingly, what the future may hold, but it is truly a rare privilege for each member of our world community to be living in an era when so many centuries-old secrets are being unlocked.

4 Manned Space Flight Program

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Each of the preceding National Conferences on the Peaceful Uses of Space coincided with major decisions about the U.S. manned lunar landing program. The first conference, at Tulsa, occurred just after President Kennedy proposed to the Congress that we establish the landing of a U.S. citizen on the Moon in this decade as a high-priority national project. NASA was deeply involved in the Mercury program and well along in the study of Apollo. However, at that time, Apollo was defined as a three-man spacecraft capable of prolonged missions in Earth orbit and, ultimately, a manned circumlunar flight.

Last year's conference at Seattle took place as we were completing the studies of the modifications required to the Apollo concept to adapt the spacecraft to the lunar-landing mission. The paper by George M. Low described both the direct flight and Earth orbital rendezvous approaches to the mission as well as the lunar orbit rendezvous mode, which was ultimately selected.

The mode selection was certified on November 7, 1962, and we are now well into the development phase of the program. All major system elements have been defined and are under contract. Indeed, significant portions of the system are already being tested in ground facilities around the country. The first flight tests to qualify the launch escape system so inherent to the safety of the astronauts will take place at White Sands Proving Ground within the next few months. These tests, however, are but the first of a long series of development tests required to assure that, late in this decade when we launch the Apollo crew toward its historic rendezvous with the Moon, we will have confidence that every element required to perform the mission will function properly.

In the following papers James C. Elms will discuss the mission profile and the spacecraft, Robert F. Freitag will report on the details of the launch-vehicle program, and David H. Stoddard will discuss our approach to the space medical problem. In the present paper the nature and importance of our overall national manned space flight program will be reviewed.

History lends perspective and, in order to understand our program better, I have studied the nature of such programs in the past. The mission most often compared with the Apollo program is Columbus' voyage on which he discovered America. He called the project "The Enterprise of the Indies."

The problems Columbus faced were somewhat different from ours. After many years as a seaman, he conceived of the possibility of sailing to China via a westward route from Spain in the early 1480's. By the standards of the day this was a fairly large program and required government support.

Columbus, although initially a Genoese, lived in Portugal during the 1480's. He developed an unsolicited proposal and attempted to sell his project to the Portuguese king during the years 1480 and 1485. The proposal was extensively reviewed and rejected as impractical.

Columbus then transferred his allegiance to Spain, at that time Portugal's rival in colonization. He changed the name of the addressee on the proposal and attempted to sell the project to King Ferdinand and Queen Isabella from 1485 to 1492.

To understand his problems, it might help to reflect on the state of knowledge of the Earth at that time. Most people, even in the fifteenth century, recognized that the earth was round. The fable that Columbus was fighting scientists who believed the world to be flat is an interesting legend, but no more than that.

The proposal was to find a short route to the Far East. Columbus proposed to land in Japan, which at that time he called Cipangu. In order to determine the distance he would have to sail, he calculated the size of the Earth by extrapolating from medieval measurements of the length of a degree of Earth longitude. Columbus supported his case by picking the lowest measurement he could find, an estimate that a degree was equivalent to approximately 57 Arabic miles as reported by a Moslem geographer. He then managed to shrink the world by some 25 percent merely by assuming that the Moslem's estimate was in Roman miles, rather than Arabic miles.

Marco Polo's journey to China had provided an estimate of the expanse of the Eurasian land mass. As might be expected, the walk seemed somewhat longer to Marco Polo than it actually was. This, in effect, provided an estimate which stretched Asia to the east. Columbus then added approximately 1,000 miles as an estimate of the distance from China to Japan.

This combination of shrinking the world and stretching the land resulted in a calculation which demonstrated conclusively that Japan was only 2,400 nautical miles west of the Canary Islands, well within reach of the sailing ships of the day. The actual distance is close to 11,000 miles. This calculation may well have set the precedent for a long line of optimistic estimates by prospective contractors on research and development projects.

After Columbus made his proposal to the Spanish Court, it was referred to a scientific advisory board. The project was considered of such urgency that the committee managed to report back its findings in the amazingly short time of only 4½ years. In addition to pointing out the erroneous basis of the calculations, the committee, headed by Fray Hernando de Talavera, raised the following six objections:

(1) A voyage to Asia would require 3 years.
(2) The Western Ocean is infinite and perhaps unnavigable.
(3) If he reached the Antipodes he could not get back.
(4) There are no Antipodes because the greater part of the globe is covered with water, and because Saint Augustine says so.
(5) Of the five climatic zones, only three are habitable.
(6) So many years after the creation it is unlikely that anyone could find hitherto unknown lands of any value.

On the basis of these recommendations, the entire project was rejected in 1491.

Columbus had about given up when he found one more friend in court, who had, perhaps, a more emotional set of arguments. In any event, Columbus was given one more audience and the negative decision was reversed in February 1492.

The total cost of the program was approximately $14,000. Although the Queen did offer to raise the necessary money on her crown jewels, it turned out not to be necessary. Columbus was, in effect, awarded a sole source contract for the exploration. Negotiation of the contract took approximately 3 months. It appears to have been a form of incentive contract, with Columbus acquiring a major interest in all lands discovered as well as Spanish titles, which apparently he coveted.

Once the contract was negotiated, Columbus proceeded to Palos de la Frontera, the Cape Canaveral of Spain, on May 22, 1942. The logistic planning for the operation went quite swiftly. He acquired the *Nina*, *Pinta*, and *Santa Maria* and a crew of officers and men.

By August 3 the expedition was assembled and the journey launched. The first phase was a relatively short trip to the Canary Islands, which were reached on August 12. We might consider that the Canaries were the fifteenth century equivalent of an Earth parking orbit. Almost another month was spent in checking out the ships, taking on supplies, and preparing for injection. On September 7 the small fleet upped anchor and headed into the unknown. Landfall was achieved on October 12, after 34 days at sea. The crew was close to mutiny during the early part of October, but the life-support equipment held out and the sight of land raised all spirits and renewed the dedication of the task force to the exploration task ahead. Columbus remained convinced that he had discovered Japan or China, when indeed he was merely the first foreign power to occupy Cuba.

It is interesting that, although Columbus consumed several years getting his enterprise accepted, he was able to execute the project relatively quickly after receiving the go-ahead. In effect, the equipment to perform this new mission was in existence. The problem was to develop an understanding of how far the equipment could be pushed and what wonders were left to explore.

Today, the situation is essentially reversed. We understand what there is to explore—the challenges which space offers to mankind. All scientists can agree on the distance to the Moon, and almost all can agree on the type of equipment required to perform the missions. Much of the discussion of the proper mode is analogous to the question of using the *Nina*, *Pinta*, and *Santa Maria* for the mission rather than developing a new, larger ship for the trip. Today, we cannot elect to do the mission with in-existence hardware. The equipment itself is not available; it must be developed, and such development takes time and much effort.

The commitment of a nation to a goal such as the Moon must be sustained over a protracted period of time, during which people are prone to change their minds and go through agonizing reappraisals. In an unclassified development program such as Apollo, there is a tendency to interpret every developmental problem as an indication of a fatal flaw in the program. Had the Columbus expedition required the development of a new ship and sure solution to potential nautical medical problems of *mal de mer* on prolonged voyages, I am sure the commitment of Isabella would have undergone periodic reevaluation. The logic which had suppressed the program for 6 years would have returned to haunt the admiral.

Today we are experiencing in this country the first wave of reappraisal of the commitment to land a United States citizen on the Moon in this decade. I do not mean to indicate that such discussions should not take place—far from it, for the forum of public debate is the key to the democratic process and the inherent strength of this country. However, for the debates to focus on the real issues, we must understand the nature of the development program we are undertaking and the fundamental reasons behind the program.

Space missions require two major elements: launch vehicles and spacecraft. Our present national program is intended to provide roughly three classes of each—to use our common commercial jargon—small, medium, and large.

Figure 4–1 summarizes our present vehicle program. The small boosters are represented by the Atlas, with a 3,000-pound capability to Earth orbit, and the Titan II (not shown), with more than twice that capability. These boosters were developed as an integral part of our military ballistic-missile program and have been adapted to manned space flight requirements. The payload capability of these vehicles, although adequate for their intended military mission, has severely limited our spacecraft designs.

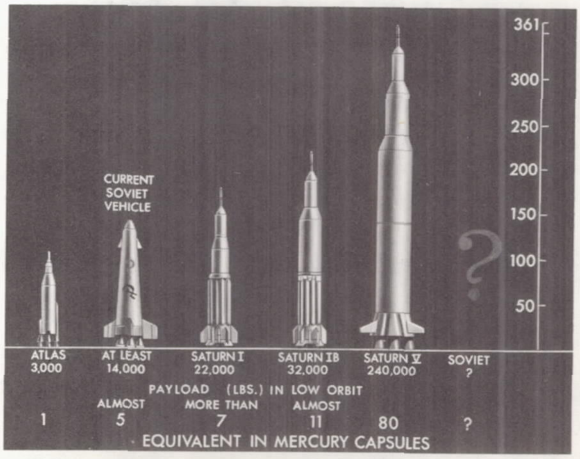

FIGURE 4–1.—Launch-vehicle power.

The first vehicle designed primarily for space flight is the Saturn I, which will have a payload capability of 22,000 pounds. As shown in figure 4–1, we will later upgrade the Saturn I by replacing the second stage with the third stage of Saturn V. This new vehicle, termed the Saturn IB, will place approximately 32,000 pounds into Earth orbit. In addition to providing the capability to test Apollo hardware early, these two vehicles will provide the Nation with the capability to place sophisticated spacecraft in Earth orbit to perform a wide variety of manned and unmanned missions.

The Saturn V vehicle, which can place approximately 240,000 pounds into Earth orbit, will be the main booster for the lunar missions. It has been under development since late 1961 and will fly early in 1966. The jump from Atlas to Saturn V will have increased our national booster capability by a factor of almost 100 in less than a decade.

As shown in figure 4–1, the present Soviet capability is also based on a vehicle developed primarily for military purposes. However, their initial capability of approximately 14,000 pounds has been significantly larger than that which we have enjoyed and has permitted them to perform the extensive series of Vostok flights which have been reported in the open press. Although we might expect them to demonstrate even more elaborate Earth orbital missions with this same booster, and perhaps even go as far as a circumlunar mission such as we had originally contemplated for Apollo, the 14,000-pound capability falls far short of that required for a manned lunar landing. As indicated in the figure, we have no way of projecting current Soviet plans for larger boosters. Since the boosters are, in a sense, the key to the capability of performing expanded missions, we are in no position to judge the true relative standing of the United States and the U.S.S.R. in the race to the Moon.

The spacecraft involved in our program are indicated in figure 4–2. We are pursuing a step-by-step program, not just to get to the Moon, but also to provide the Nation with the broad capability for manned exploration of space that will achieve and maintain United States leadership in this new arena.

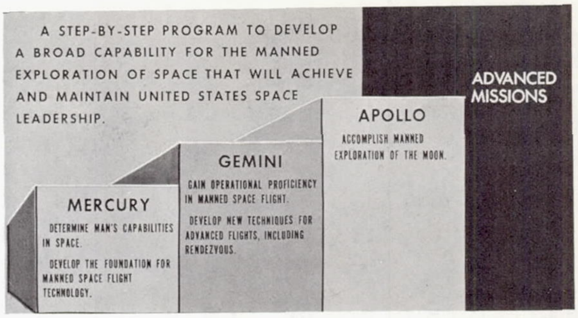

FIGURE 4–2.—Manned space flight program.

We have carried out five Mercury missions in the last 2 years—the suborbital flights of Alan Shepard and Virgil Grissom in 1961, and the orbital missions of John Glenn, Scott Carpenter, and Walter Schirra in 1962. In May 1963 Astronaut Gordon Cooper is expected to carry out a 22-orbit mission, a duration of about 24 hours. The relation of the Mercury program to our manned space effort resembles the relation of the X-series aircraft to our aviation programs. Mercury has not had an operational goal in itself. It has, however, laid the groundwork for manned space flight technology. We have learned through experience the problems of manned space research and development programs, how to train astronauts, and how to carry out the worldwide operations required for manned space flight missions.

Most important, however, is the fact that we have established man's capability to survive and function normally in space. Indeed, we have concluded that future space missions will be greatly enhanced by the presence of men aboard the spacecraft. The lessons learned in airplane development programs concerning the role of men and machines appear to be applicable to space flight as well.

The Mercury program has, in effect, opened the door of the world to space.

Gemini, our middle-sized program, is intended to advance further the technology developed in the Mercury program. Gemini is a spacecraft weighing some 7,000 pounds, capable of sustaining two men in orbit up to 14 days. It will fly approximately a year in advance of Apollo and will provide us with our first experience in long-duration manned flight, as well as rendezvous and docking. This experience will be directly applicable to Apollo.

However, Gemini is more than an experimental spacecraft. At the end of its scheduled developmental flight program, it will be available for missions ranging from scientific and engineering experiments to the ferrying of astronauts to and from a permanent space laboratory. The end goal of Gemini is, therefore, an operational spacecraft which can be launched by relatively small boosters. We expect Gemini to be a useful space vehicle for several years.

Apollo is a spacecraft capable of sustaining three men in space for prolonged periods of time. In addition to its application to the manned lunar landing program, it will be available after its development phase to perform a variety of missions either in Earth orbit or near Earth space.

The relative scale of the three spacecraft is shown in figure 4–3. Mercury carried only sufficient propulsion to deboost it from orbit. The Gemini spacecraft carries a propulsion capability of several hundred feet per second, sufficient to execute rendezvous maneuvers. The service module of the Apollo spacecraft carries sufficient fuel for entensive maneuvers in space. The lunar excursion module, shown below the service module, is the first manned spacecraft designed solely for operation in space. It does not have a heat shield and therefore is incapable of reentering the Earth's atmosphere.

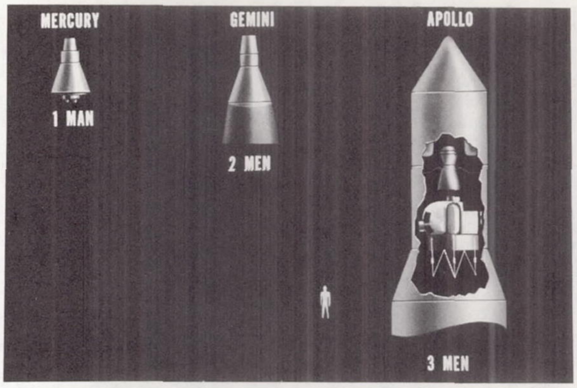

FIGURE 4–3.—Manned spacecraft.

The missions leading to the achievement of the first lunar landing are shown in table 4–I. The initial flight of the Gemini spacecraft will occur late this year. The long-duration manned flights will take place approximately a year later. Rendezvous and docking will be demonstrated during 1965. The Gemini spacecraft will reach operational status by 1966.

The initial suborbital tests of Apollo will begin this year. The command module and the service module of Apollo will be tested extensively in Earth orbit using the Saturn I launch vehicle in 1965 and 1966. The advent of the Saturn IB vehicle will permit us to include the lunar excursion module in the Earth orbital test program during 1966 and 1967. These 4 years of testing are intended to provide an operational Apollo spacecraft in time to meet the

TABLE 4–I.—*Manned Space Flight Missions*

Mission	Date	Launch vehicle
Mercury, 1 day	May 1963	Atlas
Gemini:		
Unmanned	Late 1963	Titan II
Long-duration manned	1964	Titan II
Rendezvous and docking: Spacecraft	1965	Titan II
Rendezvous and docking: Agena target	1965	Atlas
Apollo:		
Module qualification, unmanned	1963–65	Little Joe II
Manned Earth orbital, two modules	1965–66	Saturn I
Manned Earth orbital, all modules, rendezvous and docking	1966–67	Saturn IB
Manned circumlunar, lunar orbital, and lunar surface exploration	1967–70	Advanced Saturn V

Saturn V vehicle and begin lunar missions during the last few years of this decade.

The preceding discussion demonstrates that the elements which are being developed within the framework of the manned lunar landing program are also the elements required to provide this country with an extensive manned space flight capability. The boosters are not tailored exclusively for the lunar mission. The spacecraft will be capable of performing other missions in space over and above those relating to the lunar landing. In effect, the manned lunar landing program acts as a natural focus for developments necessary to provide this country with a preeminent position in space. This is perhaps, in the long run, the most important reason for so large a commitment to this single project.

Also to be stressed is the fact that we are talking here of development programs leading to ultimate operational capabilities. We have had, as a nation, a tendency to emphasize the first experimental flights in our new programs as much as, or more than, the achievement of the ultimate operational capability. The general public, perhaps, does not understand that early flight testing should be only the final certification of the correctness of our equipment designs.

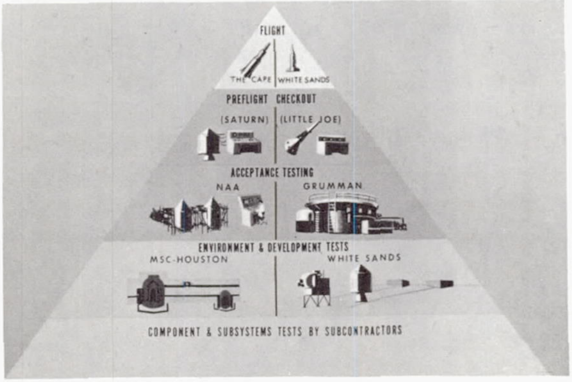

FIGURE 4-4.—Apollo spacecraft testing.

Figure 4-4 shows the testing pyramid involved in a program such as Apollo. The Space Age has matured to the point where we understand, reasonably well, the fundamental requirements which our components must meet in order to survive in space and perform their missions. We have in existence, or in development, facilities adequate for extensive testing on the ground. In effect, flight testing should be used to confirm the adequacy of the design and, ideally, will only root out those design deficiencies which we have not been able to test for on the ground. Although in the past, when we did not understand the environments, we had to resort to extensive flight-test programs to find design weaknesses, we feel that we are emerging into an era when this can be done largely in terrestrial laboratories.

The first phase of any research and development program is design. When the initial design phase is completed, the individual components and subsystems are assembled and subjected to rigorous qualification tests by our subcontractors. Environmental and development tests on units similar to those which will fly are conducted at facilities at Houston, White Sands, and other locations around the country. The equipment is tested under simulated vibration, acceleration, vacuum, and radiation. In addition, we exhaustively simulate the ultimate flight missions on the ground.

Usually in parallel with these qualification tests the actual flight equipment is delivered to our major contractors for extensive testing and integration into the complete flight spacecraft. Rigorous testing procedures in the contractors' plants assure that the equipment, as manufactured, conforms with the design and is properly integrated into the overall system. Once these tests have been completed at the factory the spacecraft is transmitted to Cape Canaveral, where it is again extensively tested to assure that no deficiencies remain. Only after we have gone through this test, retest, and test-again cycle are we willing to commit the spacecraft to flight test.

In effect, the flight-test program is the relatively small portion of the development iceberg which is clearly visible to the public. At least in the early phases of the program, the solution of each problem that arises during this testing cycle is more important to us than the actual first flight date. We normally do establish the first flight dates on a relatively optimistic schedule. This stems not so much from naïveté as from a recognition of the fact that the flight requirement introduces the necessary urgency and rigor into the testing chain. A relatively early flight date means that designs must be firmed up and the testing process begun. We feel that only by getting to this testing at a reasonable early date can we come to grips with the real problems which exist in the hardware. Too long a period allowed for initial design will, in effect, only put off the day of reckoning with the test results.

The development flight-test program normally calls for many shots, with the implicit expectation that some of these will be failures. The ground-test program that has been described is intended to preclude such failures. In the early phase of the program, prior to first flight, we must continually exercise technical judgment on the balance between maintaining flight dates and maintaining rigor in the ground program. Our conviction is that we cannot sacrifice ground testing in the interest of meeting flight dates. The success of the first four Saturn I shots and the successful flight-test record of the Mercury program are, we believe, indications that this approach is correct.

This is not meant to imply that our procedures can be sufficiently rigorous to rule out flight failure. The task is much too complex for such a promise. We must be prepared, as a nation, to accept the possibility of an individual disaster without panicking—as we have so often done in the past.

Gemini is, perhaps, a good example of this approach. The Gemini program was initially conceived as an interim vehicle, essentially an upgrading of Mercury and an extension of the experimental-spacecraft philosophy. Its first manned flight was scheduled for early 1964. As the program progressed, we recognized that the spacecraft, in addition to supporting Apollo as I have discussed, would also have operational utility to the Nation if more advanced subsystems were used. These more advanced systems slowed down the design and ground-test program somewhat. We have also reexamined the original flight-test planning, which called for a single unmanned test of Gemini. The additional complexity of the spacecraft, and our desire to be sure that all elements have been certified at least once in flight prior to committing a man, led us to conclude that not only was a more extensive ground-test program justified, but an additional unmanned flight should be performed.

Recently the scheduled date of the first manned flight in Project Gemini was moved back by about 6 months. This new schedule resulted from our assessment of what is required to achieve operational status at the earliest practicable date. We feel that the question of which flight first includes astronauts is less important than a properly phased development program.

I do feel that the approach we have adapted will, in the long run, advance our national space program at a much faster pace than any "shoot-on-schedule and hope" philosophy. Although the individual flight dates of the Mercury program have all been adjusted as hardware problems on the ground were met and solved—usually to the accompaniment of headlines advising of further slippages in the United States space program—we stand today on the verge of completing the program only 4½ years after its initiation and less than 7 years from the start of the Space Age. It has not only met all its goals, but it has provided the basis for the much more ambitious projects that have been described herein. Changes in individual flight dates, then, should be kept in perspective with the overall program goals.

The road to the Moon is long. Much of the road is hard and unglamorous. One pundit has noted that the quantity of paper generated during the project, if piled up, would reach the Moon before Apollo. We have studied the suggestion and determined that, although it is quantitatively true, the resulting structure would be very unstable and hard to climb. We concluded that the real hardware had to be developed.

Although each succeeding year will bring increasing evidence of accomplishment on the program, we must remember that the national effort and interest must be sustained over many years for this project to be successful. Continued support can come only from public understanding of the nature of complex technical programs. It is hard to get across the story of the early phases of a program, the things which must be done before we take to television for the spectacular missions.

The Nation must understand that last year was the time of definition for the program. This year will be the year of detailed design and the early phases of the ground-test program. Spectacular milestones will be few. December will bring the first unmanned test of the Gemini spacecraft, which will later sustain two men in orbit for 2 weeks.

Within the next 3 to 5 months the first two-stage Saturn I will be launched. This vehicle was developed by the Marshall Space Flight Center and will place more than 22,000 pounds of payload in orbit. This will be the largest payload injected into orbit from the surface of the Earth in a single launch. With this milestone accomplished, the United States will be second to none in booster capability.

The possibility of missions which would have application to real terrestrial problems is one of the major reasons for the national commitment to become masters of this new environment. It is far from the only one, however. The exploration of the Moon will add immeasurably to our knowledge of the origins of the Universe. Our ultimate exploration of the planets will answer the most intriguing, far-reaching question of all—does intelligent life exist on worlds other than our own. The impact of this knowledge on the philosophy of mankind can hardly be estimated.

Yet we are not conducting these programs for science alone. We are convinced that, ultimately, the feedback from these technical developments will improve our economy and increase still further our standard of liivng. Here an analog may help. For decades to come, none but a small percentage of the people of Earth will become travelers in space. It may come as a surprise to some—just because they never thought of it—but after more than a half-century only a small fraction of 1 percent of the world's population has ever been in an airplane. But hundreds of millions of individuals have helped, directly or indirectly, to build the aircraft and airports and all the other essentials to air travel. Hundreds of millions of individuals have benefited from these developments, and so will even greater numbers benefit from the developments in space.

The feedback from the space programs—communications systems such as Telstar, weather prediction from Tiros, inventions which can ease the housewife's burden—all will reshape our physical world throughout the remainder of our lifetime.

One similarity that exists between Columbus' day and our own is the fact that we cannot accurately forecast the exact nature of the benefits which will accrue from performing the explorations. Columbus may have been somewhat disappointed with the initial results of his journey. The East did not turn out to be as rich as Marco Polo's studies had led him to believe. Yet, viewed from the perspective of today, his journey advanced by several years the development of the world and, in the long run, the establishment of our own country. The lesson history teaches is that the benefits are there for those who dare to reach for them.

But the importance of the program goes far beyond the improvement of our material world. It is literally also a question of national survival. The world has come to regard space exploits as a measure of a nation's strength. And alliances and loyalty are given to the strong. We hear much talk of military missions in space, and the Russian leaders are prone to rattle their rockets. It is certainly true that the potential exists for evil, as well as benign, uses of space. Fortunately, no such uses have yet been applied. But we must be masters of this new environment, just as we have had to master the land on which we dwell, the oceans which surround us, and the air which sustains us, in order to guard against the day when mastery of space might mean world domination. The NASA program is the means for our nation to learn to operate in space—to obtain the skills we might some day need for defense—without prejudging the military uses of space and perverting, perhaps unnecessarily, the one region in which men do not carry arms against each other.

In his book "The Strategy of Peace," written before he took office, President Kennedy expressed his convictions regarding the United States role in space. He wrote: "In relation to the world outside, our democracy must demonstrate . . . that it has the energy and the sense of adventure—as well as the technical skill—to play a role of leadership in the exploration of space."

There seems to be no question of the integration of our nation in pursuit of the space effort. One of the major achievements among all our efforts in the space program has been the launching by the people of the United States of this truly national effort to demonstrate our determination and our capacity to sail on this new ocean—to master the technology of the Space Age in all its aspects—for the security of the free world and the good of all mankind.

We now face the problem of maintaining this resolve during the period when the program is not glamorous. The goal has not changed. The reasons are no different. The cost estimates are still the same. If anything, the date of expected achievement has been advanced somewhat. Yet, the voices of the skeptics grow loud. It is always easy to criticize.

The lunar landing is no stunt. The most important accomplishment will be the development by this nation of the ability to make the landing, and not the landing itself. Achievement of such ability is worth the great investment in human and financial resources, time, and industrial capacity that we are making. The lunar landing is a yardstick—a measure of this country's world leadership; a measure of the ability of this democracy to manage a great engineering and technological undertaking in the national interest.

Maintaining leadership in this age of science and technology will challenge the imagination, the ingenuity, the skill, and the courage of every American. But this is no reason to shrink from the challenge presented. On the contrary, no race of people can prosper without constantly progressing. History has conclusively demonstrated that great nations move steadily forward or they wither and die.

Some may believe that America may be able to survive as a second-rate power in space. However, accepting such a secondary role is not in keeping with the character of this nation. It would almost certainly mean second-rate survival. But if we keep compromise from our door, courage in our hearts, and conviction in our minds, Americans need be second to none in space.

5 Manned Spacecraft

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To land a man on the Moon and return him safely to Earth is a goal of mankind, just as surely as it was a goal of mankind to sail to the Americas or to climb Mount Everest. More specifically, it is a national objective of the United States, so proclaimed by President Kennedy in May 1961. As such, it is one of the key portions of our overall space program, the objective of which is to establish and maintain the United States of America as the foremost nation of space explorers, scientists, and technicians.

Although landing on the Moon and returning to Earth is an extremely specific goal, it cannot help but have an immeasurable effect upon our progress in the overall space program of the Nation. It will not only add to our scientific knowledge of the universe, but also, through its utilization of advanced electronic techniques, new materials, and novel types of electrical power production, it may have significant economic benefits. It is difficult—indeed, impossible—to predict the specific scientific and economic benefits resulting from such a program. A reflection on the payoff from this program leads to the thought that when Columbus set sail, he was looking for the Indies and the treasures of the East. Instead, all he found was oil and steel and factories and wheat fields and skyscrapers and hundreds of millions of productive people. In the space programs, we shoot for the Moon but in so doing we develop tools and minds and strength for future and greater enterprises.

There is also another justification for this program. The Moon flight is a peaceful endeavor, but its successful accomplishment cannot help but have a profound effect on our future military posture in space. Although there is no military space force in any nation's arsenal, it would be most alarming for the United States to lack the basic understanding, the basic technology, and the basic engineering which would be required in the event that an aggressor might choose to make space a battlefield. Let us recall that when Wilbur Wright flew his first primitive biplane at Kitty Hawk 60 years ago, in his own mind he was engaged in a peaceful, scientific, engineering endeavor. It is inconceivable that throughout that first brief flight he gave a single thought to the massive destructive potentiality of the modern airplane which later resulted. The lesson is: We cannot as a nation afford to be left behind in developing space technology.

Last, but not least, the execution of this program will provide a dramatic test of the technical competence of the United States, a test which we intend to pass. By so doing we shall undoubtedly enhance our prestige among the uncommitted nations of the world.

We have made considerable progress in achieving our goal of reaching the Moon. The remarkably successful Mercury program is nearing completion, having established beyond all doubt our ability to put a man into space and return him safely to Earth. It has demonstrated man's ability to control his spacecraft while out in space circling the Earth, and while reentering the atmosphere on his return trip.

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The next project, now in its full swing of development, the two-manned Gemini spacecraft, will demonstrate man's ability to live in a weightless environment for as long as 14 days and will demonstrate his ability to perform even more difficult tasks in space than those performed throughout the Mercury program. These include the process of rendezvous and docking, in other words, the process of guiding a spacecraft toward another object in space and making contact with it. Both of these are prerequisites to a successful lunar voyage. The Gemini program will give us a head start on these important aspects of the Moon program itself, which is known as the Apollo program.

The Apollo program was conceived in late 1959, and by mid-1960, a proposed flight around the Moon, known as a circumlunar flight, was announced by the National Aeronautics and Space Administration. As mentioned before, President Kennedy made the Moon trip a national goal in the spring of 1961, and by the spring of 1962 the final plans for the voyage were made. "Direct ascent" and "Earth orbit rendezvous" were studied in connection with the extensive investigation made to determine which of several methods of making the trip, which "mode," would be most expeditious. The mission mode selected, the lunar orbit rendezvous, proved by study to be the most reliable method of achieving the mission at the earliest time. It is this lunar-orbit-rendezvous mode of operation which is described herein.

By the time we are ready to launch an Apollo spacecraft for an actual landing on the Moon, it will have been tested for several years in a series of flights circling the Earth or in Earth orbit. The men responsible for the program will be satisfied that the design is sound and that all the known problems have been solved. Sometime before the end of this decade, the tremendously significant event will take place. Three astronauts will climb aboard the spacecraft, mounted atop the advanced Saturn launch vehicle at the launch site at Cape Canaveral, Fla. The five kerosene-oxygen engines of the first or lower stage flame into life, providing 7.5 million pounds of thrust. This thrust lifts the vehicle on an arching path over the ocean (fig. 5–1). There are solid-fuel rocket engines, liquid-fuel rocket engines, and exotic-fuel rocket engines. The solid-fuel engines are very much like the old-fashioned skyrocket. Of the liquid-fuel engines, the ones which have been used the most to date have kerosene as fuel and oxygen carried along to burn the fuel as the rocket is propelled along out into space where there is little or no oxygen. The engines being developed for the upper stages of this huge launch vehicle have hydrogen as the fuel instead of kerosene. This provides much more power.

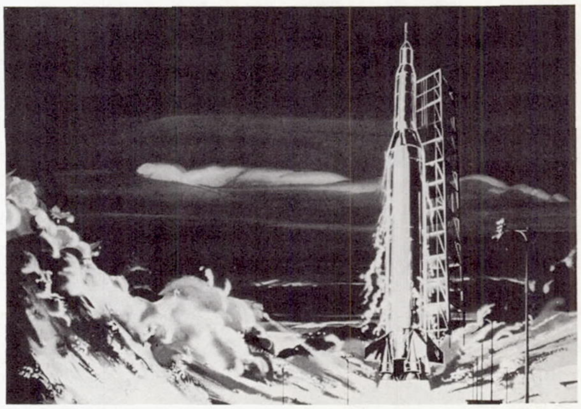

FIGURE 5–1.—Lift-off from launch pad.

After 2½ minutes, the fuel and oxygen will be exhausted and the first stage will separate (fig. 5–2). It may be wondered why these launch vehicles are made in several parts, or stages. It is done for reasons of fuel efficiency. One could conceivably build a single large booster to do what the three-stage booster does

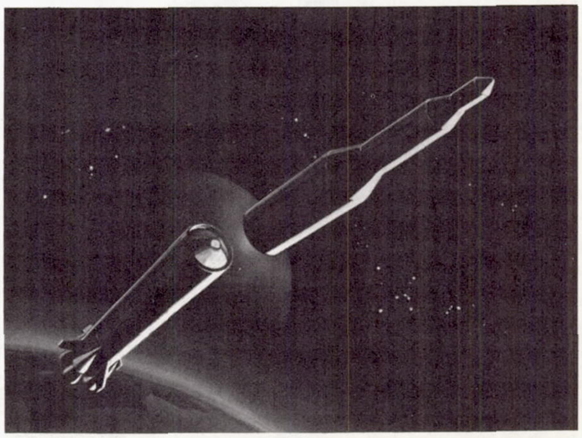

FIGURE 5–2.—Saturn V first-stage separation.

but it would be extremely inefficient. So what we do is lift the whole thing off the ground with its large collection of engines and fuel tanks, and when the fuel associated with those in the lower stage has been used up, the empty tanks and the engines and the case surrounding them are dropped off. Now we have a smaller vehicle which already has considerable velocity. The five engines in the second stage light up and produce only about one-seventh the thrust of the larger engines, but the remaining part of the vehicle is now much lighter and is already going at a pretty good clip. Almost 6½ minutes later, the hydrogen and oxygen tanks connected to these engines will be empty and this whole stage will separate and fall away (fig. 5-3).

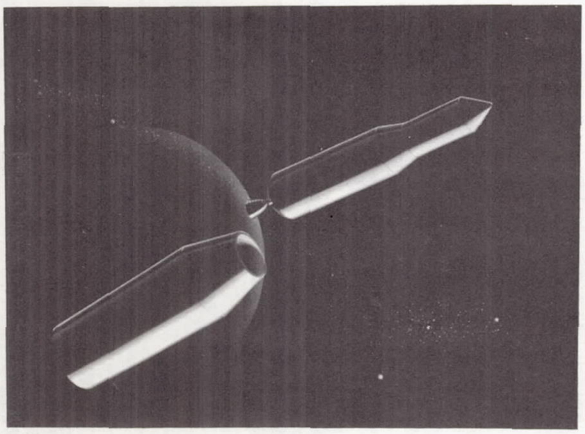

FIGURE 5-3.—Saturn V second-stage separation.

The engine in the third stage now ignites and burns part of its fuel for approximately 2¾ minutes. This is long enough to accelerate it to a speed necessary to put it into circular orbit around the Earth, which we call a parking orbit. Up until this time, there has been constant radio communication between the ground control station at Cape Canaveral and the spacecraft, but now that it has achieved Earth orbit, the ground control will shift to the Mission Control Center, located in Houston, Tex. This Center, connected by telephone lines and other communication means to large radio antennas scattered throughout the world, will be in constant communication with the spacecraft throughout its voyage.

While circling the Earth, the spacecraft will be checked out by the three astronauts on board (fig. 5-4). At the same time, giant computers located on Earth at the Mission Control Center will be checking the spacecraft, as though they were flying along with it, by means of the remote control radio link. During checkout, the spacecraft and the remaining part of the launch vehicle will circle the Earth one-and-a-half times. If all systems are functioning properly, the astronauts are ready to begin the second phase of the trip. At just the right moment, the booster engine lights again and burns for 5 minutes. The spacecraft will now reach the speed of 25,000 miles per hour (fig. 5-5). From here, it literally coasts to the vicinity of the Moon.

At the top of the spacecraft is the Command Module, which has housed the three astronauts. Next beneath it is a Service Module, which contains fuels, supplies, and an engine. Below these is the Lunar Excursion Module or LEM. The Lunar Excursion Module is the vehicle that actually lands on the Moon. Covering this vehicle is an adapter which connects the top stage of the booster to the Service Module (fig. 5-6).

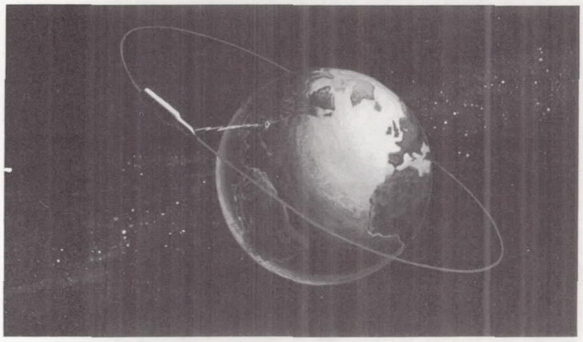

FIGURE 5-4.—Earth orbital checkout.

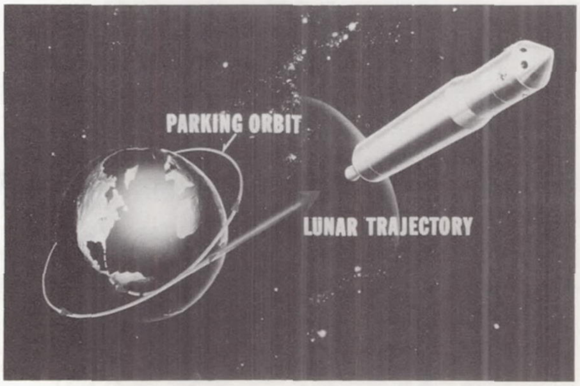

FIGURE 5-5.—Injection from parking orbit.

While the vehicle is coasting toward the Moon, the adapter separates, as shown in the figure. Then the spacecraft proper separates from the booster, leaving the LEM attached to the booster. Using their control systems, the astronauts turn the spacecraft around and dock nose to nose with the LEM and finally this combination is separated from the remaining portion of the booster. During this coasting flight, measurements will be made both onboard and from the ground. If the course needs to be corrected, the rocket engine in the Service Module will be used to make the necessary corrections. The trip from the Earth parking orbit to the vicinity of the Moon will take approximately 3 days.

When the spacecraft arrives in the vicinity of the Moon, the astronauts again use their control system to turn the spacecraft around (fig. 5–7). This is so that the engine can be turned on again with the spacecraft going backwards. This slows the spacecraft down so that instead of going right by the Moon it goes into a circular parking orbit again, this time around the Moon at a height of approximately 100 miles. While circling the Moon, the systems are checked out again. If they are fuctioning properly, the landing mission is begun. If not, a decision will be made to return to Earth in the same manner, as will be described subsequently.

Figure 5–8 shows why it was necessary to do all that separating and docking just after leaving the Earth parking orbit. As can be seen, the LEM (with its landing legs folded in) was tucked in behind the engine and between it and the top stage of the booster. It was necessary to separate the spacecraft and rotate it around to get it into the position shown. This makes it possible for two of the three astronauts to climb from the Command Module into the LEM.

Then the LEM is detached (fig. 5–9) and the landing engine at the bottom of it is turned on briefly. This causes the LEM to go into a slightly different orbit than the circular one maintained by the Command Module, or mother spacecraft. In fact, the LEM goes into an el-

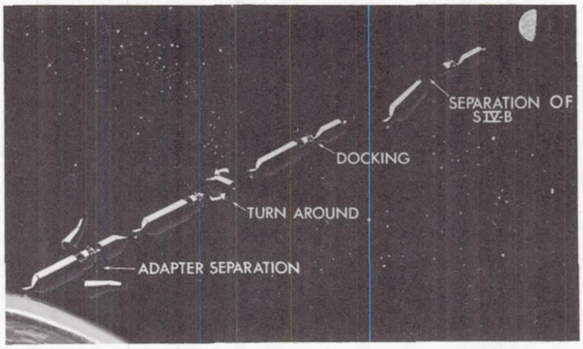

FIGURE 5–6.—Docking and third-stage separation.

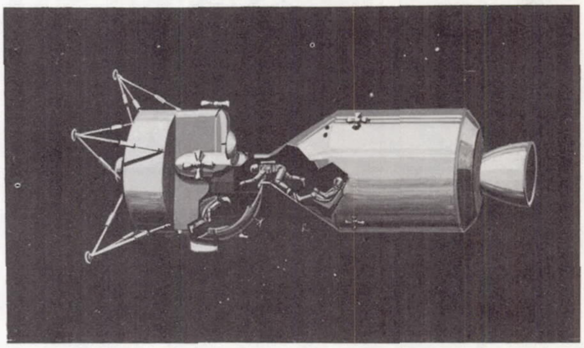

FIGURE 5–8.—Transfer to LEM.

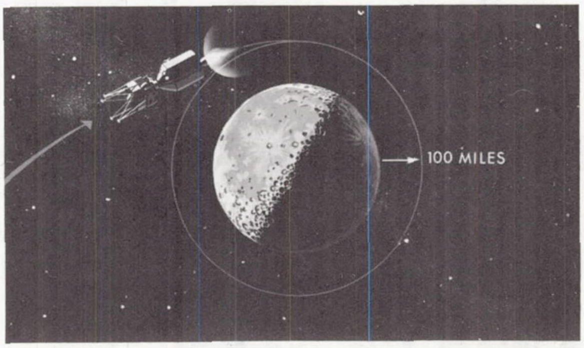

FIGURE 5–7.—Entering lunar orbit.

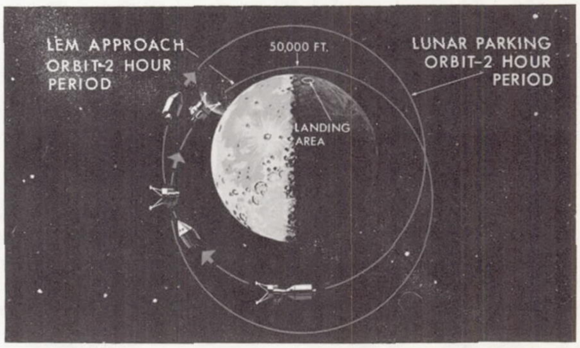

FIGURE 5–9.—LEM approach orbit.

liptical orbit with the same period. In other words, it takes the LEM the same time to go around the Moon as the mother spacecraft. However, since the LEM takes a different path, the LEM and the mother spacecraft would come together again in 2 hours if all they did was coast from this time on. We shall soon see why this is important.

When the LEM reaches the 10-mile minimum altitude of its approach orbit, it will be traveling at a speed of 4,000 miles per hour with respect to the Moon. At this time (fig. 5–10), the landing engine will be turned on again to slow the LEM down and cause it to descend toward the surface of the Moon. The power of this rocket can be adjusted so that the LEM can hover about 300 feet above the Moon's surface somewhat like a helicopter hovers over its landing site.

Windows will provide the astronauts with a clear view of the lunar surface (fig. 5–11) so that they can select the exact point at which to land. They will be able to maneuver the LEM horizontally as much as 1,000 feet until it is above the desired point. The LEM will then descend slowly to the surface and land at a speed of less than 7 miles per hour (fig. 5–12).

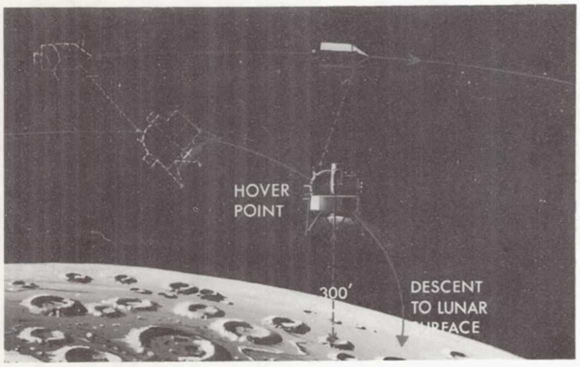

Figure 5–10.—Lunar descent.

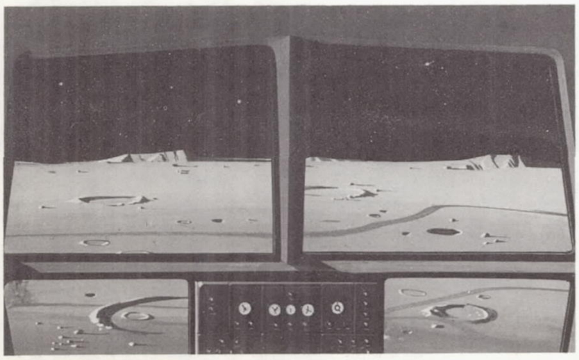

Figure 5–11.—LEM field of view.

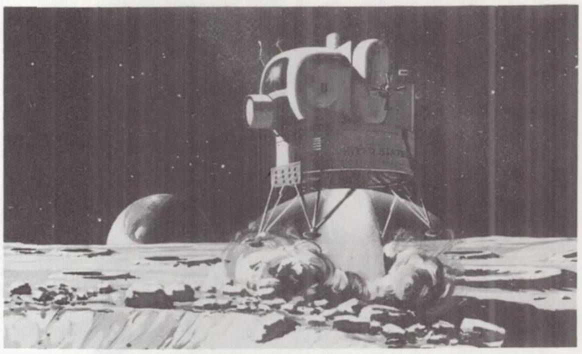

Figure 5–12.—Lunar touchdown.

At any time during this maneuver, if the astronauts experience difficulty with the equipment or for any other reason wish to abort the mission, they simply light an engine and return to meet the mother spacecraft during the first orbit. This is the very important reason, mentioned earlier, for putting the LEM in the particular elliptical orbit which would cause it to rejoin the mother spacecraft 2 hours after it separated from it, if the landing were not completed.

While on the Moon, the astronauts will first check out the LEM in preparation for the return flight. Then they will explore in the immediate vicinity (fig. 5–13). The astronauts will observe the surface, make measurements,

Figure 5–13.—Lunar exploration.

collect samples, and place instruments on the Moon which will continue to make measurements and radio information to the Earth after they have departed.

On the first mission, the total length of stay on the Moon will be about 24 hours. After completing their exploration and sleeping a few hours, the two astronauts will begin the countdown for the return trip. The takeoff is to be accomplished at a time when the Command Module is in sight overhead. In order to save weight and therefore fuel on the return flight, the ascent stage of the LEM separates and takes off from the landing stage (fig. 5–14). This is the engine which would have been used if an abort, as mentioned previously, had been required during the landing phase. Its 3,000-pound-thrust engine will burn for about 6¼ minutes until the LEM reaches orbital speed of about 4,000 miles per hour, at an altitude of 10 miles. During powered flight and the coast phase that follows, radars aboard both the mother spacecraft and the Lunar Excursion Module are operating so that they can keep track of each other. The LEM engine will make any major course corrections needed to assure the rendezvous.

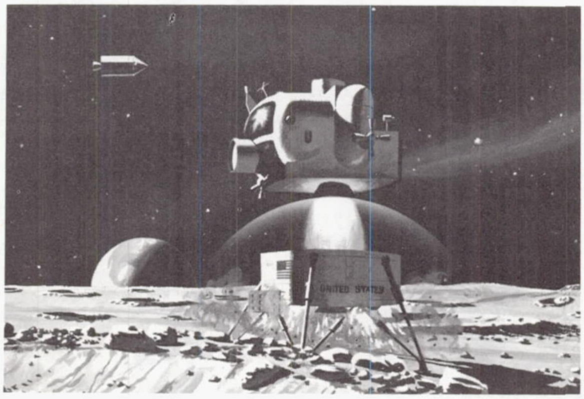

FIGURE 5–14.—Lunar lift-off.

About an hour later, after both spacecraft have coasted halfway around the Moon, they will be quite close and the relative difference in their speeds will be about 70 miles an hour (fig. 5–15). When they are about 5 miles apart, the LEM guidance system will command its engine to provide bursts of 3,000 pounds of thrust, which will be used to bring the LEM closer to the mother spacecraft. When the distance has been reduced to a few hundred feet, the two astronauts in the LEM will take over control personally and complete the docking or rejoining of the two spacecraft.

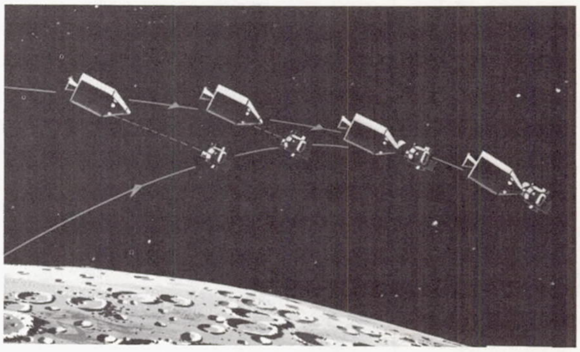

FIGURE 5–15.—Lunar orbit rendezvous.

This maneuver is clearly essential to the success of the mission. Consequently, we are providing a capability within the mother spacecraft for the third astronaut, who remained aboard while it circled the Moon, to perform the rendezvous even if the LEM has become incapacitated. In this case, the LEM crew can still be rescued and the mission successfully completed. This is why the method of accomplishment, or "mode" is called lunar orbit rendezvous.

Once the astronauts have climbed back aboard the Command Module, the LEM will be detached and left in lunar orbit (fig. 5–16). The Service Module engine will be ignited and will generate its 22,000 pounds of thrust for about 2½ minutes. This thrust will provide the additional velocity of 2,000 miles per hour that will speed the spacecraft on the homeward

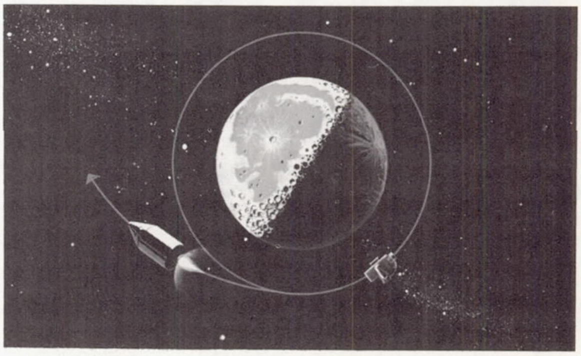

FIGURE 5–16.—Leaving lunar orbit.

journey to the Earth. During return, the Service Module engine will be employed to make corrections in the course as required (fig. 5–17).

After the final flight path adjustments have been completed to assure grazing the Earth's atmosphere at the correct angle, the Service Module is abandoned and the Command Module containing the three astronauts is oriented for reentry into the Earth's atmosphere.

During reentry, the Command Module can be steered something like a glider because, although it does not have wings, it does, because of its shape and attitude and its tremendous speed, have lift as though it did have wings. When the atmosphere has slowed the Command Module down below the speed of sound, three parachutes pop out (fig. 5–18) to slow it down much further, and the Command Module floats down to land on the Earth's surface (fig. 5–19).

It all looks very easy when it is described with help of an artist. These illustrations are deceptive. It just looks easy—like playing a violin. In order to have a successful mission, no matter how skilled and well-trained the operating personnel, it is required that the equipment work.

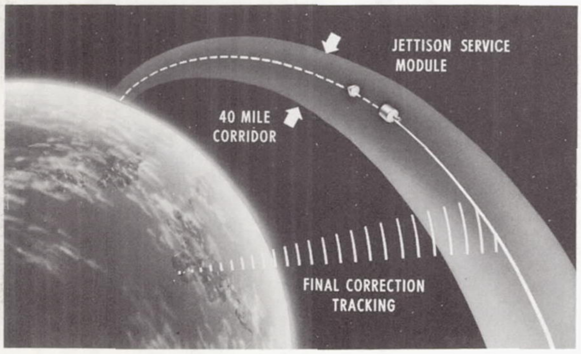

FIGURE 5–17.—Reentry corridor.

FIGURE 5–18.—Terminal descent.

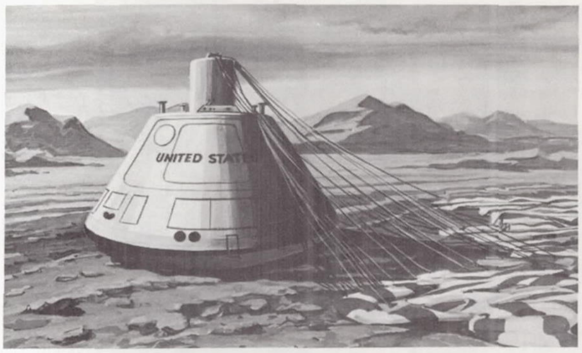

FIGURE 5–19.—Earth touchdown.

In this regard, there are two words often heard in our business these days. One of them is "quality," and the other is "reliability." In simple terms, reliability means the item is designed so that it will work; and quality means that it is built so that it will work. Although we sometimes have a great deal of trouble with quality, it is a more straightforward objective to achive than reliability. You simply work harder at building something, you work harder at inspecting it, and the result is a good piece of equipment—provided it is designed correctly. Someone has said: "Quality cannot be inspected into a product; it must be designed into it!" This is entirely correct. For the purposes of the present paper, though, this should be paraphrased as follows: "Reliability cannot be inspected into a product; it must be designed into it!"

Reliability is a subject less understood than quality, even by members of our profession. Although all agree to the desirableness of reliability, there is considerable discussion regarding how to achieve it. We must examine each and every possible item which could fail and then, to the best of our ability, change the design so that the probability of that individual failure is essentially zero. Then, at last, we can say that we have a product which is designed reliably and which, if manufactured correctly, inspected meticulously, and tested sufficiently, will work.

⑥ Large Launch Vehicles in the Manned Space Program

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The Nation's program to achieve preeminence in space and to insure that the United States occupies first place among the nations of this world in science, in technology, and in conquest of space is critically dependent on the power of the rocket.

Much has been said about the "booster gap" and the effect this situation has had on our position vis-à-vis the Soviet Union. The Soviet Union started well ahead of us in the development of the large rockets so necessary for manned flight. The Soviets have been ahead of us, and are still ahead of us, in their ability to launch reliably large masses into Earth orbit.

However, with the acceleration of our own progress and by the establishment of our program on a sound engineering basis it is possible to surpass the Soviets in time and clearly to establish and demonstrate United States preeminence in manned space flight. Already, early successes with the powerful Saturn I launch vehicle during the past year give confidence that our goals will be reached. The most recent test launching of Saturn in late March was successful in all respects and completes the initial phase of that booster's development. Later in 1963 the second phase involving initial orbiting operations with the two-stage Saturn I will commence.

The purpose of this paper is to describe the intensive effort and broad program underway to provide the family of large boosters necessary for this nation's manned space flight program and lunar landing program. Initially, our manned space flight operations will utilize booster vehicles evolved from U.S. Department of Defense ICBM vehicles. Typical of these vehicles is the Atlas booster used to place the Mercury spacecraft in orbit, as described in previous papers.

The Mercury-Atlas that boosted Astronaut Glenn into orbit February 20, 1962, is shown in figure 6–1. 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).

Similar adaptations of ICBM rockets with other upper stages are utilized for unmanned test operations, lunar probes, and planetary probes, such as the recently successful flyby of the planet Venus with the Mariner spacecraft.

Later, another ICBM, the Titan, will be adapted as booster for manned space operations. There are three versions of the Titan ICBM. Titan I, the smallest and least powerful of the three, is operational, whereas the Titan II is just entering the flight-test stage. This latter carrier, shown in figure 6–2 has been selected by NASA to boost into orbit our Gemini spacecraft 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 its capabilities are expected to be used in the NASA manned space flight program. It was captive test fired in

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Denver, Colorado, on December 28, 1961, and on March 8, 1962, underwent a similar test at the Atlantic Missile Range.

Figure 6–1.—Mercury-Atlas 6 launch.

Then, on March 16, 1962, Titan II successfully made its maiden flight and carried a payload of instruments 5,000 miles over the Atlantic Ocean. Figure 6–3 shows a 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 becames operational, the plan is to use it to orbit the 6,000-pound Gemini two-man spacecraft now under development. In the Gemini project it will be possible to practice rendezvous maneuvers in orbit to help pave the way toward successful completion of the Apollo program.

Much larger than the Atlas- and Titan-based carriers are three space vehicles being developed by NASA under the Saturn program. Saturn vehicles will be capable of sending pay-

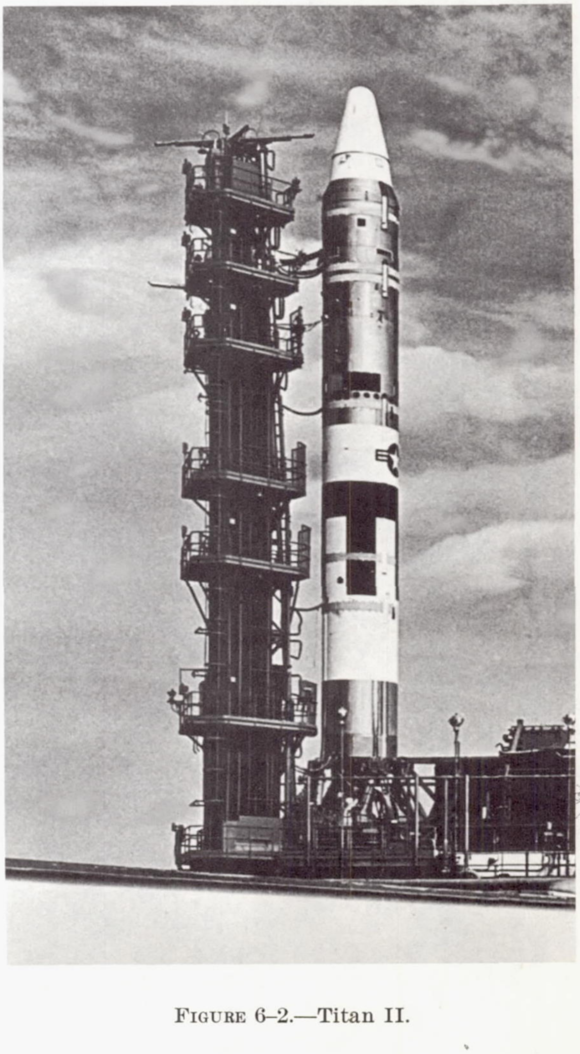


Figure 6–2.—Titan II.

loads of many tons into Earth orbit, to the Moon, and into deep space. The main purpose of the project is manned space exploration which includes 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.

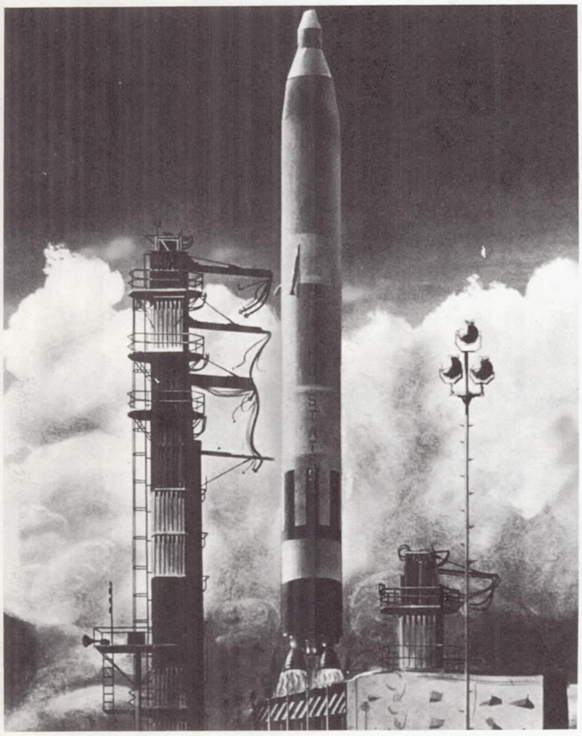


FIGURE 6–3.—Concept of launching of Gemini spacecraft.

The Saturn I configuration consists of two stages, S–I and S–IV. A "third stage" or instrument unit is mounted on top of the second stage to carry guidance and instrumentation equipment. There are two so-called Block I and Block II designs. In the Block I design (fig. 6–4) 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 can be gimbaled for booster control. They burn RP–1 fuel, kerosene with liquid oxygen as the oxidizer. The second (S–IV) stage has been flown as a dummy stage in the first four of the programed 10 vehicle flight test programs.

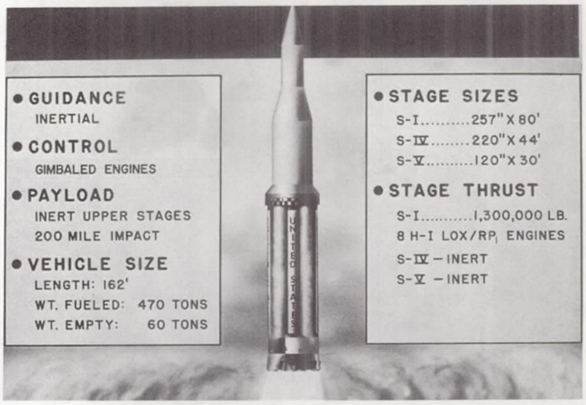


FIGURE 6–4.—Saturn I (Block I) characteristics.

Figure 6–5 shows the first launch of a Saturn I 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. A total of four 100-percent-successful launches were accomplished from Cape Canaveral in the past year and a half, the last being in March 1963.

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 if it were in the cold vacuum of space.

In the Block II design the S–1 stages will have eight H–1 engines each capable of generating 188,000 pounds of thrust at sea level. (See fig. 6–6.) Figure 6–7 is a concept of the Block II design of the Saturn I on launch pad.

After the Saturn I vehicle will come a major modification known as the Saturn IB. An uprated second stage known as the S–IVB will replace the S–IV second stage of the Saturn I. This change will increase the performance of the Saturn I to the extent that 32,000 pounds or a slightly greater weight than a DC–3 can be placed in low Earth orbit as compared with 22,000 pounds for the earlier Saturn I. This

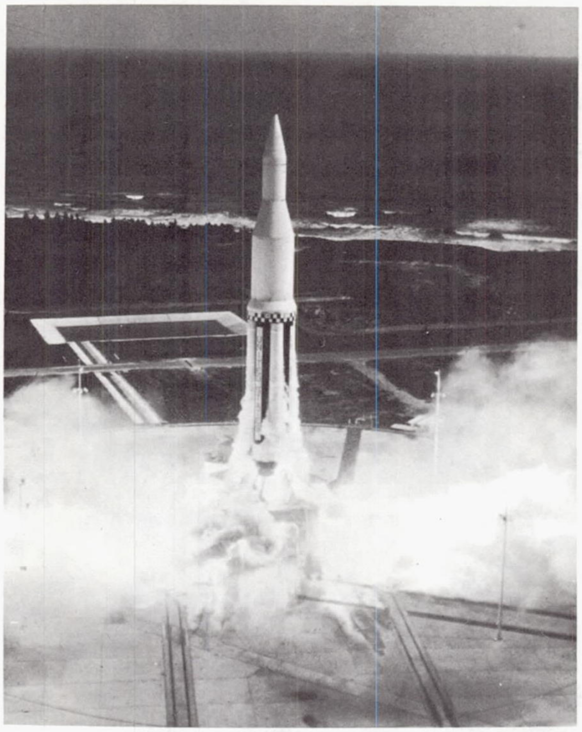


FIGURE 6–5.—Launch of Saturn I.

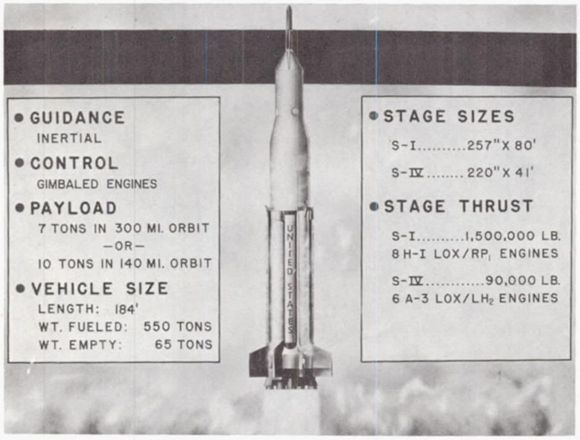


FIGURE 6–6.—Saturn I (Block II) characteristics.

upgrading will allow earlier experiments with the Apollo spacecraft than would be possible with only the Saturn V lunar rocket.

After the Saturn I and IB will come Saturn V or, as it is sometime called, the Advanced Saturn. The Saturn V will be 33 feet in diameter and have a lift-off weight of more than 6 million pounds. First stage of the Saturn V will be powered by five F–1 kerosene–liquid-oxygen engines which yield a total thrust of 7.5 million pounds. This thrust is five times that of the first-stage booster of Saturn I. The second stage of Saturn V will be powered by five J–2 liquid-hydrogen—liquid-oxygen engines each of which will provide 200,000 pounds of thrust. The third stage is powered by a single J–2 engine. The Saturn V will be capable of placing a payload in excess of 200,000 pounds into low Earth orbit, or of speeding 90,000 pounds out into deep space. (See fig. 6–8.)

The secret of the tremendous lift-off strength of Saturn V is the F–1 engine, shown in the background in figure 6–9. Eight of the H–1 engines, shown in the foreground, are clustered in the first stage of the Saturn I. At one jump a "single barrel" engine that will have the same thrust as all eight H–1 engines, that is 1½ million pounds, has been obtained. Like the H–1,

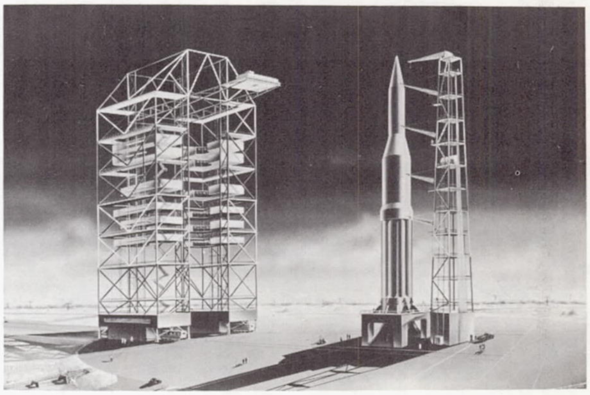


FIGURE 6–7.—Concept of Block II design of Saturn on launch pad.

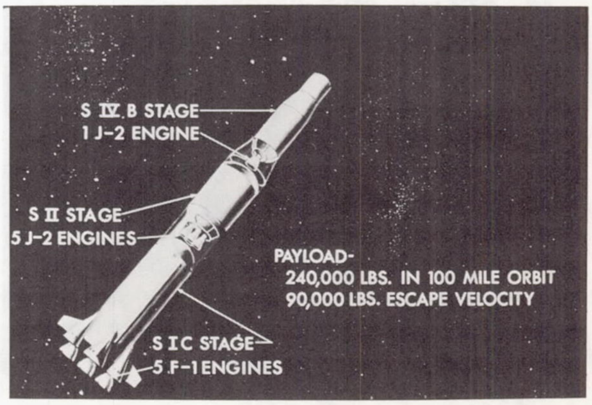


FIGURE 6–8.—Saturn V.

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, California, in full-duration tests at maximum proficiency. (See fig. 6–10.)

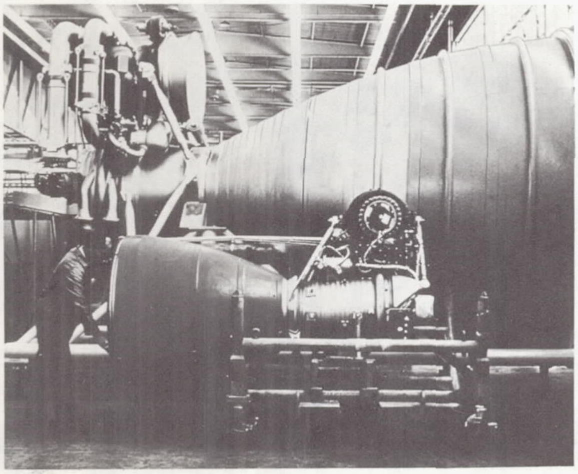


FIGURE 6–9.—H–1 and F–1 engines.

The S–IC will be the first stage of the Saturn V. (See fig. 6-11.) Preliminary planning for the booster is underway at the Marshall Space Flight Center at Huntsville, Alabama. A contract for its development and fabrication has been signed with The Boeing Company. Nine flight boosters and one ground test version are to be produced at the Michoud Plant in New Orleans. Static testing will be at the Marshall Space Flight Center Mississippi Test Facility, 35 miles east of New Orleans, which is being carved out of an isolated swamp near the Pearl River.

The S–II will be the second stage of the Advanced Saturn vehicle. (See fig. 6–12.) A contract for its development and production has been signed with the Space and Information System Division of North American Aviation, Inc., and early work is in progress. The S–II, like the S–IC, will be 33 feet in diameter. The J–2 engine is under development by the Rocketdyne Division of North American, the first delivery to NASA being expected in 1963.

The third stage of the Saturn V vehicle will be known as the S–IVB, a modification of the S–IV stage which is used on the Saturn V. (See fig. 6–13.) A contract for the modification and production of the unit has been signed with Douglas Aircraft Company, Inc. The length of the new stage will be increased to approximately 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

FIGURE 6–10.—Static firing of F–1 engine.

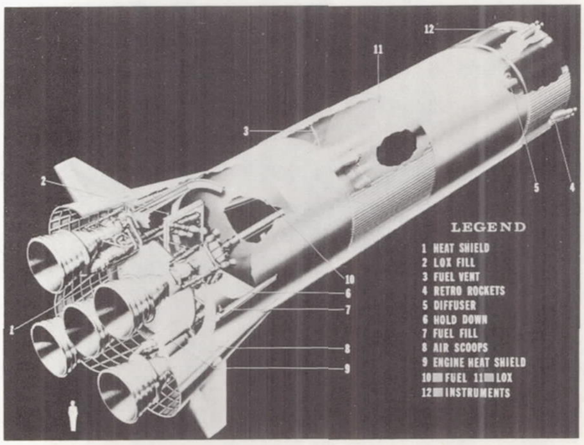


FIGURE 6–11.—Saturn V booster.

new stage will have a thrust of 200,000 pounds compared with 90,000 in the S–IV.

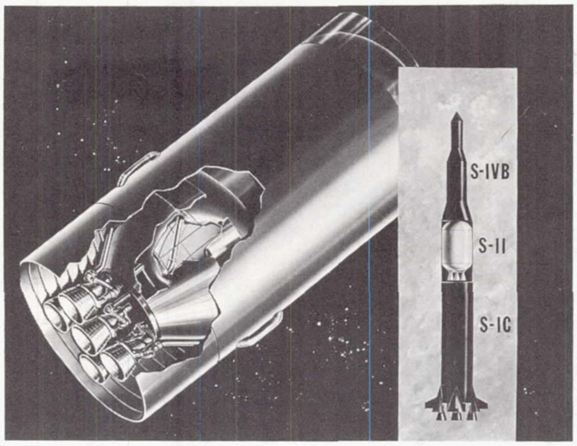


FIGURE 6–12.—S–II cutaway.

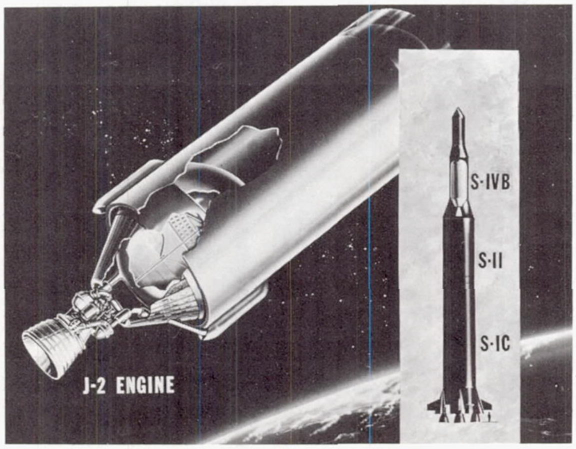
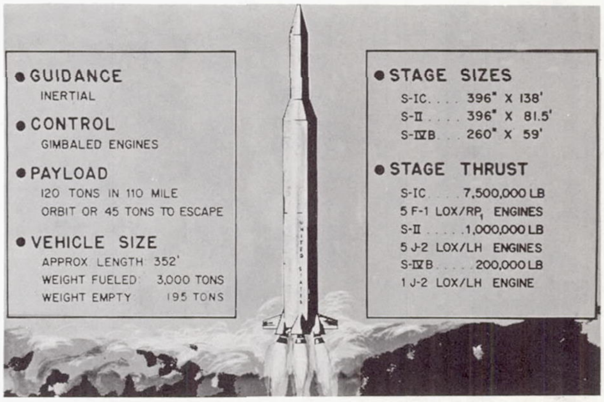


FIGURE 6–13.—S–IVB cutaway.

Figure 6–14 summarizes the characteristics of the Saturn V. The Saturn I will be used to place Apollo spacecraft carrying three men into Earth orbit for a period up to 2 weeks. The Saturn V will be used for sending the three-man spacecraft around the Moon. It will also be used for manned lunar landings with the lunar rendezvous technique.

Beyond the Saturn I, Saturn IB, and Saturn V, studies of other advanced vehicles are underway to provide payload capacities for even greater payloads on the Moon or for interplanetary missions. These studies, sometimes known as Nova studies, are in an advanced state. Also under active development are more powerful engines for these future requirements. For example, the M–1 engine having a thrust of 1.5 million pounds using liquid hydrogen and oxygen is well underway as a critical long lead-time item. Ultimately, a recoverable and reflyable space booster for economical and routine operation is sought.



- GUIDANCE
  INERTIAL
- CONTROL
  GIMBALED ENGINES
- PAYLOAD
  120 TONS IN 110 MILE
  ORBIT OR 45 TONS TO ESCAPE
- VEHICLE SIZE
  APPROX LENGTH 352'
  WEIGHT FUELED 3,000 TONS
  WEIGHT EMPTY 195 TONS

- STAGE SIZES
  S-IC.... 396" X 138'
  S-II.... 396" X 81.5'
  S-IVB... 260" X 59'
- STAGE THRUST
  S-IC.... 7,500,000 LB
  5 F-1 LOX/RP_1 ENGINES
  S-II..... 1,000,000 LB
  5 J-2 LOX/LH ENGINES
  S-IVB.... 200,000 LB
  1 J-2 LOX/LH ENGINE

FIGURE 6–14.—Saturn V characteristics.

Most of NASA's large space carrier vehicles are launched from the Atlantic Missile Range at Cape Canaveral, Florida. A very major expansion of the Cape Canaveral launch area is underway on Merritt Island, Florida, known as the Merrit Island Launch Area (MILA). The two Saturn vehicles which have already been successfully launched were flight tested from the NASA Vehicle Launch Facility 34 shown in figure 6–15. This facility occupies 45 acres of the 20,000 acres of the Atlantic Missile Range and was completed in June 1961. The word complex is a good one to describe this facility. The major elements of the facility 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.

The Launch Control Center, the nerve center of the complex, is a reinforced concrete blockhouse 156 feet in diameter at the base and 26 feet tall. (See fig. 6–16.) The blockhouse is designed to withstand blast pressures 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 is the electrical terminal area and contains the telemetry equipment and other communications equipment. The upper level (fig. 6–17) has the instrumentation controlling the actual servicing, launching, and guidance of the vehicle into orbit. At that point control is assumed by the Mission Control Center described by James C. Elms in the preceding paper.

The service structure, used to erect the Saturn on its launcher and to check out the assembled vehicle, is 310 feet high. (See fig. 6–18.) Each of its two supporting legs contains a two-floor building that houses the operating equipment and vehicle checkout apparatus of the structure.

Figure 6–17.—Instrumentation controlling servicing, launching, and guiding of vehicle into orbit.

Figure 6–15.—NASA Vertical Launch Facility 34.

Figure 6–16.—Launch Control Center.

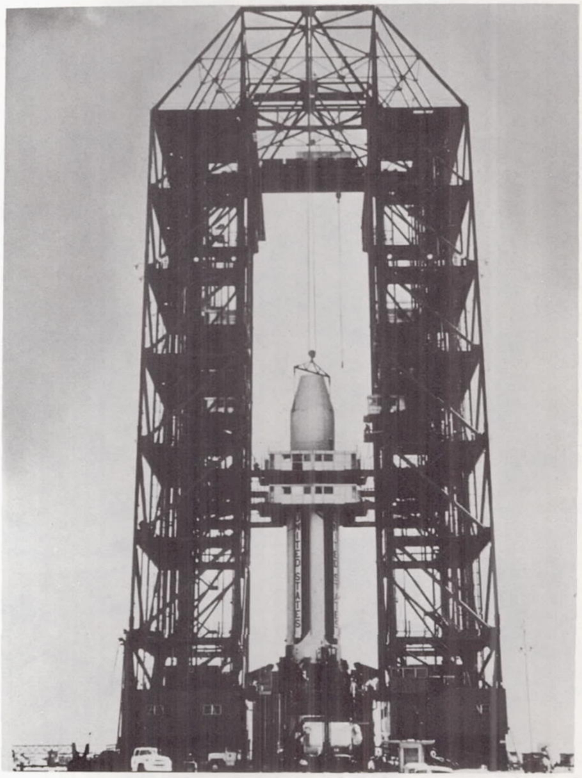


Figure 6–18.—Service structure.

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 a launching pedestal, a launcher, and a flame deflector. An aerial view of Vertical Launch Pad 34 is shown in figure 6–19. The pedestal is made of reinforced concrete and is 40 square feet and 27 feet high. On top of 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 240-foot umbilical tower adjacent to the launcher pedestal, which contains the electric, hydraulic, and pneumatic lines for supplying each stage. It is structurally complete now, but only one swing-arm has been installed to date because we have been firing only inert upper stages. By the time the first complete Saturn is flight tested all three swing-arms will have been installed.

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 6–20 shows a Saturn on the launch pad.

Vertical Launch Complex 37 is located about 1 mile north of Complex 34, but unlike Complex 34, it will have two pads served by the same support facilities. (See fig. 6–21.) 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.

In the future, to handle and launch Saturn V 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. (See fig. 6–22.) These new installations will require bold new means of handling extremely large and heavy vehicles. But already plans are being made for the time when these sites must be constructed, and a few concepts have emerged.

Figure 6–23 is an artist's concept of an aerial view of Launch Complex 39. Around the Vertical Assembly Building, shown at the lower left, are the Crawler assembly area, three Launcher-Umbilical Towers (L–UT) erection

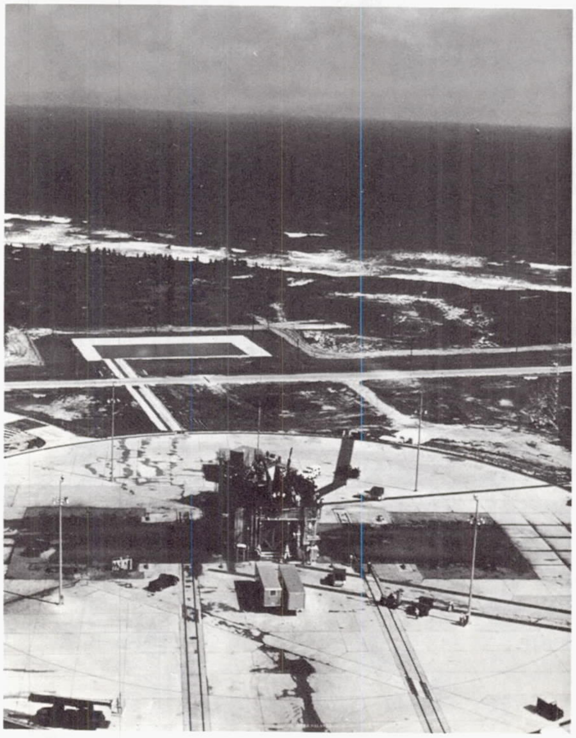


FIGURE 6–19.—Vertical Launch Pad 34.

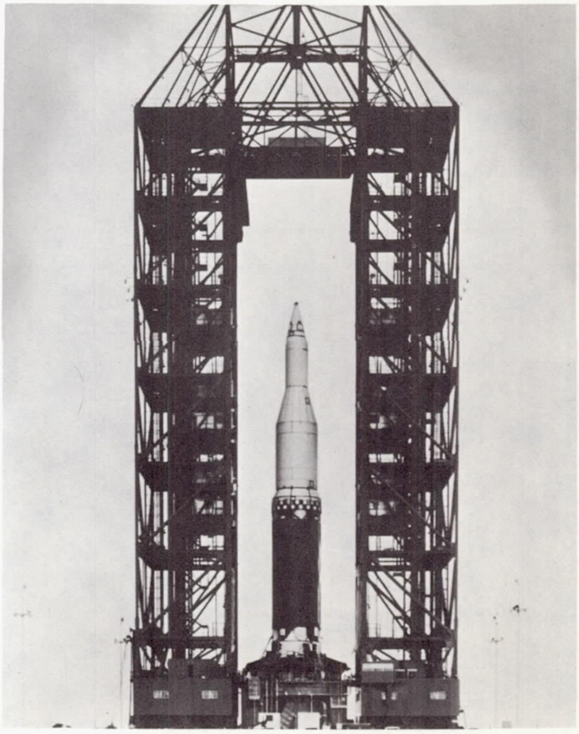


FIGURE 6–20.—Saturn on launch pad.

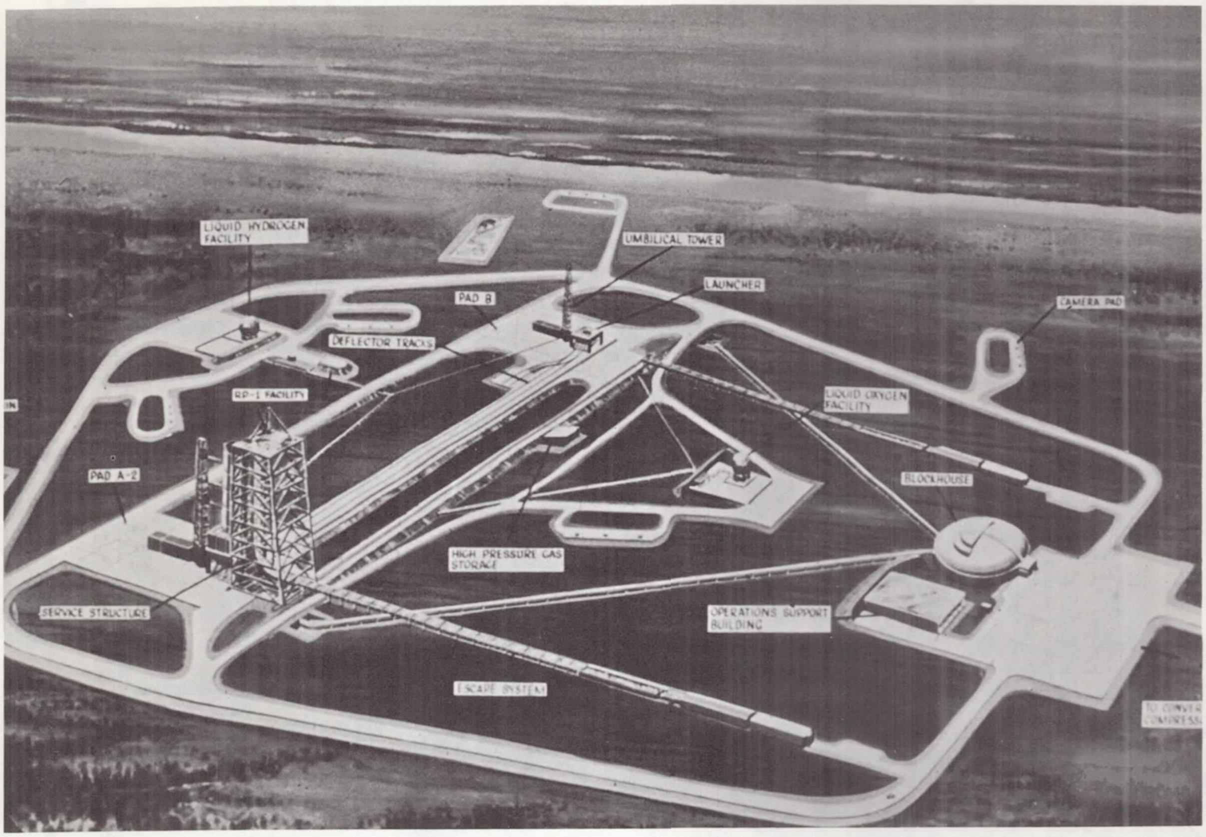


FIGURE 6–21.—Concept of Vertical Launch Facility 37.

and refurbishment sites, and the ordnance stowage facilities. Along the crawlerway to the pads are the high-pressure gas facilities and the Arming Tower park position. Below the crawlerway are the turning basin and the access channel through which all the stages arrive. The small buildings along the crawlerway are amplifier facilities for the data-link transmission lines. Also, three pads with a tentative siting of a fourth, in the event that such a need should arise, may be seen.

Figure 6–24 shows an overall concept of Complex 39 which gives a clear view of the Vertical Assembly Building, the working center of the launch complex. Set on pilings which penetrate 170 feet of this Florida swamp for firm support, the high bay alone measures 524 feet high, 418 feet across the entrances to the bays, and 513 feet deep. The low bay area has a maximum height of 210 feet, adds a width of 256 feet to that of the overall structure, and has various depths at different heights. Associated with this structure are the Launch Control Center and a Utilities Annex. The high bay alone encompasses some 128 million cubic feet.

The high bay area is structurally configured to handle the assembly, the readying, and checkout of four Saturn V vehicles simultaneously in four bays. The low bay is configured to accommodate four of the second stages in an upright position on one side of a center transfer aisle and four of the third stages on the opposite side of the aisle. The first stage receives its individual checks in one of the high bays on the Launcher–Umbilical Tower.

Operationally, all stages come into the center transfer aisle which extends the length of the low and high bay areas. The first stage is placed immediately on the Launcher–Umbilical Tower in one of the high bays. The upper stages, once completely checked out as stages, are transferred down the transfer aisle by means of an overhead bridge crane of 150-ton capacity into the high bay area adjacent to the bay re-

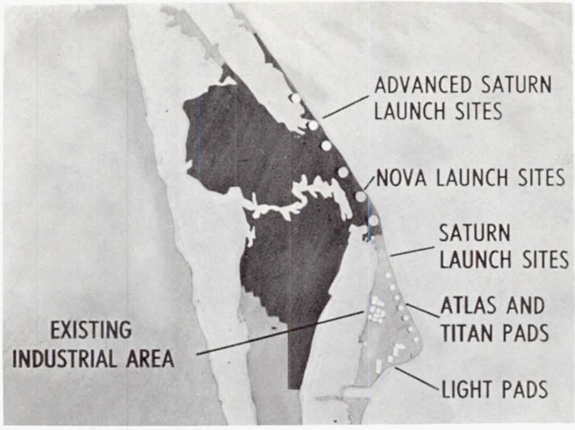


FIGURE 6–22.—Cape Canaveral.

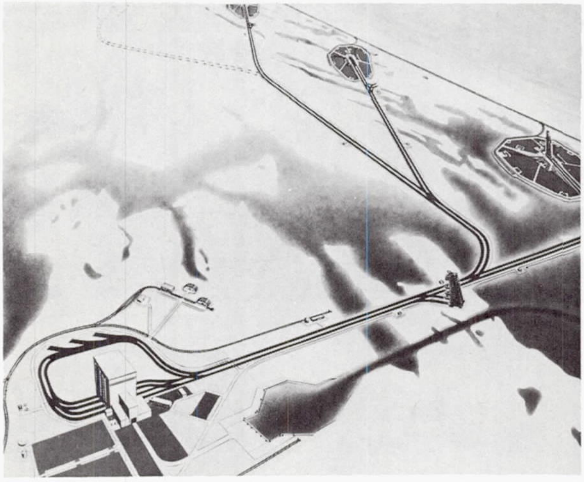


FIGURE 6–23.—Concept of Launch Complex 39.

ceiving it. It is then picked up by the overhead bridge crane serving a particular pair of opposing bays and transferred outboard and placed in position. This crane handles 250 tons and has a hook height of 456 feet. When the integrated checkout of the entire vehicle and spacecraft combination is completed, one of the crawler-transporters picks up the Launcher–Umbilical Tower—vehicle combination and carries it to the launch pad.

The two-story building to the left of the turning basin (fig. 6–24) is the high-pressure gas storage facility used to store gases necessary in the vehicle checkout in the Vertical Assembly Building. The vehicle, launched straight and true from Pad B, can be seen in the background.

Figure 6–25 is a view of the L–UT and vehicle combination in place on a launch pad with the mobile arming tower in position adjacent to it. These are brought into position in two separate operations by the crawler-transporter shown being withdrawn from the area. The L–UT is composed of two basic and identifiable portions, the platform measuring 135 feet long, 160 feet wide, 25 feet thick and the tower approximately 395 feet over the platform deck. This platform structure mounts the launch pedestal which supports the vehicle prior to launch, the water deluge systems, and so forth, as well as houses all the computers and other electronic devices which are part of the checking out equipment and which

FIGURE 6–24.—Vertical assembly building and area.

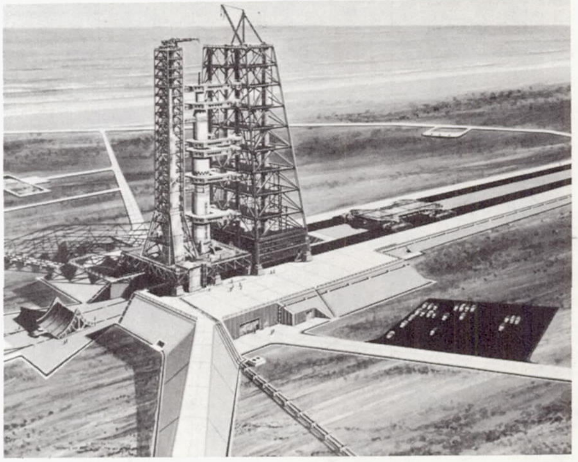


FIGURE 6–25.—Concept of Launcher-Umbilical Tower and vehicle.

keep the vehicle under surveillance during transit to the pad. The tower carries the eight swing arms that provide all of the on-pad access, fueling, cryogenic loading, and electronic monitoring required on the pad. The hammerhead crane on top of the tower, used primarily for swing-arm installation, has a capacity of 25 tons with 10-ton capability over the vehicle. The L–UT is estimated to weigh 11.5 million pounds, the empty vehicle adding about ½ million pounds for a 12.0-million-pound load to be transported.

The arming tower primarily provides external access to the sides of the vehicle for the attachment of explosive ordnance, retrorockets, ullage rockets, and so forth, deemed too dangerous for attachment in the Vertical Assembly Building. It serves a secondary function of providing on-pad external access to the vehicle for servicing minor items which otherwise might require return to the Vertical Assembly Building. It has a base of 125 feet by 150 feet and stands 415 feet tall not including the 75-ton-capacity stiff leg derrick. It is estimated to weigh about 7.0 million pounds.

In conclusion, a few words might be said about the manufacture and testing of large space carrier vehicles. While developing Saturn at the Marshall Space Flight Center, it became obvious that a large fabrication and assembly building would be required when the vehicle went into production. Such a plant was located in September 1961; the Michoud Plant is shown in figure 6–26 and is approximately 15 miles east of New Orleans. This one-story building encloses more than 40 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–I first stage for the Saturn I and will produce 20 of them during the length of its contract. Also at Michoud, The Boeing Company will produce at least 15 S–IC stages, the first stage for the Saturn V.

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 6–27 will be constructed; these test stands will be capable of testing boosters with thrusts up to 20 million pounds.

This summary of the Nation's program to provide vehicles for the assault on the Moon indicates that progress is being made. The grand "countdown" is underway toward the goal of landing a U.S. astronaut on the Moon and bringing him back in this decade.

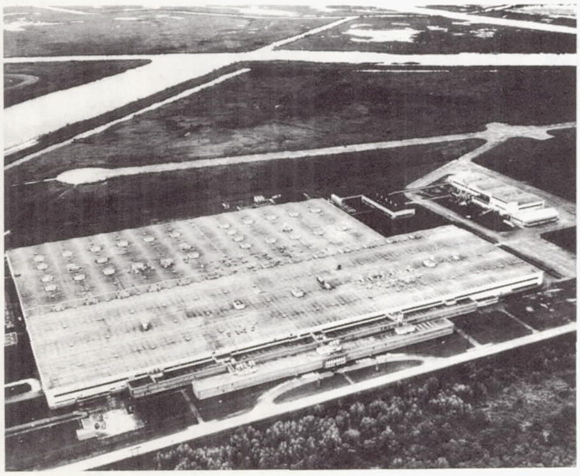


FIGURE 6–26.—Michoud Plant.

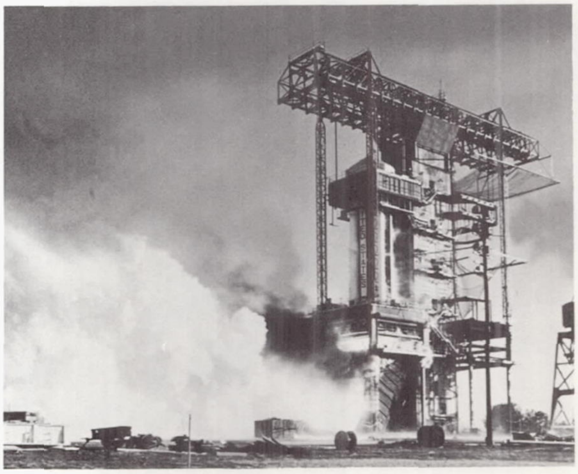


FIGURE 6–27.—Static test stand.

7 The Human Factor in Manned Space Flight

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Office of Manned Space Flight, NASA

To many concerned with the exploration of space it has been apparent for a long time that because of his enormous curiosity and his willingness to probe the unknown, man would probably not let the first reasonable opportunity to go into space go by unnoticed. This reasonable opportunity has been made available to us by way of the rockets developed as a result of the missile program. As is well known, it has been possible to contain and maintain man in a modest circular orbit for a relatively short period of time. Plans are laid to extend gradually the duration of these orbital flights to a maximum of 14 days in the near future. Such flights will serve to establish our readiness and proficiency for the landing of a team of American astronauts on the surface of the Moon in this decade.

To date, the flight experiences have produced no significant physiological abnormalities that can be attributed to the space environment. It has been established that man can perform safely and effectively as a participant in space flight missions. In Project Mercury missions it has become apparent that he can perform at least as efficiently as in the cockpit of an airplane for as long as 9 hours. In addition, the inclusion of man as an occupant of the spacecraft has provided many advantages as a result of his unique capabilities. Man adds considerably to system reliability and the likelihood of mission completion; he provides logic and a decision-making capability. In flight he is able to diagnose trouble and make necessary adjustments. If necessary, he can act to cope with the unexpected.

It must be borne in mind, however, that all of these benefits are contingent upon our ability to provide man with a suitable environment during the flight. Even the most carefully selected astronaut crew can survive only if provided an Earth-equivalent environment.

It would appear that a satisfactory approach to the human factor in manned space flight might be found in a discussion of the biomedical activities making up our space medicine program which are made necessary by the introduction of man as a participant in the space flight mission.

These activities are divided into two broad general categories: (1) development, test, and evaluation of components and systems required to insure man's survival and safe effective performance in space flight, and (2) the operational medical support incident to the selection and maintenance of flight crews, their preparation for flight, surveillance during flight, and evaluation upon termination of the flight.

The first category of activity is the responsibility of the Crew Systems Division of the Manned Spacecraft Center. The Crew Systems Division is responsible for the development of systems for the control of spacecraft environment. It also provides personal equipment for crew members, such as pressure suits and survival gear. It evolves means by which the astronauts are protected from radiation hazards. It determines the requirements for life support in all phases of the space mission and it provides physiological instrumentation and medical analysis of crew performance. Standards are set to provide guides for prime and associate contractors and subcontractors. Development programs are conducted in cooperation with Department of Defense laboratories, universities, medical facilities, government agencies, and scientific organizations.

Within the division, equipment which cannot be obtained elsewhere is designed and constructed. Whenever possible, existing facilities are brought to bear on design problems in order to provide timely data which meet the needs of the National Aeronautics and Space Administration and to provide a source of information for other programs and organizations. Whenever possible, existing materials and equipment are adapted to keep pace with the accelerated space program while maintaining a minimum requirement for new concepts. A review of the development of the space suits which protect the astronauts and provide them with a suitable environment indicates how current equipment is adapted to meet new requirements.

When the Mercury space suit was developed, for example, work began with the Navy's Mark IV pressure suit as a basic unit. Performance requirements were established and a long list of modifications were made to insure sufficient mobility and comfort. Provision for instrumentation and other adaptations for the space flight program were added. Other suit designs are employed in the development program and suits presently in use are modified as solutions are achieved. Working with contractors and in its own laboratories, Crew Systems helps to originate new concepts and determines that the requirements of the program are met in the final design. Constant testing and examination are necessary to keep pace with the demands of new missions. A prototype of the suit which may be used in the Gemini flight is evaluated to make certain that the specific requirements of that mission will be satisfied. The final Gemini suit must be adapted for partial wear in order to provide habitability during missions up to 14 days in length. Intensive effort attends the development of the pressure seals. They must be easy to assemble and absolutely reliable. An important part of space-suit development determines the dexterity which can be achieved within the Gemini spacecraft mockup. The space suit must permit the craft to be entered with reasonable ease. The extent of reach must be evaluated under both pressurized and unpressurized conditions. All of the motions necessary to turn on switches and handle other equipment must be checked. A thermal coverall may be required to permit operations outside a spacecraft during flight.

The design requirements for the pressure suit which will be used ultimately for the Apollo lunar flight are determined. The Apollo pressure suit will be complete with its own life support system to permit the astronauts to move about on the lunar surface for periods of up to 4 hours without any supply requirements on the spacecraft. Crew members must be able to remove the suit and put it on in a confined space. Considerable effort is spent in the analysis of landing forces in order to provide data on which to base the design of the equipment used to protect crew members from injury. The sinking speed of a spacecraft determines the magnitude of the vertical component of the impact force. The horizontal drift due to wind is another prime component of the impact force applied. In addition to these, other variables add complexity to the problem. Since the goal is to insure that crew members may experience impact without suffering physical injury, the interrelationship of all the landing forces must be carefully examined in order to develop impact-attenuation devices and other equipment to protect the crew members. The Manned Spacecraft Center conducts a comprehensive program to establish the tolerances and limitations which must be observed in providing impact protection. The Wright Field biomedical laboratory in cooperation with the Aeromedical Field Laboratory of the U.S. Air Force and the Navy Air Crew Equipment Laboratory has amassed the necessary data through an extensive NASA supported program of drop tests in which human subjects are employed. These tests establish the maximum g units which can be tolerated under various environmental conditions. At the Aeromedical Laboratory, physiological tolerance data on the effects of prolonged vibration are accumulated during dynamic tests. Experimentation is being concentrated on vibration in the supine position for which no previous data were available. This program typifies the efforts of the NASA to utilize existing national capabilities to solve critical voids in bioastronautic data and thus to establish common research programs useful to other technical activities. This information aids in the development of such spacecraft items as a new net support couch which may be employed in future flights. The net fabric stretches on impact and thus absorbs shock. It saves considerable weight which is of importance since approximately 100 pounds of booster must be employed for each pound of payload placed in orbit. Using a special drop-test device developed from a surplus ejection seat training tower obtained from the Department of Defense, engineers check the net couch with the aid of an anthropomorphic dummy. The impact resulting from the 30-foot-per-second sink speed of the spacecraft in the parachute descent is simulated as the stretch of the material is carefully measured to determine its effectiveness.

Special survival gear is developed to meet the unique requirements of the Manned Space Flight program. In addition to the need for complete reliability, survival equipment must be light in weight and require very little storage space. Life rafts, special survival vests, water tanks, auxiliary equipment such as special flashlights, knives, and ancillary items have been developed within the division. The in-house construction facilities have been of considerable assistance in cutting the time required to provide such survival gear as the special lightweight three-man life raft to be used in Project Apollo. A cape over the one-man Gemini life raft provides protection from the elements. It also may be detached to provide a rain-protection poncho. A newly developed inflatable radar reflector is carried in a package about the size of an ordinary envelope. It requires only three or four breaths for inflation. Floating in the water it can reflect a radar signal at a range of 50 or 60 miles to help direct recovery crews. The speed with which survival equipment needs can be met is exemplified by the need for an extremely lightweight emergency life vest which was demonstrated during Astronaut Grissom's flight. In less than 3 months an extremely small, easily used, and lightweight vest was designed, evaluated, manufactured, and tested with the Center's in-house construction facilities. When Astronaut John Glenn boarded his spacecraft, the tiny new vest was contained in a yellow envelope on the front of his space suit.

Continuous examination of radiation phenomena is required in our manned space flight program. Investigations determining the extent and configuration of the radiation belt surrounding the Earth are conducted by the National Aeronautics and Space Administration personnel. The potential hazards resulting from radiation present in the inner and outer Van Allen belts and solar proton events encountered beyond the belts are the subjects of intensive study. In the current Earth orbital mission, radiation from the inner Van Allen belt is not encountered since the altitude of these flights is below the belts. However, because of an increase in radiation stimulated by the recent high-altitude nuclear test, it was thought that a portion of the belt over the South American continent might be encountered at the Mercury altitude. Checking the increased radiation by means of dosimeters attached to Astronaut Schirra's orbiting spacecraft, it was determined that the nuclear-test-induced radiation was negligible and posed no problem. Dosimeters were qualified for this flight by placing them on the spacecraft hatch and subjecting them to radiation in a powerful simulator. During future orbital space flights the amount of radiation will be recorded both inside and outside the spacecraft by dosimeters placed on the hatch and on the retropack. These measurements will provide data which are essential to verify the theoretical calculation of the required spacecraft shielding. Although the Apollo flights will pass through the Van Allen Belts, the time of exposure will be short. However, the radiation encountered will be carefully measured with dosimeters in order to keep an accurate record of the astronaut's exposure and to make certain that the allowable limit is not exceeded. Once beyond the belt, the spacecraft and its occupants may be exposed to radiation as a result of solar proton events. The intensity and frequency of such encounters must be established in order to determine the shielding requirements. The Atomic Energy Commission is conducting radiation studies under a Manned Spacecraft Center contract to determine the suitability of various materials for use in the construction of the Apollo spacecraft. Some materials which would be desirable for structural use cannot be employed because of the extent of the hazardous secondary radiation they produce under proton bombardment.

In order to meet the need for information regarding the physiological characteristics of healthy subjects under high stress, a ground-based program is being conducted. Much of the stress information previously available was concerned only with individuals having physical abnormalities. A library of electroencephalograph tracings and other physiological data for 200 healthy individuals is being compiled and subjected to various analytical techniques in order to provide information regarding normal subjects under stress. Hormone chemistry investigations are conducted to determine the physical demands of continuous high stress in space flight. A series of automatic syringes have been designed for use in space flight to provide self-administered medication. Four different drugs including those to control motion sickness, pain, a stimulant, and a depressant are furnished. With one hand, the needle is activated, penetrates the suit layer, and discharges the medication.

Many of the bioinstrumentation techniques employed in development and during flight require the application of measurment electrodes to the body surfaces. The earlier wet electrodes cannot be used for long-duration space flights because of skin irritation. New dry electrodes which eliminate the use of a paste have been developed. In one of the new dry electrode techniques, silver nitrate is applied to the skin to provide the electrical continuity required.

Because of the broad range of problems involved in manned space flight, many of the developments originated and constructed by the Crews Systems Division and many of the programs which are conducted under its supervision have wide application in other areas of vital national interest. The long-wear body electrode concepts are being investigated for use in hospitals where they are used to monitor the condition of critically ill patients. The automatic syringes have valuable applications in Civil Defense disaster kits and in certain Department of Defense programs. Several of the survival gear innovations also meet other requirements. The general information which has been accumulated regarding the effects of stress on normal subjects is a valuable contribution to the general knowledge of human physiology.

Working with government research laboratories, employing the Nation's developmental and test facilities, working with contractors, adapting presently available equipment, modifying systems and gear to meet future requirements, and providing rapid solutions to immediate problems are the tasks and challenges met every day. The accomplishments are manifold: space suits, survival gear, restraint systems, life support systems, food, medication, and the accumulation of research information vital to the national interest. Taking primary responsibility for providing these items of flight equipment fully qualified and ready for flight use is the mission of the Crew Systems Division of the Manned Spacecraft Center.

There is also a group of carefully selected medical personnel—the Medical Operations Group at the Manned Spacecraft Center—charged with the responsibility for the medical portions of the actual flight operation. Their activities include the medical selection of astronaut candidates, the medical training of those candidates selected, a rigorous medical maintenance program to insure the continuing physical fitness of these men during training, the medical preparation of astronaut crews for specific flight missions, the design of medical experiments to be performed in flight, the medical monitoring of crews in real time during the flight mission, the provision of medical support as part of recovery operations, and the physiological evaluation of the crew upon the completion of a flight mission. One of the most significant contributions of this Medical Operations Group is the preparation of a postflight medical report in which is summarized all of the medical data pertinent to a given flight. This report includes data related to the crew (acquired during their training), baseline data obtained immediately prior to flight, inflight data developed by biotelemetry relayed to the ground and interpreted by medical monitors at tracking stations along the global communications network or recorded on board the spacecraft and analyzed during the postflight period, and the results of a searching medical examination conducted during the period immediately following completion of the flight mission. All these data, interpreted and evaluated, become a postflight medical report. This report constitutes an invaluable aid in planning future missions. This report also guides the planning of both basic and applied research. It also documents the progress toward the medical goal of establishing man's ability to live safely and perform effectively in the hostile space environment.

The small group of National Aeronautics and Space Administration biomedical specialists making up the Medical Operations Group are ably and enthusiastically assisted by a large group of carefully screened personnel made available by the Department of Defense. For an average orbital mission, approximately 16 Department of Defense specialists and technicians assist the recovery forces and a group of about 10 top-level clinical specialists stand by at selected hospitals, alerted for deployment should an unforeseen emergency arise. There is no appreciable change foreseen in our need for Department of Defense medical support in early Gemini flight operations. However, as the flight safety problems incident to manned space flight are reduced by experience and increased vehicle reliability, it is to be expected that our need for extensive emergency medical support will be reduced accordingly.

This paper is a brief description of the activities carried out in support of the human occupant of our spacecraft. In conclusion, it is worthy of note that, to date, man has demonstrated his ability to take space flight in stride. With flight experience it has been possible to validate the concepts on which our present life support systems were based. Peculiar constituents of the space environment, such as the weightless state, have not proven to be serious problems and an acceptable degree of reliability in the components of our life support systems has been developed.

Indeed there is confidence that the biomedical needs of our currently approved manned space flight program can be met within the scope of our existing technology.

8 The Research Basis for Future Space Programs

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Those who operate the industrial firms of our day have learned that continued progress cannot depend solely on promotion based on technology of the past and present, but that a sharp cutting edge of advanced research is necessary for progress, and, in time, survival itself. Unless a reasonable fraction of profits is expended to bring along new ideas for replacement of old, all technological enterprises drift slowly to stagnation, whether they are industrial or commercial firms, a government agency, or even a nation. So it is with the space program.

It is our firm conviction that preeminence in space requires a balanced use of our resources in which a certain fraction of them, something like 10 percent, is invested in research looking toward space operations beyond the current projects and missions. There are four principal areas where a continuing and driving program of research is required if our nation is to achieve preeminence in aeronautical and space activities in the decades to come. These are energy conversion and propulsion; materials and structures; control, guidance, and communications; and space sciences and the environment of space.

The challenge of the future in the field of energy conversion and propulsion embraces some of the most difficult problems faced by mankind. Man's efforts to propel himself along the surface and above the earth have always involved an energy conversion cycle which converts energy supplied by nature into thrust or torque. In space applications, we are interested, in general, in two types of energy converters: a propulsion device to supply thrust, and an onboard power supply. The three principal sources of energy are chemical, solar, and nuclear. All three are exploited in advanced research in our national space program.

The largest existing space boosters utilize as much of the energy as our technology will permit us to extract from the propellant combination of liquid oxygen and kerosene. The growing need for more powerful and efficient chemical engines has spurred research into higher energy propellant combinations—oxygen and hydrogen, fluorine and hydrogen, and oxygen-difluoride and diborane, to name a few. At present, these propellant combinations are considered especially promising for use in upper rocket stages.

Figure 8–1 illustrates a possible next generation in chemical rocket engines having a thrust of about 24 million pounds. If the state of technology underlying the F–1 engine were scaled up to a 24-million-pound engine, we would obtain the monstrous engine shown second from the left. If we make use, however, of new research advances, we could develop an engine with a configuration such as shown by the sketches at the right.

However, the most promise for increasing performance of upper stages is believed to lie in the nuclear rocket which is being developed as Project Rover under the joint sponsorship of

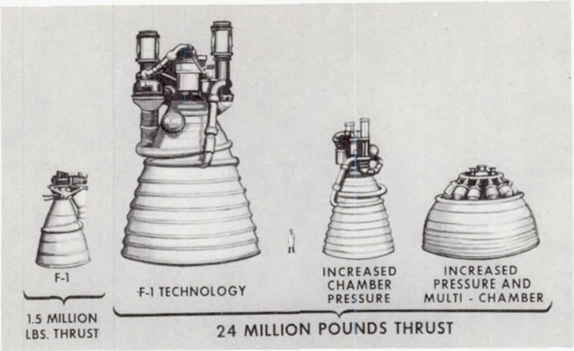


FIGURE 8–1.—Scale-up of conventional and advanced concepts.

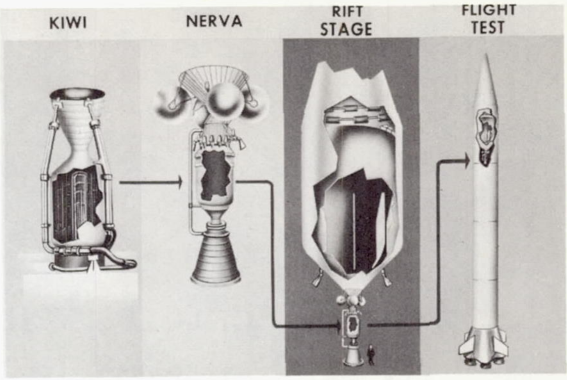


FIGURE 8–2.—Major steps in nuclear rocket program.

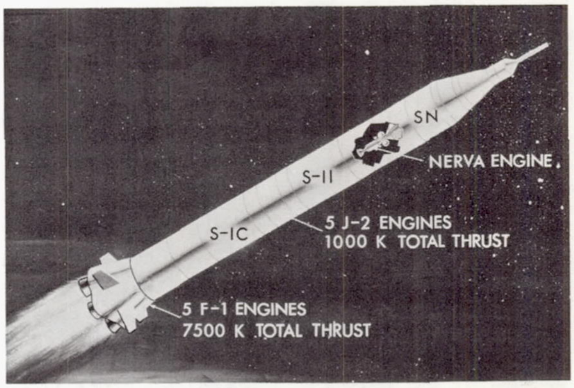


FIGURE 8–3.—Nuclear Saturn V concept.

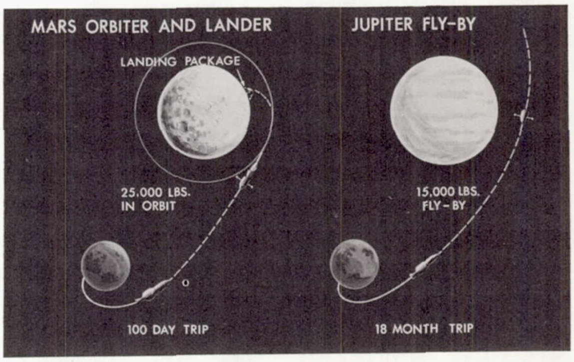


FIGURE 8–4.—Interplanetary missions with operational version of Rift stage.

the Atomic Energy Commission and NASA. The nuclear rocket employs uranium-loaded solid-fuel elements. A propellant such as hydrogen is pumped through the fuel elements, whence they are heated to temperatures approaching 5,500° F. The heated propellants expand as gases through a nozzle to produce thrust. Although some difficulty has been experienced in developing the nuclear power source for the Rover engine, known as Nerva, it is our belief that this development will proceed into the flight test stage before the end of this decade.

Figure 8–2 illustrates the major steps in the nuclear rocket program leading from the Kiwi reactor to a flight test of the Nerva engine. Flight tests of the Nerva engine would be conducted as an upper stage of the Saturn V vehicle as illustrated by figure 8–3. The chemically powered S–IC and S–II boosters would in this concept propel the nuclear engine into Earth orbit at which place the engine would be started on a journey to a neighboring planet. Figure 8–4 illustrates two possible missions that could be carried out by means of the nuclear Saturn V concept.

The field of electric propulsion is being given very strong research support in our national space program. Such electrical thrusters as ion rockets, although their thrust may be measured in pounds, could impart very high velocities to spacecraft over extended periods of time. In the contact ionization type of ion engine, cesium propellant is passed through a porous hot tungsten plate which extracts an electron from each cesium atom, thereby producing positive cesium ions. The ions are accelerated by field electrodes and prior to exit through the nozzle are neutralized by the addition of electrons through an electron gun. Figure 8–5 illustrates the building-block concept which is employed in the development of contact ion engines.

Electric thrust devices require onboard electrical generators. For small engines requiring powers of around 3,000 watts, solar or isotopic electric power generating systems must be used. Such systems are under active development. Larger systems will require the use of nuclear energy. An example is the 30-kilowatt Snap–8 double-loop Rankine cycle nuclear-turboelectric space power system shown by figure 8–6. Such systems must employ liquid metals as working fluids. For advanced electric thrusters, nuclear-electric space power systems in the power range of 10,000 watts or more will be required. The difficulties which must be overcome here may be appreciated when it is realized that these systems must weigh less than 20 pounds per kilowatt, and operate reliably over continuous periods of months.

The opportunities for ingenuity in effecting energy conversion in space are limitless. Some of these possibilities are illustrated by figure 8–7, which shows the spectrum of space power sources. Fuel cells are an example of a concept which is being pursued vigorously. These are electrochemical devices similar to batteries except that the reactants are supplied to the cells from external tanks. One version of our fuel cell research involves the employment of human waste as an energy source.

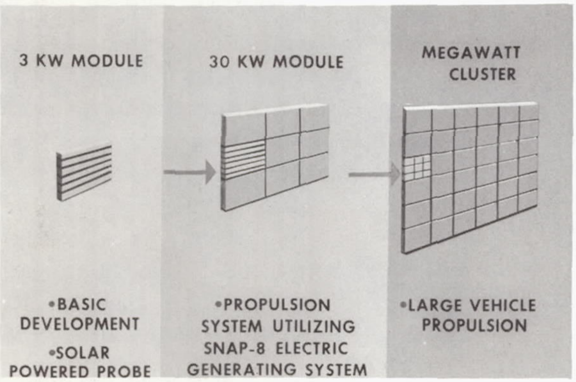


FIGURE 8–5.—Electric engine development.

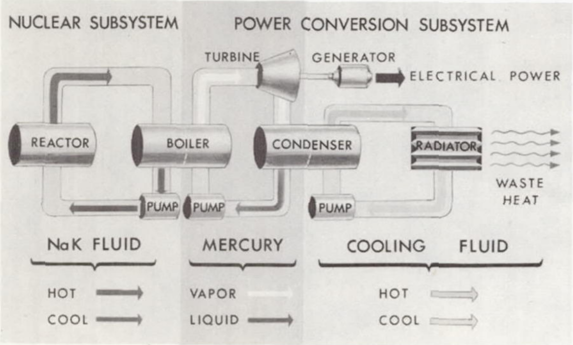


FIGURE 8–6.—Snap–8 electrical generation system (schematic drawing).

Man's engineering achievements have always been linked with his ability to use the materials surrounding him in nature. Only a few years ago, before we possessed capabilities of launching spacecraft or of operating aircraft at hypersonic speeds, the engineering demands could be satisfied with relatively few classes of materials. Furthermore, our aircraft did not operate in an environment drastically different from those of other forms of transport, such as locomotives, automobiles, or ships. With the arrival of space vehicles and supersonic aircraft, many new materials requirements have arisen, and they incur problems of far greater magnitude than before. In most instances, the materials used in the older technologies could not be adapted to the new needs. Consequently, new approaches using entirely new classes of materials had to be found. Table 8–I indicates the growth in materials essential to aerospace vehicles.

The majority of our problems in space technology today are traceable to the lack of a suitable material for solution. Materials research under NASA sponsorship extends over a wide range from the study of the physical principles to vehicle applications. Our materials work may be connected with a tank in a rocket vehicle, a heat radiator, or a reentry body, or it may be concerned with a theoretical understanding of

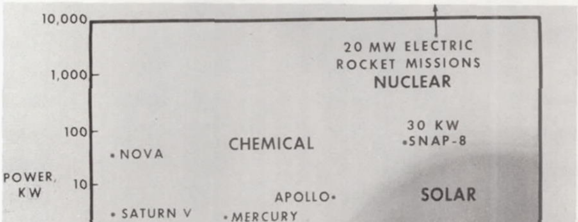


FIGURE 8–7.—Spectrum of space power sources.

surface phenomena and crystalline structures. This research is basic to studies of interplanetary travel and reentry where the main concern is extreme environments—low and high temperatures, vacuum of space, and high launch and reentry forces. Figure 8–8 illustrates the progress which has been made in high-temperature alloys research, together with the immediate goals that we seek.

One of the most refreshing byproducts of our space program might be termed "materials gadgeteering." It has long been the desire of materials scientists to engineer a material to meet specific requirements. To a limited extent, this is now possible. For example, a rocket nozzle throat material requires a combination of strength and thermal conductivity. A metal which in a pure state does not have the desired characteristics may be conventionally strengthened by the addition of alloying materials. However, in nearly all cases, the thermal conductivity is drastically reduced, which leads to cooling difficulties and, therefore, to wall destruction. Intense research efforts are being devoted to combining high strength with high thermal conductivity. One method of accomplishing this is by fiber-strengthened alloys, in which many small fibers are mixed in the material, such as aluminum-oxide fibers in aluminum. We find that fiber-strengthened materials may have the same strength but many times the heat conductivity of conventional materials.

TABLE 8–I.—*Materials Essential to Aerospace Vehicles*

	1952	1957	1962
Beryllium			●
Thermal-control materials			●
Thermoelectric materials			●
Photoelectric materials			●
Shielding materials			●
Ceramics			●
Filament-wound materials			●
Ablation materials			●
Sandwich materials		●	●
Polymers		●	●
Refractory metals		●	●
Superalloys	●	●	●
Steels	●	●	●
Titanium alloys	●	●	●
Magnesium alloys	●	●	●
Aluminum alloys	●	●	●

The most efficient space vehicle would be useless if it could not be controlled, guided, and communicated with in space. The heart of a control and guidance system is the gyroscope, an object which has been improved continuously over the past decade. Reliable inertial gyro units with drift rates of 1 minute per hour have been developed. The difficulty of this task is emphasized when we realize that such a drift rate requires a center-of-mass deviation of the gyro of less than 15 crystal lattice dimensions of the material employed for gyro construction. Attempts to improve gyros further have led us along several pathways, one of which is toward the cryogenic gyrorotor illustrated schematically in figure 8–9. The cryogenic gyrorotor utilizes the phenomenon of superconductivity discovered by the Dutch physicist Onnes in 1911. Onnes discovered that the electrical resistance of some supercooled metals vanishes near absolute zero. In the 1950's, Matthias of the Bell Telephone Laboratories and Bardeen of the University of Illinois succeeded in catalog-

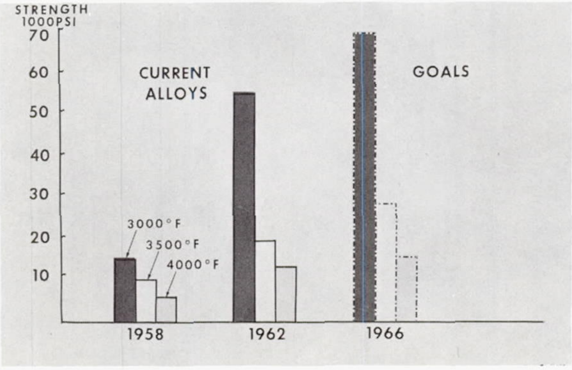


FIGURE 8–8.—High-temperature alloys research.

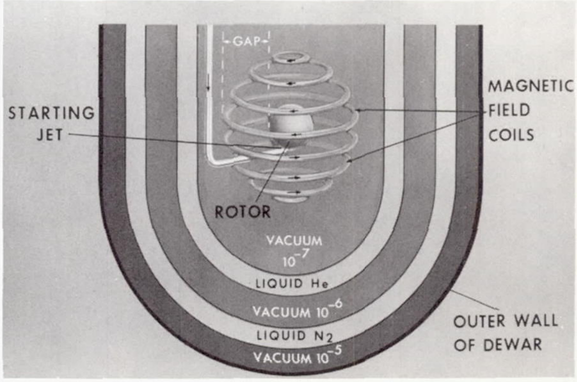


FIGURE 8–9.—Cryogenic gyrorotor.

ing a number of superconductor materials and in improving the understanding of the phenomenon.

We are attempting to put this phenomenon to work by making a metal sphere levitate in a vacuum. If this can be done, a gyroscopic mass can be suspended in an almost frictionless environment. Once "spun up" to gyroscopic speed, the run-down time constant is expected to be measured in years. The levitation is accomplished by surrounding the sphere with suitable magnetic fields so that a current is induced in the sphere. If the sphere is off center, nonequal repulsive forces will develop which cause it to "ride" the geometric center of the external fields.

During the historic flights of Colonel John Glenn and others, we have all been made painfully aware of the communications blackout which occurs during reentry. This is due to the inability of radio-frequency waves to penetrate the ionized plasma sheath which surrounds the spacecraft as it is aerodynamically heated in the Earth's atmosphere. For some time, we have attempted to find a great understanding of the problem and a means of alleviating it. We now have evidence that small amounts of atomized water injected into the ionized flow field appear to act as a catalyst in reducing the electron concentration. This and other means of overcoming the communications blackout problem are being studied theoretically and experimentally in shock tubes.

An immediate problem area in the electronics field is concerned with the advent of significantly new techniques for communication. Laser technology promises to open the tremendous range of the optical spectrum for man's use in space communications. Since lasers are only approximately 2½ years old, a good many challenges exist which stimulate the imagination. Figure 8–10 illustrates schematically some of the space applications of laser technology. Some of these are:

(1) Efficient generation of coherent optical radiation

(2) Efficient and practical methods of modulation and detection

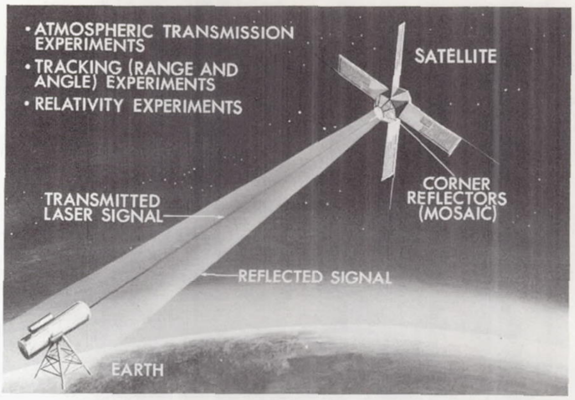


FIGURE 8–10.—Laser (optical) tracking.

(3) Detailed investigations of signal transmission characteristics as a function of range and propagation medium

(4) Relativistic effects

Even more important, however, is the demand for reliability in electronic systems, which has been a notable weakness at the very time that space development activities have made such spectacular contributions in the past 5 years. The rigorous demands for performance and for successful accomplishment of complex missions have taxed our skills and abilities as no other problems have.

Electronics technology provides the sensing and control for propulsion and space vehicle units, and the components for data processing, navigation, communications, and tracking. Conservatively, about 70 percent of spacecraft costs go into electronics; hence this field is of major significance to the NASA mission.

The area of the space sciences and the environment of space is so vast that I cannot dwell long enough here to establish its true identity. It is the area which has moved forward most dramatically during the past few years because of man's newly found ability to peer beyond the Earth's atmospheric blanket with satellites, sounding rockets, and space probes.

We have steadily increased our researches in the environmental factors of space, including radiation, vacuum, extremes of temperature, weightlessness, and meteoroid hazards. An important recent stride has been the successful orbiting of the meteoroid penetration satellite, Explorer XVI. Since meteoroids present such a great potential problem to vehicles traveling in space, we must know much more about the expected frequency and severity of impact damage of this hazard of the space environment before we can design long-life spacecraft with confidence. Reports giving the first data received from Explorer XVI have been released and we hope to continue receiving data from this space experiment for another year.

NASA recently selected the Fairchild Stratos Corp. to build the large and advanced meteoroid penetration satellite illustrated by figure 8–11. It will be launched by a Saturn booster late in 1964. In addition, there are several ground-based studies underway to determine the physics of meteoroid impact and to formulate structural designs and material combinations which can protect the spacecraft from disabling damage.

Probably one of the most important areas of space research, illustrated schematically by figure 8–12, is one which we have only recently begun to expand—biotechnology. As our space and aeronautics programs advance rapidly, we need a far greater understanding of man, his capabilities, and the problem of integrating him into complex flight systems. We are studying life support and protective systems and associated instrumentation, together with human factors, in relation to the basic parameters of the environment. We must obtain more basic knowledge of man himself—his body systems in relation to the normal and abnormal internal and external environments.

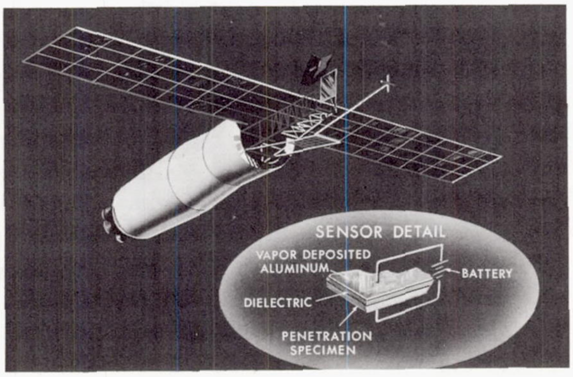


Figure 8–11.—Meteoroid detection satellite.

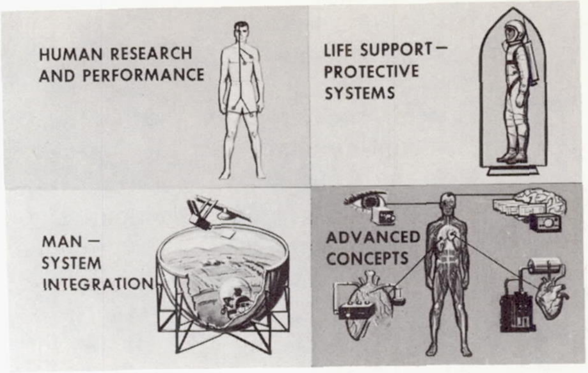


Figure 8–12.—Program requirements.

We are sponsoring advanced life support systems beyond the Apollo system. For example, work is underway on a completely integrated five-man, 30-to-60-day life support system, which includes atmospheric control (superoxide), water, food, and waste management. We will soon commence the design, fabrication, and test of a prototype 6-month life support system for four men. A study now in progress will determine the requirements for a 1-year life support system.

Other studies are aimed at understanding the involvement of the pilot in planetary missions. One such task involves piloted simulations and flight tests to determine the proper function of the human operator within a planetary atmosphere, the characteristics to be built into the vehicle and its systems for optimum performance and reliability, and the requirements for applicable research and training simulators. Still another study uses simulation techniques to determine the role of the pilot in the rendezvous of spacecraft.

Space research remains intimately concerned with basic research and with applied mathematics. For example, the mathematical formulation of the laws governing physical processes is a prerequisite for systematic and rapid progress. Hence, it is necessary to introduce mathematical methods and principles at an early stage in physical investigations. Many of the modern problems cannot be solved at all without mathematical approaches and especially without the use of high-speed computing machines. But, on the other hand, we do not always need complex computers to obtain information from mathematical deductions which give our thinking a new twist.

Despite the pioneer efforts of Samuel P. Langley and the Wright brothers, the European countries forged ahead in the development of aircraft design and technology prior to World War I. To deal with this deficiency, we established in 1915 the National Advisory Committee for Aeronautics (NACA), the predecessor of the National Aeronautics and Space Administration (NASA), with a $5,000 annual budget attached as a rider to the Naval Appropriations Act of that year. The NACA was charged with the conduct of research to advance aeronautics. We can say that this was one of our country's first steps into so-called big science.

In the early years of this century, another American, Robert H. Goddard, carried forward the pioneer work in the development of the rocket and demonstrated that a rocket, carrying its own oxygen supply, could provide thrust in a vacuum. But again it was European countries, Germany and the Soviet Union, which built the first hardware capitalizing on this principle for military purposes.

These and other examples have demonstrated that our country cannot afford to lag in the advancement of human knowledge. Clearly a nation with the responsibilities of ours in today's world must continue to pursue knowledge to provide assurance that it will fulfill its responsibilities. As the realization of this truth has grown since World War II, the participation of the National Government in research and development has expanded in geometric progression.

The late Charles Wilson once said research is what you do when you don't know what you are doing. There is, of course, a certain element of truth here, but more important it is a reminder that the most significant results often come from expenditures of human energy toward goals which may seem impractical. Charles H. Towne has pointed out that the ancient Japanese scholar Takawan has given modern technology some useful advice: "When your opponent is at the point of striking you, let your mind be fixed on his sword and you are no longer free to master your movements, for you are controlled by him." A complete absorption of our energies and resources on the obvious next step in a technology may very well not be the wisest course of action. Thus, research would play a prominent role in our thrust for preeminence in space.

9 Applications Satellites—Communications and Weather

LEONARD JAFFE
Director, Communications Systems, NASA

Unmanned satellites are already being employed experimentally for transoceanic communications and television, and for weather observation and weather forecasting. This presentation will try to give a better understanding of what has been and is being done in these areas, what we hope to do in the future, and where individuals and organizations might fit into this program.

The NASA Office of Applications program (fig. 9–1) is devoted to Communications Systems, Meteorological Systems, and Future Applications of satellites.

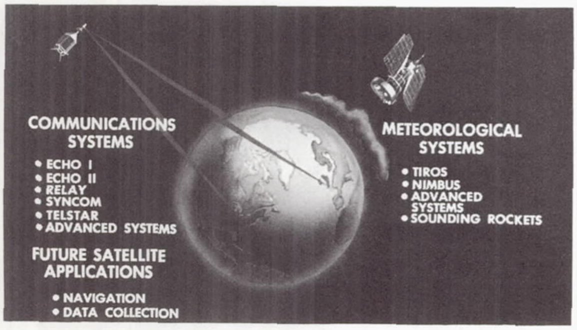


FIGURE 9–1.—Office of Applications programs.

COMMUNICATIONS SATELLITES

The dramatic demonstrations of transatlantic television which have taken place via Telstar and Relay during the past year have proved conclusively that satellites are capable of providing excellent intercontinental communications. There is little doubt that their capabilities will be needed, in addition to the more conventional but limited-capacity overseas communications facilities we have now. During 1960 there were almost 4 million overseas telephone calls, and reliable estimates indicate a fivefold increase in overseas calling during the next decade. Such an increase in traffic will overtax the current and planned undersea cables, and high-frequency radio facilities, especially if one postulates substantial television transmission requirements in addition to voice and data communications. Communications satellites may well be the only way in which to provide high quality communications to remote, less-developed areas.

Burgeoning telephone and television traffic requirements on overland routes have been met through the use of microwave repeater systems, notably the American Telephone & Telegraph Company "TD–2" system whose towers are now a familiar sight throughout the United States. Microwaves, however, travel only in a straight line, and repeaters must be spaced at intervals of 20 to 30 miles. It is logical to extend this interval by increasing the height of the repeaters—but one soon runs into impractical tower heights. If we can place a repeater in a satellite thousands of miles above the Earth, the horizons as seen from the satellite can span whole continents and oceans.

The communications satellite era began in 1958, when the Project Score satellite transmitted to the world the famous Christmas message from the President. In 1960 NASA launched Echo I, the first passive communications satellite, and the Department of Defense launched Courier, a "delayed repeater" satellite. Telstar was orbited in July 1962, Relay in December 1962, and Syncom in February 1963. Another Telstar was launched on May 7, and another Relay and an additional Syncom are scheduled for launching before the end of 1963.

The development and full exploitation of the possibilities of communications satellite systems are immensely important to the Nation's economy and to its prestige. The need for the capability afforded by satellites is urgent, and there is general agreement among all concerned to proceed with their development as rapidly as possible. This attitude was voiced by President Kennedy in a public statement last year in which he said, "There is no more important field at the present time than communications, and we must grasp the advantages presented to us by the communications satellite to use this medium wisely and effectively to insure greater understanding among the peoples of the world."

In keeping with these objectives, the Communications Satellite Act of 1962 authorized the creation of a private corporation, subject to appropriate governmental regulation, to plan, construct, and operate a commercial communications satellite system. The Communications Satellite Corporation is now being organized under the provisions of this legislation.

The objectives of the NASA communications satellite program are to:

(1) Insure that the technology required for the establishment of operational systems becomes available at the earliest possible date, in concert with the Corporation and the Department of Defense;

(2) Study and technically assess the applicability of communications satellites for other than common carrier utilization;

(3) Insure that the technical possibilities are clearly established for the full exploitation of the potential of satellites to meet communications requirements of the future; and

(4) Meet NASA's responsibilities as outlined in the Communications Satellite Act of 1962.

To achieve our objectives involves, broadly, investigation and exploitation of three basic techniques applicable to operational communications satellite systems. These are:

(1) Active satellites in low and medium altitude orbits;

(2) Active satellites in 24-hour synchronous orbits; and

(3) Passive reflector satellites in low orbits.

Our earliest experience was with Echo I, the passive reflector satellites, a 100-foot metallized balloon which is in effect a radio mirror. Many successful transcontinental and transoceanic experiments and demonstrations were conducted with Echo I—but passive satellites merely reflect signals, they do not amplify them, so the reflecting area of the satellite must be large and the ground stations must be large and complex. On the other hand, the active communications satellite holds great promise for the future, and this is the area in which we are expending our greatest effort. The active satellite carries receivers and transmitters for amplifying and retransmitting the received signals, and it has other electronic equipment for control, telemetry, and power. Because it is a powered, amplifying repeater, the active communications satellite can be quite small and it is possible to use less sensitive ground receiving equipment and less powerful ground transmitting equipment than are needed for passive satellites.

Figure 9–2 shows in schematic form the two major orbital altitudes of interest for active communications satellite systems. The low and intermediate altitude systems are shown as a number of satellites in relatively close proximity to the surface of the Earth, and the syn-

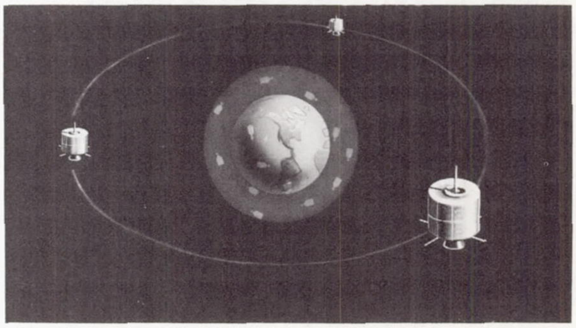


FIGURE 9–2.—Active communications satellite systems.

chronous or stationary-orbit satellites are shown in equatorial orbit at an altitude of 22,300 miles. The 22,300-mile satellite is called a synchronous or stationary satellite because at this altitude the satellite completes one revolution around the Earth every 24 hours, and if it is in an equatorial orbit it will appear stationary to an observer on the Earth. The advantages of the synchronous orbit are at least in part associated with the fact that only three operable satellites are theoretically needed to provide almost complete coverage of the whole world. At the low or intermediate altitudes a large number of satellites are required. A typical analysis shows that a minimum of 40 satellites will be required to provide essentially continuous worldwide coverage.

Relay and Telstar are experimental satellites of the intermediate-altitude type, but they are quite different in detail. Power ratings of the transmitters as well as the number of transponders or repeaters available are different in the two satellites. The mechanical structure is quite different. The operating frequencies are also different so that we can examine the effects on transmission of operations in more than one frequency band.

Telstar, shown in figure 9–3, is a cooperative project between NASA and AT&T. The first Telstar was launched July 10, 1962, and its accomplishments have been well publicized. The second Telstar differs from the first in that some of its electronics have been redesigned for greater resistance to radiation damage; its instrumentation and telemetry system has been expanded and changed; and its orbit will have a higher maximum altitude, which will reduce its exposure to high intensity radiation and at the same time increase the length of mutual visibility periods with Europe.

Figure 9–4 is a picture of the Relay spacecraft. It weighs about 175 pounds, is 33 inches high, and has a maximum breadth of 29 inches. The ringlike extension from one end is the antenna structure which handles both transmission and reception of communication signals. The eight sides of the satellite contain more than 8,000 solar cells. The whiplike antennas at the broad end of the satellite are part of the systems for turning Relay experiments on and off, and for acquiring and sending to Earth data on component behavior and on radiation in space.

Figure 9–5 shows the stations cooperating in the Relay experiments. The broad international interest in communications satellites is illus-

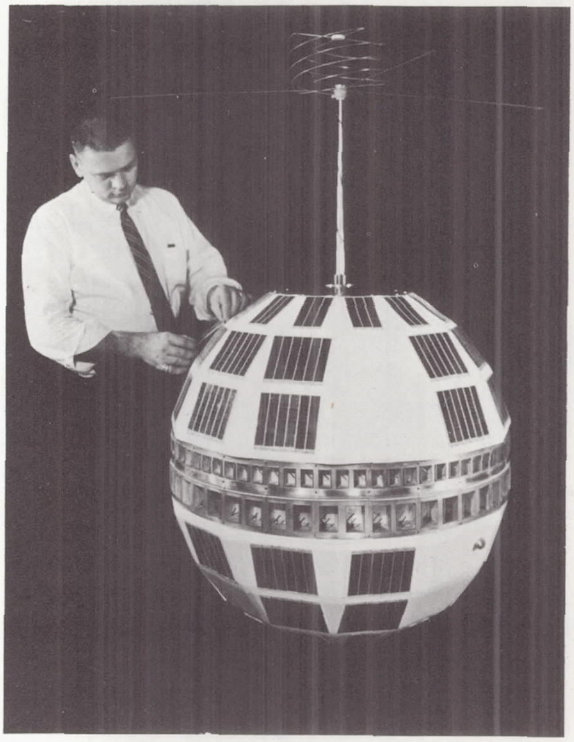


Figure 9–3.—Telstar spacecraft.

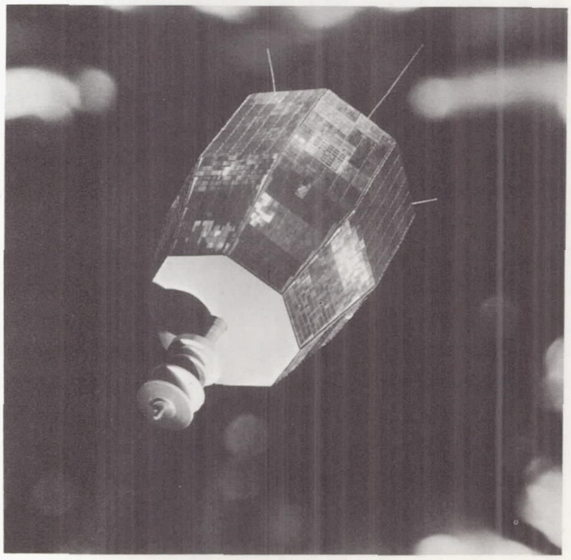


Figure 9–4.—Relay spacecraft.

trated by the extent to which other countries are willing to fund ground facilities for experimental purposes. The stations in the United States, England, Brazil, France, and Italy are operational. The station in Germany should be operating by the end of this year, and that in Japan will be in operation in 1964.

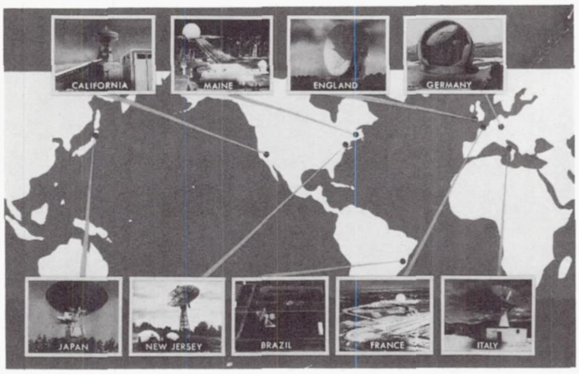


FIGURE 9–5.—Relay satellite ground stations.

Several other countries have indicated interest in providing ground stations for communications satellites, including the Scandinavian countries, Canada, and India.

Both Relay and Telstar were highly instrumented to measure the effects of the space environment, particularly radiation, on the components of the statellites.

The economics of operational communications satellite systems depends heavily on the useful life of each satellite in orbit, and the lifetime of an active satellite depends on the behavior of a large number of electronic components in the spacecraft. The difficulties we presently have in achieving reasonably long life with complex satellites are illustrated by the outages experienced with both Telstar and Relay. These satellites were given all the possible care that one could conceive of in their design and construction. Telstar was designed to have a usable life of at least 2 years, but failed to obey commands transmitted from the ground controller after only a few months. With the use of specially designed ground commands, Bell Telephone Laboratories engineers were able to cause Telstar to respond to its commands again for a time, but unfortunately the trouble has again occurred, and Telstar is now silent.

In Relay we found that after a very successful launching the power supply voltage dropped unexpectedly. This, it was later determined, was due to leakage in one of the voltage regulators. Fortunately, two completely independent repeaters are carried in Relay. When the leak reduced itself with time, we were able to turn on the second transponder and it performed well. Relay has been in use since early January 1963 and is still in use. Numerous engineering tests and demonstrations have been performed using this satellite.

Figure 9–6 emphasizes how thoroughly three synchronous satellites in the Earth's equatorial plane can cover the Earth's surface from the 22,300-mile orbit. Each shaded section indicates the area of visibility for a single synchronous satellite. One satellite can cover South America, the east coast of the United States, and major portions of western Europe and Africa. Another one can tie Europe to the Far East and a third one stationed above the Pacific can tie the western United States to Japan and Australia.

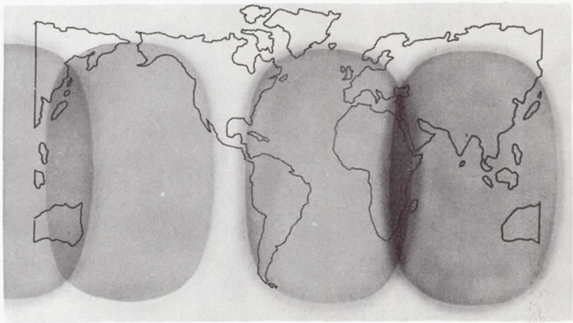


FIGURE 9–6.—Synchronous-satellite Earth coverage.

NASA has established Project Syncom as a first step toward providing experience in the synchronous orbit. Figure 9–7 is a photograph of Syncom. A distinguishing feature of Syncom is the fact that it carries within it a rocket stage. This rocket is required in addition to the capabilities of the launching vehicle to place the 75-pound spacecraft in a near synchronous orbit. Syncom also carries a gas jet system to orient the satellite in the proper direction with respect to the Earth, and to maintain the satellite's relatively stationary position above the Earth. The added complexity of the synchronous satellite over that of the intermediate altitude satellites is illustrated by the fact that *all* of these subsystems must work in order to complete the Syncom mission successfully.

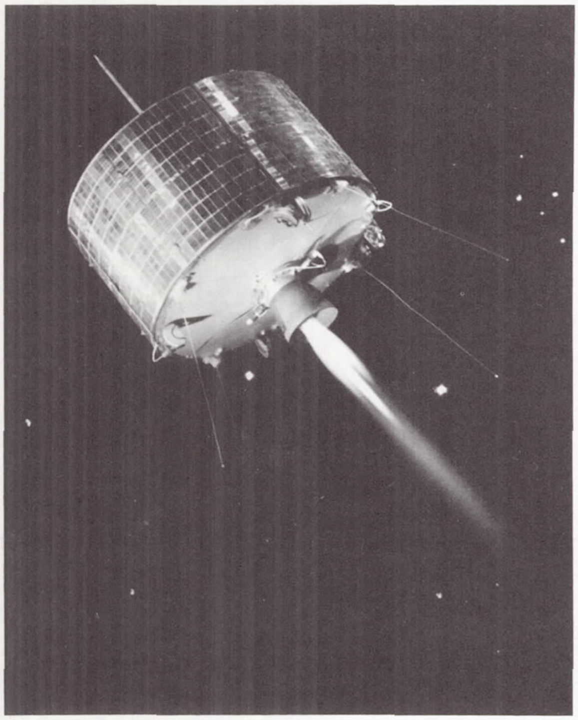


FIGURE 9–7.—Syncom spacecraft.

For Syncom, we are making use of ground stations developed by the Department of Defense for their programs, as shown in figure 9–8. The DOD fixed station at Fort Dix, New Jersey (lower left), adapted for use with Syncom, provides a communications backup for the Lakehurst station. The *USNS Kingsport*, stationed in the Harbor of Lagos, Nigeria, performs the initial tracking and control of the Syncom satellite, and would conduct communications experiments with Lakehurst or Fort Dix.

The first Syncom was launched from Cape Canaveral on February 14, 1963. The launch was near perfect, and the satellite was injected into an elliptical orbit, the peak altitude of which would be about 22,300 miles. At that point the onboard rocket stage would be fired, adding enough velocity to keep the satellite at the synchronous altitude. During the 5 hours it took for Syncom to reach the 22,300-mile altitude, the communications equipment was checked out with satisfactory results. Approximately 20 seconds after the onboard rocket was fired, however, all signals from the spacecraft ceased, and Syncom has been silent since then. It has been established through telescopic observations that Syncom I is indeed in an orbit with a period of approximately 23 hours and 45 minutes. Thus, for the first time, a satellite has been placed into a nearly synchronous orbit. Analysis of the data is still continuing to determine the cause of the failure, so that remedial measures may be taken prior to a second launching.

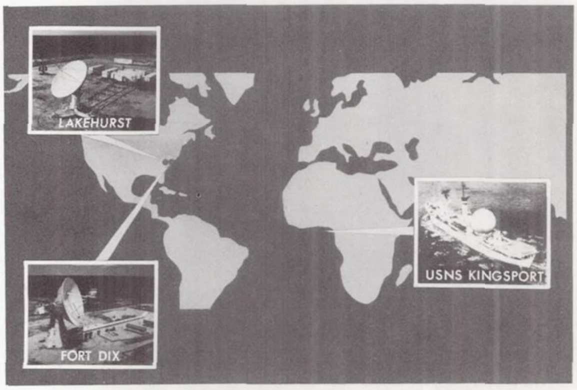


FIGURE 9–8.—Syncom ground stations.

The Syncom project will continue through this coming year. As a follow-on to Syncom, NASA has initiated studies on an advanced synchronous communications satellite. This satellite will be appreciably larger and heavier, and will require an Atlas-Agena booster vehicle for launch rather than the Thor-Delta used in the Syncom project. One of the major changes which we hope to introduce in the advanced synchronous satellite is the inclusion of a technique for continuously directing the radiated energy from the satellite to the Earth. The present Syncom satellite (fig. 9–9) is spin-stabilized, and its antenna accordingly must radiate uniformly in all directions about the satellite, so that no matter what the rotational position of the satellite is, some of the radiated energy will hit the Earth. This is illustrated on the left side of figure 9–9. However, as the satellite gets larger and more weight becomes available for us to work with, it is possible to include a contrarotating antenna whose radiation pattern is such that all its radiated energy is directed to the Earth, as shown on the right side of figure 9–9. As soon as the preliminary studies are completed, we will initiate the development of the advanced synchronous satellite. This should be well underway in fiscal year 1964. Such a spacecraft may be of considerable interest in areas other than communications satellites; this configuration is being studied for possible application to the stationary meteorological satellite requirements.

One other item of interest among many that will represent the changes between Syncom and the advanced synchronous satellite is the inclusion of what we designate as multiple access capability. By this we mean the ability for a fairly large number of independent ground stations to use the satellite simultaneously as a relay point without mutual interference, as is shown in figure 9–10. The experimental active repeater satellites with which we have been working to date include Telstar, Relay, and Syncom; these are all essentially two-party communications systems. A multiple access capability would make possible the participation of a larger number of stations in a single operational communications satellite system.

Although we are concentrating our efforts on active satellites, we are still exploring the potentialities of passive reflector satellites. The 100-foot metallized plastic balloon, Echo I, which was launched in 1960 is still a worldwide object of interest, as it is the only artificial satellite visible to the unaided eye.

We have been developing a larger passive reflector satellite, called Echo II, which is 135 feet in diameter and is made of a heavier, stiffer material so that it will retain its shape and its reflecting capability even after the inflating gas has escaped. Two space tests of the Echo II structure were conducted in 1962. These were vertical shots from Cape Canaveral in which the satellite inflation process was tested above the Earth's atmosphere. In the first of these, the balloon burst; in the second, the balloon inflated in an essentially satisfactory manner.

We hope to place an Echo II satellite in orbit late in 1963 and to use it in the communications tests recently agreed to jointly by the United States and the U.S.S.R.

The question has been asked, "Why continue at all with passive satellites, when they require ground installations larger and more complex than those required for an equivalent traffic capability using active repeater satellites?" Two of the reasons for continuing are that the passive reflector satellite is one relatively easy solution to the multiple access problem—any

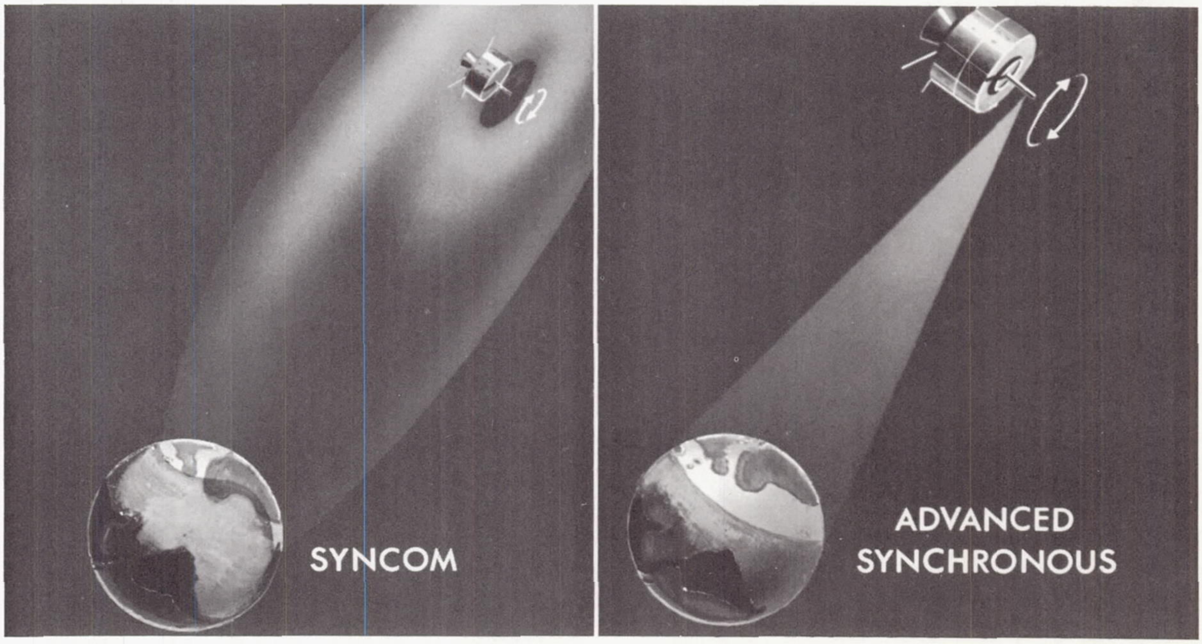


FIGURE 9–9.—Synchronous satellite projects.

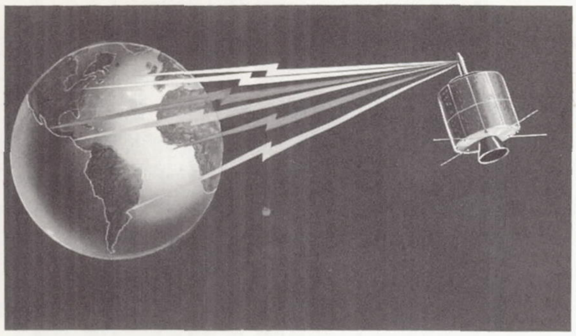


FIGURE 9-10.—Multiple-access communications satellite.

number of stations may use the reflector simultaneously—and the reliability of a passive reflector satellite is inherently good because it has no electronics to fail.

The experimental flight programs described have demonstrated the technical feasibility of employing satellites for intercontinental communications. However, this is not the only objective of our communications satellite program. Not only do the currently available systems have many technical shortcomings, but there are other potential uses for communications satellites which have not begun to be explored. Examples of such areas include use of higher frequencies to extend the frontiers of the useful frequency spectrum and to minimize interference problems; investigation of high-powered satellites which would permit use of very small ground facilities which might be carried on ships, emergency mobile land units, and aircraft (this capability could result in an application of communications satellites to air and sea traffic control procedures); incorporation into stationary communications satellites of additional equipment to provide for other observations in the national interest such as scientific experiments or meteorological sensors; and investigation of high-powered broadcasting satellites which could broadcast radio or television programs directly to all the home receivers in a very large area on the Earth.

Toward these ends, NASA conducts an extensive program of supporting research and advanced technical development, and here is where the resources, imagination, and talents of private industry and universities can be applied to good advantage.

The general objective of this supporting research and development program is to provide the foundation for new systems having substantially greater capabilities than those now attainable.

We will aim for intermediate-altitude active repeater satellites with increased communications capabilities, multiple access, a passive or semipassive control system for orienting the satellite toward the Earth, and other improvements.

In the area of synchronous satellites, we hope to achieve greater orbital stability, antennas with greater directivity, multiple access, longer orbital lifetimes, improved systems for stationkeeping and attitude control, and systems providing more onboard power for the satellite electronics.

For passive reflector satellites, we plan research and development of shapes and structures having substantially greater radio reflectivity for a given size, and having less weight per unit area, than the current passive reflectors.

This supporting research and technology program will not necessarily result in flight programs of complete spacecraft. It will consist of studies and investigations of components and techniques—antennas, transmitters, receivers, power supplies, new modulation schemes, and new and better techniques for maintaining satellites in a predetermined position relative to the Earth. Last, but by no means least, will be efforts to improve the reliability and thus the useful lifetime of satellite systems. Individual components must have extremely long life; subsystems must be as simple and straightforward as possible, consistent with the function to be performed; and systems must be analyzed and designed to minimize the consequences of a failure when one does occur.

These programs are discussed in more detail as follows:

METEOROLOGICAL SATELLITES

A summary of our objectives is given as follows:

(1) Develop an operational meteorological satellite system

(2) Develop and apply space technology to satisfy meteorological observational requirements

(3) Develop meteorological satellite and sounding rocket systems

(4) Maintain a continuing program of modification and improvement.

We are currently engaged, together with the U.S. Weather Bureau, in the development of an operational meteorological satellite system. This system is to be used by the Weather Bureau in the fulfillment of its service responsibilities. Our objective is to develop various aspects of space technology and integrate this technology into appropriate systems which will provide the meteorological observations required by both the operational and the research meteorologists. In more specific terms, our objective is the development of meteorological satellite and sounding rocket systems. Finally, it is our objective to maintain a continuing program for modifying and improving the developed systems.

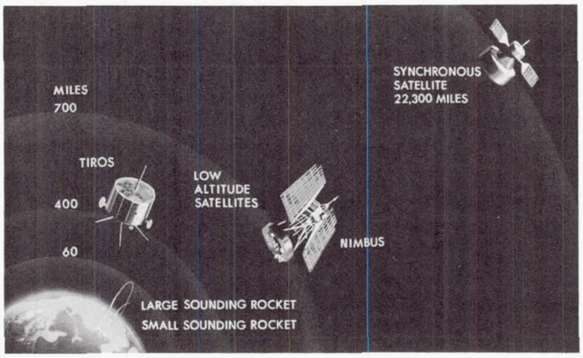


FIGURE 9–11.—Meteorological systems program.

The hardware elements of our flight program are ilustrated in figure 9–11. In the lower left corner is a representation of the small and large sounding rockets which are used; then Tiros, the spin-stabilized satellite which has demonstrated the capabilities of satellite technology in meteorological flight systems, and Nimbus, which incorporates as many as possible of the techniques now available to us to improve the quality of the satellite systems, are shown. In the upper right is a synchronous satellite orbiting at an altitude of 23,300 miles. Such a spacecraft, now under study, should make it possible to observe the weather conditions continuously over a selected segment of the Earth's surface.

These programs are discussed in more detail as follows:

Table 9–I shows some of the characteristics of the six Tiros satellites that we have already launched successfully. Tiros V, now operating on one camera, has been providing usable data for more than 10 months. Tiros VI, also operating with one camera, has completed over 7 months of successful functioning. Tiros has severe limitations from the point of view of data coverage. Briefly, they are that, as shown on the left side of figure 9–12, since Tiros is space oriented it does not see the Earth continuously, and it is also limited in coverage by the angle of its orbital inclination. On the other hand, Nimbus will give more extensive coverage for, as shown on the right side of the figure, it is Earth oriented and in a near-polar orbit.

TABLE 9–I.—*Tiros Satellites*

Satellite	Launch date	Useful life, months	Inclination, deg
Tiros I	Apr. 1, 1960	2½	48
Tiros II	Nov. 23, 1960	10	48
Tiros III	July 12, 1961	4½	48
Tiros IV	Feb. 8, 1962	4½	48
Tiros V	June 19, 1962	Still operating.	58
Tiros VI	Sept. 18, 1962	Still operating.	58

Table 9–II is a compilation of some of the operational support that Tiros has given. This type of support has, of course, proved extremely valuable to the Weather Bureau and the DOD

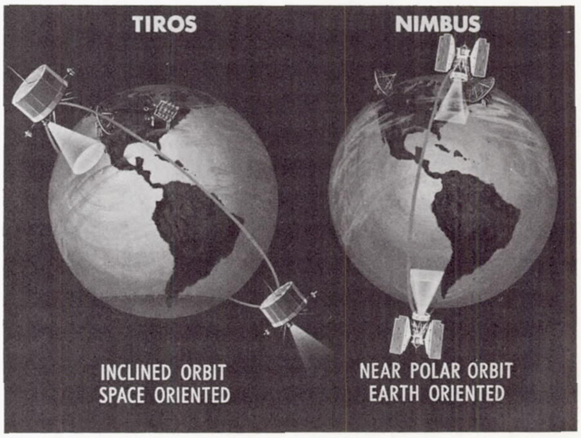


FIGURE 9–12.—Meteorological satellite development.

in their day-to-day operation. Tiros has also provided a wealth of very useful data to research meteorologists, both within the government and at various universities and research institutes.

TABLE 9–II.—*Tiros Satellites—Operational Support Aspects*

[All numbers shown are as of Feb. 28, 1963]

Usable pictures	168, 148
Cloud cover analyses	5, 048
Special storm advisories	712
Weather analyses improvements	300
Hurricanes observed and tracked	10
Typhoons observed and tracked	21

The Tiros project is on schedule in all of its phases. We now have relative freedom to schedule the next few launches, not on the basis of spacecraft availability, but on the basis of the most favorable time with regard to meteorological coverage. The present NASA program calls for five additional Tiros launches. In order to insure the availability of operational data until the next family of satellites—Nimbus—is able to provide observations on a regular basis, the Weather Bureau has scheduled two additional launches in the Tiros series. These are referred to as the "operational" Tiros satellites. In view of the continuing excellent performance of Tiros V and VI, our original launch date for the next Tiros has been intentionally delayed twice. While Tiros V and VI are providing data in one part of the globe, the next satellite will provide data in another. This additional coverage will increase the frequency of observation over the South Atlantic during the hurricane season and thus assist in maintaining a continuous vigil over the area where these severe storms are born.

As was the case with all the previous R&D Tiros satellites, the planned additional five Tiros satellites will be able to provide data for operational use in current analysis and forecasting while at the same time executing their R&D missions. Some of these missions are listed as follows:

(1) 15-micron radiometer to assist in development of Nimbus horizon scanner
(2) Automatic picture transmission for test purposes
(3) To provide TV and IR data in polar latitudes
(4) Cartwheel configuration
(5) Will view disk of the Earth from an eccentric 300- to 3,000-mile orbit
(6) May view disk of the Earth from an apogee of 22,300 miles.

As stated, one of these Tiros satellites is expected to flight test the Automatic Picture Transmission System (fig. 9–13). This APT system is designed to transmit continuously pictures of local cloud conditions to weather stations near the track of the satellite. Weather satellite cloud pictures are usually transmitted to elaborate Command and Data Acquisition stations at a relatively rapid rate. This requires the use of wide radio bandwidths and large antennas. In the APT system we use slow transmission rates and thus permit the use of small bandwidths and a relatively small antenna. The picture is snapped in a fraction of a second. The rest of the 3-minute cycle time is used to slowly scan the picture electronically and transmit it to the ground station. At the ground station, the console is used to point the antenna towards the satellite; to receive the picture; and to display it on a facsimile recorder. Each picture will cover an area a bit larger than the Tiros pictures. The ground equipment costs less than $50,000 per set and so will ultimately permit use by many major U.S. and foreign weather stations.

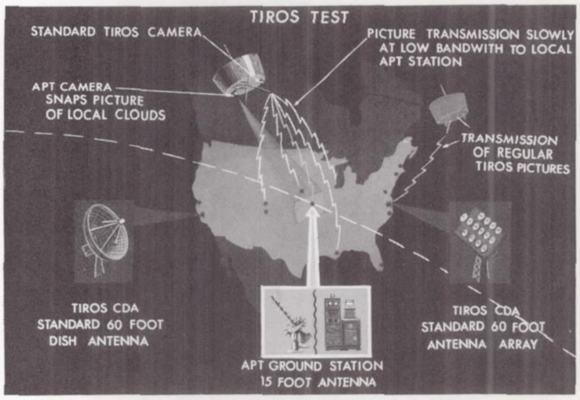


FIGURE 9–13.—Automatic picture transmission (APT).

The Automatic Picture Transmission System was designed for the Nimbus satellite, but a flight test on Tiros will permit checkout of the system using a number of ground stations. When used later with Nimbus, APT will enable ground stations to obtain direct cloud cover pictures of their local area.

The Nimbus satellite is shown in figure 9–14. In Nimbus we are doing much more than merely improving the sensors. In essence, Nimbus represents a major step forward over Tiros in these five elements:

(1) *Orientation.*—Only during a very small portion of its orbit does Tiros look straight down. The oblique angle of the majority of pictures causes difficulty in rectifying the pictures and in interpreting the cloud patterns due to the changing scale. Nimbus will view the Earth vertically during its entire lifetime.

(2) *Coverage.*—Tiros provides somewhere between 10 and 25 percent of the global cloud cover per day. Meterological requirements are for total global observations. Nimbus is to be launched in a near polar orbit and is to view every portion of the Earth every day.

(3) *Direct local readout.*—The automatic picture transmission subsystem developed for Nimbus has already been discussed. Eventually, this system may represent one of the greatest contributions of the meteorological satellite program to local forecasting.

(4) *Lifetime.*—An operational system must have a reasonably long life. The Tiros lifetime was estimated to be about 3 months. In general, we have exceeded this. An operational system should have a lifetime of at least 6 months and eventually 1 year or more. In addition to carefully engineered systems and reliable quality control in manufacturing, design redundance plays a major role in achieving useful long life. Due to weight limitations imposed on it, the first Nimbus will be launched without this redundancy. However, the future developed operational spacecraft will include redundant systems.

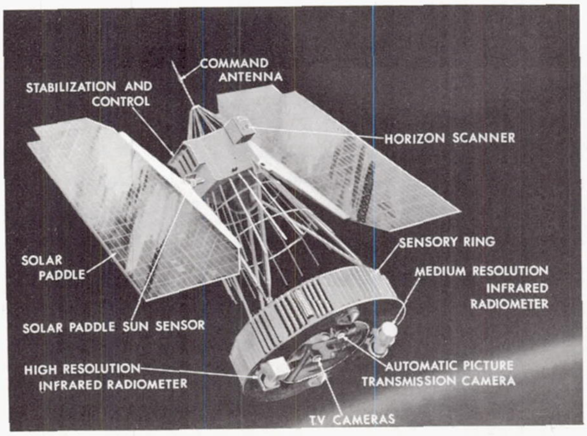


FIGURE 9–14.—Nimbus spacecraft.

(5) *Growth Potential.*—One of the more important elements of Nimbus is its potential for growth. Cloud pictures and the infrared radiation measurements satisfy the operational meteorological requirements only in part. Other requirements for operational systems include the need for instrumentation to provide many more kinds of observations. Thus, it is important that a meteorological satellite have the flexibility to accept without too much difficulty new instruments when developed. *Nimbus is designed to do just that.*

Each one of these five elements represents a major advance over Tiros. Nimbus, including all these, represents an extremely large step forward beyond the Tiros capability.

The prototypes of the various subsystems have been tested successfully. It remains now to combine the developed Nimbus subsystems and to check them out together as operating prototype and flight system. When the spacecraft passes the testing procedures, we will be ready to launch Nimbus and we estimate this to be before the end of this year.

The data acquisition hardware development has also been moving forward. Figure 9–15 is a photograph of the Command and Data Acquisition Station in Fairbanks, Alaska. An

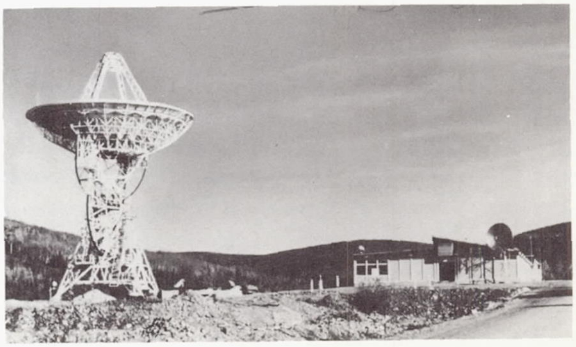


FIGURE 9–15.—Command and Data Acquisition Station, Fairbanks, Alaska.

agreement has been signed with the Canadian government for the establishment of a similar antenna installation in the northern part of Nova Scotia. The combination of the Alaskan and Nova Scotian stations will give us coverage of practically every orbit of Nimbus. One antenna also backs up the other antenna to a sufficient extent to maintain reasonable service, should one station be temporarily inoperative.

Sounding Rockets

We are also concerned with the development of sounding rockets for the exploration and measurement of the atmosphere in the region accessible to neither satellites nor balloon-borne instruments.

Experimental sounding rockets as applied to the region of 20 to 40 miles have revealed the potential value of systematic study of this atmospheric region by means of a network of sounding rockets. We are engaged in developing a small meteorological rocket sounding system for this purpose.

The development requirements for the system are rather stringent. The motor must be reliable. It must be launched at a specific time under a variety of adverse weather conditions and its flight path must be reliably predicted; that is, there must be a small impact area. The wind sensor should accurately respond to the vertical variations of the wind rather than have an integrated response over a large vertical interval. The sensors of temperature, density, and/or pressure should provide accurate and as direct as possible measurements of ambient atmospheric conditions with minimum reaction to outside influences.

To permit use in a network, the data acquisition component should be a self-sufficient unit independent of the present range support required. The data reduction components of the system should permit rapid conversion of the telemetry records into the necessary meteorological units to allow quick dissemination of the data for analysis and utilization.

Our work with large sounding rocket systems involves techniques which extend our knowledge of the atmosphere to altitudes up to about 100 miles. The experiments are distributed throughout the seasons of the year, and at several locations to sample the geographical and seasonal variations of the atmospheric structure.

In this large sounding rocket area, Meteorological Systems works closely with NASA's Office of Space Sciences, since many of the experiments provide atmospheric measurements required by research and applications groups in both meteorology and aeronomy.

Supporting Research and Technology

Accomplishments in supporting research and technology provide improvements for current projects and the technical foundation for future progress. Three areas are illustrative of what is being done (fig. 9–16).

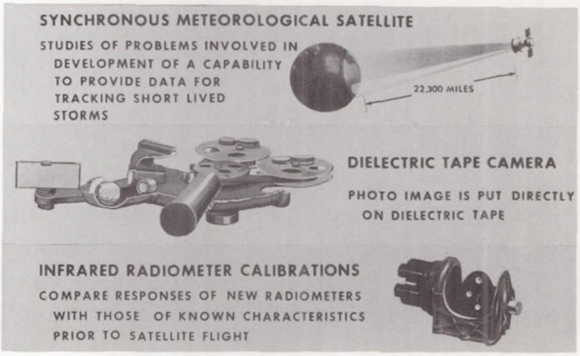


FIGURE 9–16.—Meteorological systems—supporting research and technology.

The first item in the figure indicates our continuing effort toward a system capability for continuous monitoring of atmospheric events particularly for the tracking of short-lived storms. During the current fiscal year, contract and in-house activities are being conducted to uncover and evaluate the problems associated with the subsystem developments required to provide this kind of a capability. The results of these studies will be applied in the initiation of the development of preprototype hardware requiring long leadtimes.

A second item is the dielectric (or electrostatic) tape system development. The dielectric tape camera is a technique whereby the image which is normally formed in the TV camera of our meteorological satellites is formed not on a fixed screen within a vacuum tube, but on a piece of plastic tape which has been appropriately coated to be photoresponsive. This is in contrast to the TV camera unit where we would normally scan the TV image and store the electrical signals on a magnetic tape recorder which would then be read back. Two cooperating systems would be needed to achieve the same objective that the dielectric tape can handle in one step. With this system we hope to be able to improve the performance of future meteorological satellites by reducing their complexity and weight.

The third supporting research item is the work we carry on in calibrating and improving our infrared sensors. Infrared detector systems record data such as the temperatures of the clouds and the ground cover as they come into view beneath the satellite.

FUTURE APPLICATIONS SATELLITES

Communications and meteorology are the first, but certainly not the only, applications for unmanned satellites. Under the heading of Future Applications, we are concentrating our attention in two other areas—navigation satellite systems and data collection satellite systems.

In navigation, we have signed an agreement with DOD assigning to NASA the responsibility for determining the suitability of the Transit navigation satellite system for nonmilitary use. Figure 9–17 illustrates the operation of Project Transit. The satellite is tracked from the Earth, and the tracking data are sent to a computing center, where orbital parameters are determined and sent back to the satellite. The ship at sea receives position and orbital information from the satellite, and from these data the position of the ship can be determined by simple onboard computations.

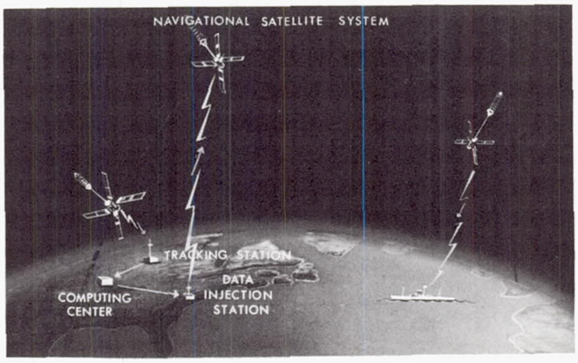


Figure 9–17.—Project Transit.

The NASA–DOD agreement involves testing of equipment provided by the Navy, and such further development of receiving and computing equipment as is justified. In order to provide a yardstick for these tests, we have been conducting a study to establish navigation requirements of nonmilitary ships and aircraft. We are finding that one all-weather navigation system providing worldwide coverage would be desirable, but that to have wide acceptance it would have to be moderate in cost of user equipment, easy to operate with minimum training of personnel already available, be capable of meeting the needs of a wide variety of users, both at sea and in the air, and have a long useful life.

We shall shortly begin a study to select the best of several possible techniques, define the system, and determine the data handling requirements of such a system. If the results of this study are favorable, we plan to proceed with a design study on such a system.

We are also investigating the possible application of a satellite system to collecting data from automatic unmanned observation stations, particularly in remote or otherwise inaccessible areas, which measure and record meteorological data, oceanographic data, magnetic data, and the like. Usefulness of the data gathered at these stations is limited by the inability to "collect" the information, by radio or other means, except at infrequent intervals. Use of satellites for collecting data from these stations would offer the advantages of worldwide coverage, timeliness of data, synoptic information, station failure notification, recovery of data before loss of a station, and economy.

We have had informal discussions with several oceanographic and meteorological activities, and have recently begun a study to define the requirements in detail. In coordination with this study, a second study will be initiated soon to define the system and determine the data handling requirements.

Figure 9–18 illustrates one concept of such a system, involving interrogation by one or more satellites of transponders within the Earth's atmosphere. The system would determine the location or identity of each station and collect various useful data. The information would be stored on magnetic tape in the satellite and returned to Earth by command from one or more data retrieval stations suitably located.

These studies should be completed before the end of 1963. If the results are favorable, a design study would follow.

All in all, the Satellite Applications Program ranges over a very broad spectrum of activity. We go all the way from investigations of purely scientific interest to problems associated with commercial communications satellites. It is a very challenging area to work in, and it is most satisfying to find that the benefits which are accruing to the Nation as a whole from communications and meteorological satellite developments are so broadly recognized and are receiving so much support and encouragement from all who are in contact with these program efforts.

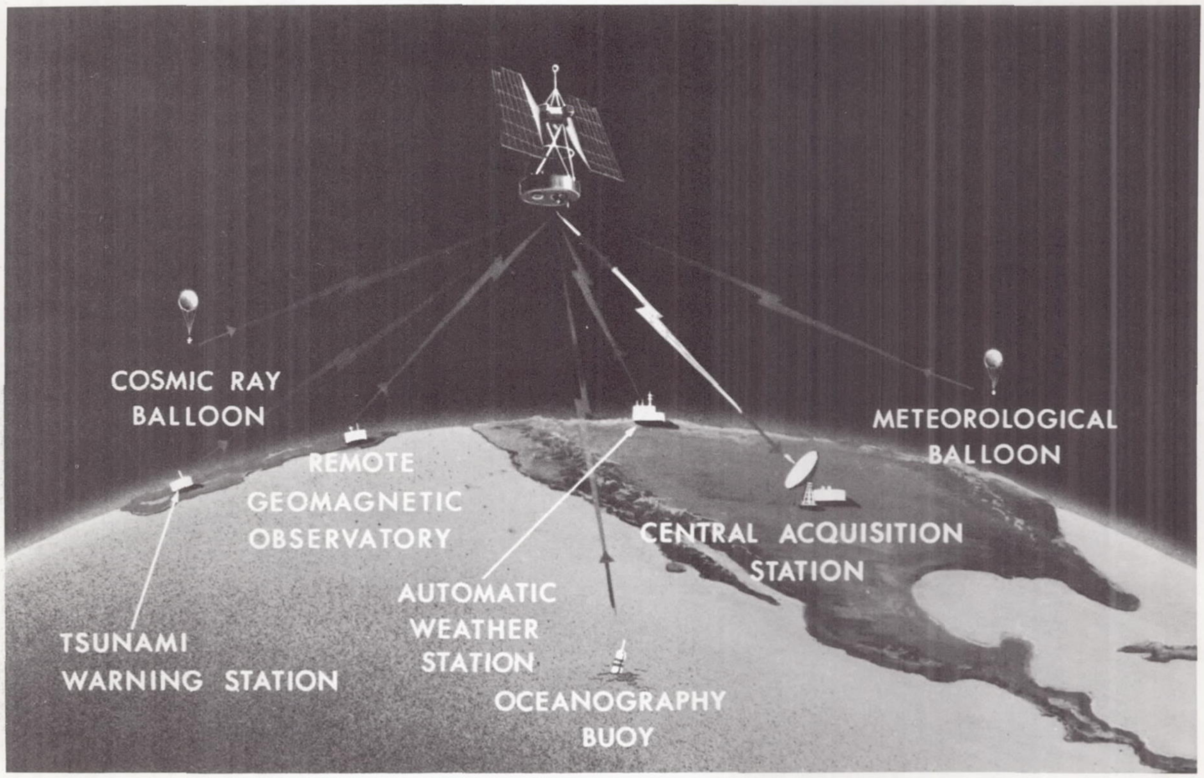


FIGURE 9–18.—Data collection by satellite.

10 Scientific Spacecraft

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

This country is busily engaged in a broad program to explore the solar system with unmanned instrumented spacecraft. There is nothing esoteric about this space sciences program. It is exploration in the most understandable and romantic sense. It makes use of men, rockets, and spacecraft. The men remain on Earth and reach throughout the solar system with their instrument eyes, ears, and hands. They reach to spots now inaccessible to man, but which some day man himself may visit.

Exploration of space is one of the most difficult technological challenges of our day, but good men and strong nations thrive on tough problems. By successfully meeting this challenge, our preeminence as world leaders in science and technology can be maintained. The space program can be expected to set the pace for the technological development of this country for the foreseeable future.

No segment of our space technology is more exciting than the creation of those weird and wonderful devices called spacecraft. Several thousand of this country's best scientists, engineers, and technicians are hard at work on our Explorers, Monitors, Observatories, Rangers, Mariners, and Surveyors. A brief introduction to these spacecraft and some indication of our operating experience with them will be presented. Much progress has been made since Explorer I was launched in 1958 but much more is needed.

SPACECRAFT GEOPHYSICS AND ASTRONOMY

Since the preceding papers have illustrated those spacecraft which have dominated the scene during prior years, this paper will review those which are now under active development.

Figure 10–1 illustrates the type of unmanned Earth satellite with which we have the most experience, the Explorers and Monitors. The satellites shown are planned for launch this year, and one, the Atmospheric Structure Satellite, has already been successfully launched.

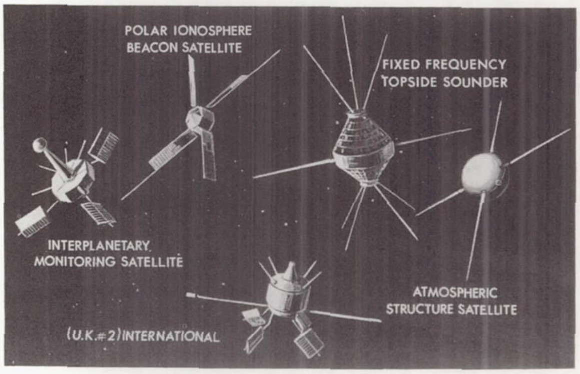


FIGURE 10–1.—Planned 1963 launchings of Explorers and Monitors.

These satellites typically weigh several hundred pounds and carry half a dozen interrelated scientific instruments as well as the electronic equipment to code and transmit information to Earth. Radio receivers are also carried to permit the satellites to receive commands from the ground. The satellites operate on less power than a small electric light bulb. This power is usually generated by solar cells and batteries. Most Explorers and Monitors are spin-stabilized; that is, they are intentionally spun about an axis which then remains fixed in space. Although this is the simplest of our attitude-control techniques, it is complicated somewhat by the presence of slight forces from the upper atmosphere, the Earth's magnetic field, and the pressure of sunlight. These and other disturbances must be understood and accounted for.

The second generation of Earth satellites beyond these Explorers and Monitors is far more complex. These satellites are referred to as Observatories and, indeed, they are. The Orbiting Solar Observatory, flown in 1962 and discussed in a preceding paper by John E. Naugle, was our first Observatory and has proven to be remarkably successful.

In 1964, an even more advanced satellite, the Orbiting Geophysical Observatory (OGO), shown in figure 10–2, will be flown. This satellite is designed to obtain simultaneous measurements of a large number of geophysical and solar phenomena. It will provide a better understanding of the Earth's environment and the Earth-Sun relationships. Twenty correlated scientific experiments are now being tested for the first OGO mission. The OGO weighs slightly over 1,000 pounds including a scientific payload of 150 pounds. It is designed to fly with complete attitude control maintained by a combination of gas jets and inertia wheels. This control permits simultaneous pointing of selected experiments at and away from the Earth, in the direction of flight, and at the Sun. The 32,000 power-generating cells mounted on the solar panels are also oriented toward the Sun. The satellite carries an advanced high bandwidth data system capable of stored and direct data transmission which will be monitored by a series of ground stations in the Northern and Southern Hemispheres. As with all of our advanced spacecraft, OGO employs an active mechanical system of temperature control for its vast amount of electronics. The OGO is designed for two types of missions. It will be launched with a Thor-Agena into a circular polar orbit at relatively low altitudes. In addition, an Atlas-Agena will be used to place it into a highly elliptical orbit with apogee exceeding 50,000 miles.

The largest of our Observatories is the Orbiting Astronomical Observatory illustrated in figure 10–3. The OAO is a 3,600-pound spacecraft to be launched into a 500-mile circular orbit by the Atlas-Agena launch vehicle early in 1965. A number of important experiments are being developed for this satellite. They include four 12-inch telescopes to map the sky in ultraviolet; these telescopes are being developed by the Smithsonian Astrophysical Observatory. Four 8-inch telescopes and one 16-inch telescope are being developed by the University of Wisconsin to study selected bright stars and nebulae. A 36-inch Goddard Space Flight Center telescope will make detailed studies of 5,000 stars and nebulae. The Goddard system is illustrated in figure 10–3. A 32-inch Princeton telescope is being developed for detailed studies of interstellar matter.

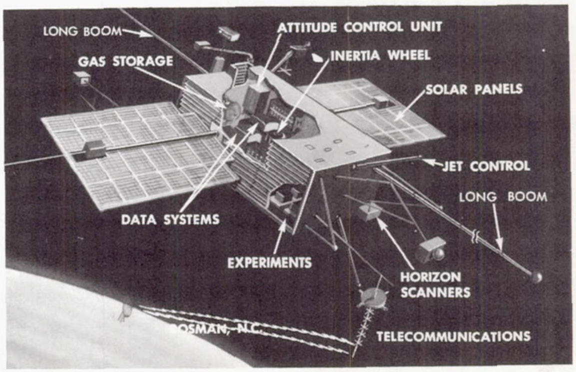


FIGURE 10–2.—Orbiting Geophysical Observatory.

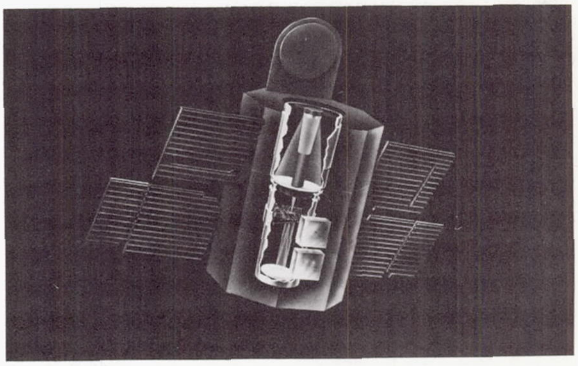


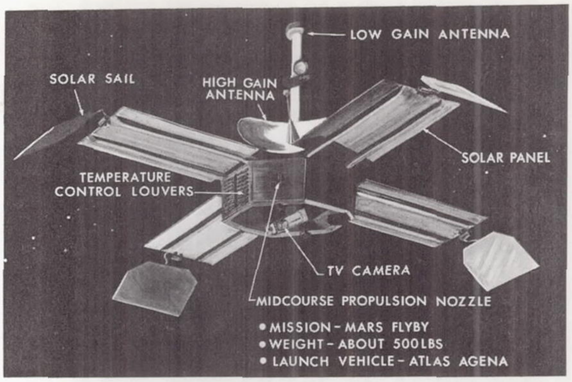
FIGURE 10–3.—Orbiting Astronomical Observatory.

In order to make full utilization of these advanced instruments, we are solving a series of very difficult technological problems. These include the problem of maintaining a precisely alined optical structure after the rigors of launch and in the heating and cooling conditions which prevail in Earth orbit. In addition, the attitude-control system will have an eventual capability of pointing the OAO to an accuracy of 1/36,000 of a degree. The spacecraft computer and its data-handling system represent significant advancements in the state of the art. Since Orbiting Astronomical Observatories will only be launched about once a year, great pains are being taken to insure a high probability of successful launch and a long lifetime orbit.

The OGO and the OAO will be the backbone of our geophysics and astronomy programs for many years to come.

LUNAR AND PLANETARY SPACECRAFT

In a previous paper, Oran W. Nicks illustrated the Mariner II and the Ranger spacecraft, both of which have flown. In the next two figures second-generation lunar and planetary spacecraft will be illustrated. Shown first is the Mariner spacecraft designed to fly to Mars in 1964. (See fig. 10–4.) This 570-pound spacecraft is a growth version of the highly successful Mariner II and will also utilize the Atlas-Agena launch vehicle. The 1964 Mariner will, however, have some important innovations. The Mars mission is considerably more difficult than the Venus mission in several respects. Whereas Mariner II had to fly 180 million miles and 109 days to reach Venus; the Mariner will have to fly about 320 million miles and 230 days to reach Mars. Longer lifetime of all components will be required. To both back up and conserve the gas used to control the Mariner, stabilizing vanes are being added to the tips of the solar panels. These vanes use solar pressure for control. At Mars, the Mariner will be about 130 million miles from the Earth. It will thus have to look at the bright star Canopus rather than the dim Earth for an attitude reference in addition to the Sun. Because available solar energy at Mars is one-fifth that at Venus, the solar panels will be increased in size and number. Also, the increased communication distances require a new and more powerful transmitter. The Mariner II signal received on Earth from Venus was only about one billionth of a billionth of 1 watt. These are but a few examples of the problems with which the spacecraft designers must cope.



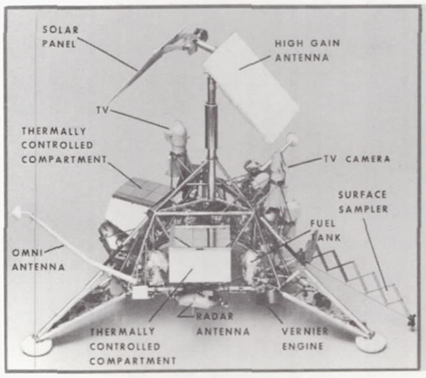
- MISSION - MARS FLYBY
- WEIGHT - ABOUT 500LBS
- LAUNCH VEHICLE - ATLAS AGENA

FIGURE 10–4.—Mariner spacecraft designed for Mars flight, 1964.

For our lunar missions, the problems of long lifetime and great communication distances are replaced by other equally difficult problems. The Surveyor spacecraft, shown in figure 10–5, represents our most advanced effort at unmanned lunar exploration. The Surveyor is a 750-pound spacecraft designed to soft-land about 115 pounds of scientific and engineering instruments on the Moon in 1965. Inasmuch as Surveyor's solid propellant retrorocket, used to slow it down at the Moon, weighs about 1,350 pounds, the all-up weight will initially be about 2,100 pounds. This weight requires the new Atlas-Centaur launch vehicle.

Consider the technological problems confronting the developers of Surveyor. Once launched, Surveyor must accomplish the following difficult tasks:

(1) Remain in flawless working condition for three days until the landing is complete



- •DEMONSTRATE
  - SOFT LANDING TECHNOLOGY
- •SURVEY
  - VARIOUS LANDING AREAS
- •MEASURE
  - PHYSICAL & CHEMICAL PROPERTIES

FIGURE 10–5.—Surveyor spacecraft.

(2) Retain perfect altitude control and execute upon command from Earth one or two midcourse maneuvers to bring the landing within the 50-mile aiming circle
(3) Complete an attitude orientation on approaching the Moon
(4) Detect the proper altitude for firing the main retrorocket to slow its 8,600-foot-per-second approach speed
(5) Jettison the spent retrorocket and land automatically with small vernier rockets under complete control of its own radar system
(6) Survive a landing in unknown terrain which may vary from soft dust to boulder fields
(7) Once landed, point its antenna at the Earth, its solar cells at the Sun, and conduct scientific experiments on command from Earth for about 1 month.

These tasks perhaps sound fantastic, but they can and will be done. They, however, cannot be accomplished without advances in our technology. To illustrate how difficult this mission is, let us compare it with that of a typical ballistic missile. In essence, the Surveyor spacecraft must do everything the missile must do and then some, but it must do it in reverse and back down to an imaginary pad on the Moon with not even a "hold" of a few seconds in the final descent.

THE TECHNOLOGICAL CHALLENGE

Typical military launch vehicles have averaged 20 flights to achieve 50 percent reliability. Similar development cycles for our equally complex spacecraft are simply too expensive. In fact, a relatively complex spacecraft with its scientific instruments costs more than its launch vehicle. Including development costs, they average about $20,000 per pound for spacecraft weighing up to 1,000 pounds. Carbon copies of a developed model cost less.

Why do spacecraft cost so much? Simply because they are very complex pieces of electromechanical equipment which must function nearly flawlessly from the outset. They are not mass-produced and hence cannot enjoy the economy of volume production. In a sense, they are individual works of art. As this art of low-volume high-quality production is learned, the new knowledge and skills will set the standards for all types of equipment throughout the country. Furthermore, the costs will be brought down and the quality up.

The complexity of Mariner II is illustrated in figure 10–6. The approximate number of parts in each of the six major subsystems, and the man-years required to design, develop, fabricate, and test two complete spacecraft are indicated. A large percentage of these many thousands of parts played an active and critical role in determining the success or failure of the Mariner.

Happily, Mariner II was a remarkable success. All are not always so successful. What makes us think the reliability and quality assurance problem can be licked? Perhaps, our greatest strength lies in our ability to test all parts, components, subsystems, and systems thoroughly. This testing takes time and money but is well worth the effort in terms of missions saved. Figure 10–7 illustrates the Mariner II undergoing tests in the 25- by 50-foot space simulator at the Jet Propulsion Laboratory. This facility simulates the vacuum and cold of outer space and the radiant energy from the Sun. Facilities such as this at NASA centers and at contractors' plants enable us to prove the validity of the designs in advance of flight.

PROGRESS IN SPACE FLIGHT OPERATIONS

An assessment of our progress must be continually made. Figure 10–8 illustrates operating experience with both the spacecraft and the rockets used to launch them. On the left side of figure 10–8, it can be seen that the flight performance of our spacecraft has been increasing dramatically. The time to first malfunction of any part had increased steadily to a value of about 2 months by the end of 1962. Because of redundancy and backup modes of operation, however, the useful life of unmanned spacecraft launched in 1962 has exceeded 6 months and is still rising because most of those intended for long life are still operating successfully.

Progress with launch vehicles has been equally gratifying. In 1962, 82 percent of all major NASA launchings were successful. This performance has been paced by the remarkable Thor-Delta which has successfully launched 16 out of 17 spacecraft. In addition, the huge Saturn has scored four out of four perfect flights. During this time period, both the Thor-Delta and the Scout payloads were increased over 60 percent at no increase in their $2.5 million and $1 million price tags. These dramatic increases in performance, life, and reliability of spacecraft and launch vehicles represent by far the most effective way to achieve economy in the space program.

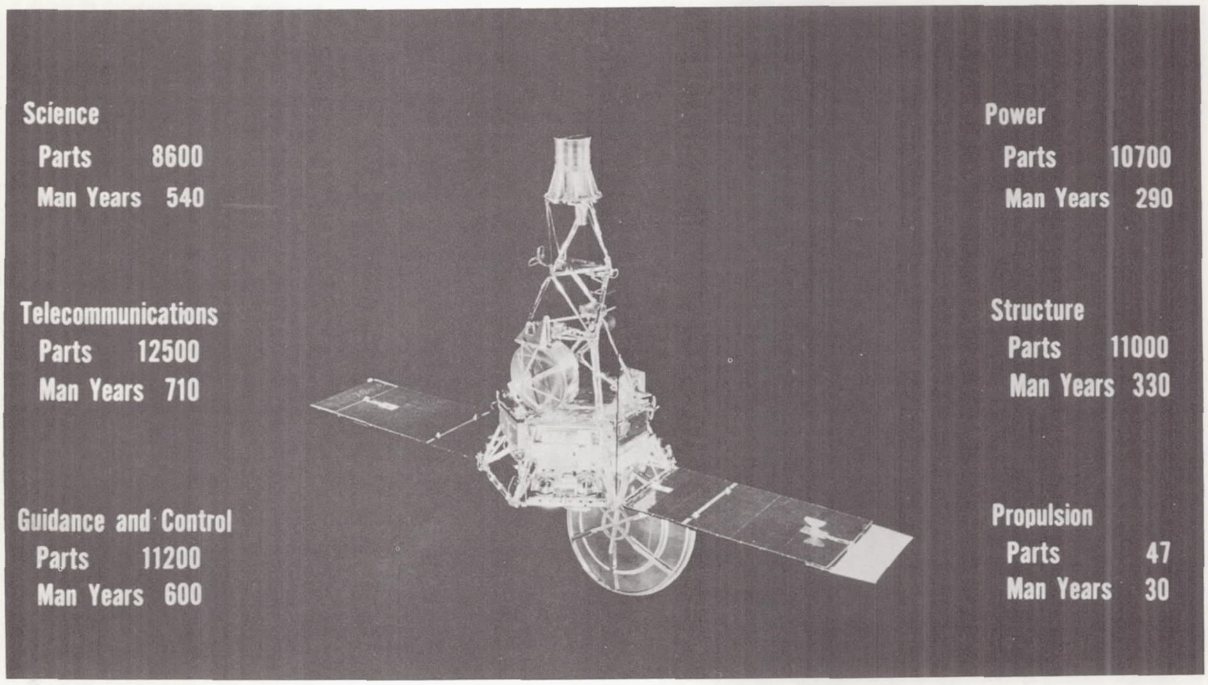


FIGURE 10–6.—Spacecraft complexity. Mariner II.

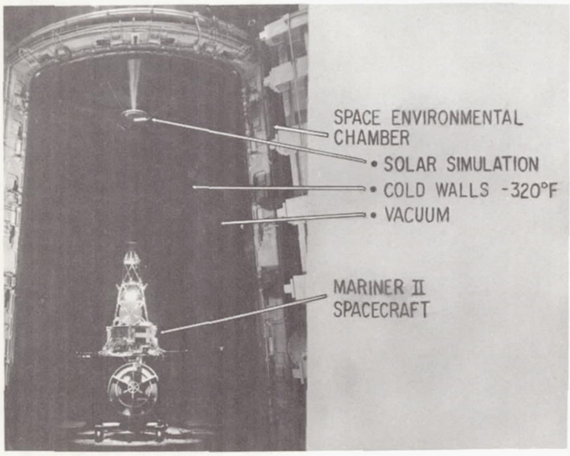


FIGURE 10–7.—Spacecraft testing.

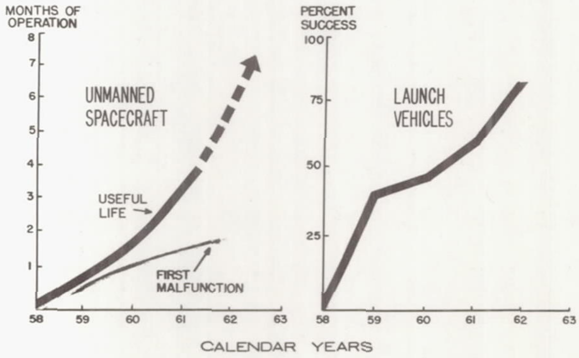


FIGURE 10–8.—Space flight operations.

11 International Cooperation in Space Exploration

ARNOLD W. FRUTKIN
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and
RICHARD J. H. BARNES
Chief, Cooperative Programs,
Office of International Programs, NASA

It is becoming increasingly better understood that our national space program is a response to a major international challenge. That challenge is not simply to our prestige. The challenge is to our ability to organize and implement long-range programs which can produce the basic knowledge and technology needed for security and economic well-being in a highly competitive world. The space program is one important national vehicle for answering this challenge because it comprehends an incredible range of sciences and technologies which reach into far corners of our university and industrial life. It gives us an unparalleled opportunity to stimulate our scientific and engineering communities, our educational systems, our industries, and government at all levels, to new accomplishment, to higher standards, to new awareness of their interdependence, and to joint effort which can immeasurably strengthen our society.

But all this country's energies in meeting international challenges are not directed narrowly toward survival and competition. Vast energies are spent in stimulating other countries to narrow the gaps between us, the disparities which make these countries economic, political, or military liabilities. In the broadest sense, we are seeking to reduce international tensions, to transmute dangerous rivalries and ambitions into constructive competition, to build communities of interest—in Europe, Latin America, and elsewhere, and to establish patterns of cooperation in the world.

The prospects for cooperative activity among the nations have seemed particularly appealing in space research and exploration because, in some respects, space is still relatively uncomplicated; there are no vested interests in space and no known economic or strategic advantages to be won by single nations. In other respects, of course, there are complications, because the tools of space research, from rockets to radar, the techniques and even the scientific content, are all of concern to military as well as civilian interests. Nevertheless, there has been a tremendous amount of sentiment here and abroad—and especially in the small nations—for international cooperation in exploring space in the hope that this cooperation might reduce rather than expand the dimensions of the cold war.

The National Aeronautics and Space Act, which established NASA in 1958, reflects this inescapable duality: The Act lays down the basic policy that this country must become a leader in space research and exploration. At the same time, it directs NASA, in conducting its programs, to do so in cooperation with other nations and groups of nations.

Since the Space Age is very young, one is warranted in assuming that few nations besides the

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Soviet Union and the United States have done very much in this field and that, as a consequence, the opportunities for cooperation are very few. Newspaper editorials, for example, in calling for cooperation in space research have made this assumption. But, the fact is that a surprising number of countries have entered into a surprising degree of space activity and that a significant amount of joint effort has in fact taken place and more is planned. The attention of the press remains focused, perhaps understandably, upon competition in space rather than upon cooperation. This is a phenomenon with which we are all familiar. For example, most people know that England was excluded from the common market because of French opposition, but the public has been given very little help by the press to learn what the common market does, how it does it, and what it has achieved. There is an old law in the world of finance that bad money drives good money out of circulation. So in the world of journalism, the news of controversy appears to drive the news of cooperation out of circulation.

What other nations are doing in space and, in particular, what they are doing together, is in fact small when compared with the resources going directly into national programs in the U.S. and U.S.S.R. Yet, what has been accomplished provides substantial evidence of the feasibility, the benefits, and the promise of joint action by the nations in this new field.

Consider the European television programs which were brought into U.S. homes via the Relay and Telstar communications satellites. (See fig. 11–1.) To send and receive these programs via satellite, special ground terminals costing many millions of dollars were required both here and abroad. The European terminals were constructed entirely by the British and French at their cost under cooperative agreements for the testing of our communications satellites. Besides England and France, Germany, Italy, Brazil, and Japan have entered into this testing program through construction of cooperating ground terminals, and the participation of several additional countries is expected. These arrangements help prepare the way for the future international cooperative exploitation of commercial communications satellites.

FIGURE 11–1.—Relay satellite ground stations.

Consider the U.S. weather satellite program as another example. Six successive Tiros weather satellites have been successfully placed in orbit to give us information on large-scale weather patterns by photographing cloud cover, each photograph covering thousands of square miles. (See fig. 11–2.) The data are more extensive than we can analyze by ourselves. Besides, it is important that the analysis of weather from cloud pictures taken hundreds of miles above the Earth be correlated with detailed information of the local weather below. To permit such analysis and correlation, the weather agencies of now forty other countries have been enlisted in cooperative programs under which they, at their own cost, conduct special observations of local weather conditions with aircraft, balloons, and other devices, and synchronize these observations with the passes of the satellites above. (See table 11–I.) This program, too, prepares the way for the broadscale international cooperation which will come with the meteorology of the future.

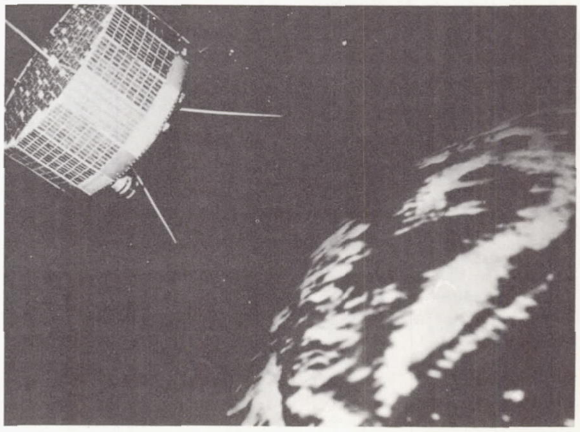


FIGURE 11–2.—Tiros weather satellite.

TABLE 11–I.—*NASA International Programs Ground-Based Projects*

Projects	Countries
Weather observations coordinated with Tiros passes	(35) Argentina Australia Austria Belgium Brazil Burma Chad China, Rep. of Colombia Costa Rica Czechoslovakia El Salvador France Hong Kong Hungary Iceland India Iraq Ireland Jamaica Japan Kenya Mauritius Netherlands New Zealand Poland Portugal Rhodesia/Nyasaland, Fed. South Africa Sudan Switzerland Thailand United Arab Republic United Kingdom West New Guinea
Participation of ground terminals in COMSAT testing	(6) Brazil France Germany, Fed. Rep. of Italy Japan United Kingdom
Ionosphere beacon	(20) Argentina Australia Austria Brazil France Germany, Fed. Rep. of Greece India Italy Japan Kenya New Zealand Nigeria Norway Peru Singapore Spain Sweden Switzerland United Kingdom
Ionosphere sounding	(14) Argentina Belgium Bolivia Chile Colombia Denmark France Germany, Fed. Rep. of Jamaica Netherlands Peru Spain Sweden United Kingdom

Consider, as another example, the operation of stations which NASA requires around the globe to track its satellites and to acquire data from them by radio. (See figs. 11–3 and 11–4.) The establishment of such stations on the territory of foreign nations requires not only the consent of these nations but also their cooperation in the acquisition of land, the importation of equipment, the movement of personnel, and the use of certain radiofrequencies. But beyond this, the interest of other countries in participating with us in the technology and the adventure of space exploration have prompted them to make available their own technicians to work side by side with ours in many of the stations. At a few stations, the host country, of its own volition, has even assumed responsi-

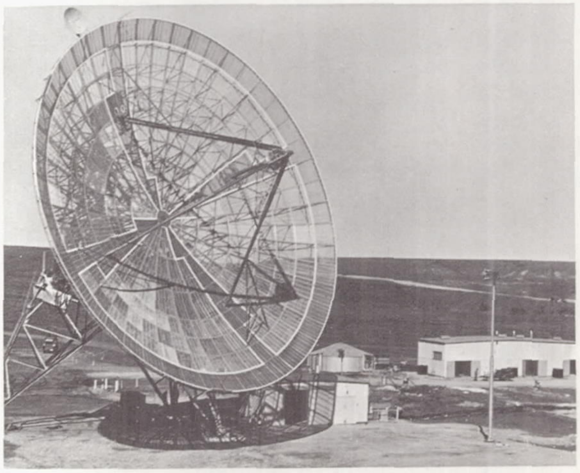


FIGURE 11–3.—Eighty-five foot radar dish at Johannesburg, South Africa.

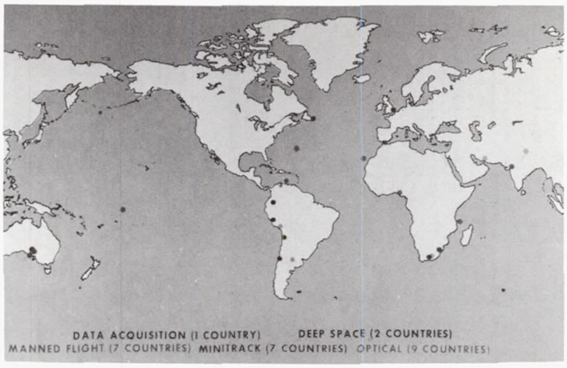


FIGURE 11–4.—International station agreements.

bility for the operating costs. Such stations represent common efforts and centers for the continued growth of understanding and cooperation. (See table 11–II.)

TABLE 11–II.—*International Programs Personnel at Overseas Tracking Stations*

	NASA	*U.S. contractor*	*Foreign nationals*
Scientific satellite net:			
Antofagasta, Chile	1	14	29
Johannesburg, South Africa	0	0	34
Lima, Peru	1	7	33
Quito, Ecuador	1	19	26
St. John's, Canada	0	0	16
Santiago, Chile	1	19	22
Winkfield, England	0	0	14
Woomera, Australia	0	0	20
Manned flight net:			
Grand Canary Island	1	22	15
Kano, Nigeria	1	23	23
Zanzibar	1	19	28
Guaymas, Mexico	1	23	17
Bermuda	2	31	51
Woomera Muchea } Australia	1	0	24 20
Deep Space net:			
Woomera, Australia	0	1	16
Johannesburg, South Africa	4	0	28
Totals	15	178	416

So far these examples have been concerned essentially with ground-based activity which supports or enhances our satellite experiments. International cooperation has gone beyond this to actual joint flight experiments. Two international satellites are already in orbit. The first is the satellite Ariel which was launched by NASA in April 1962. (See fig. 11–5.) It contains instrumentation conceived, designed, constructed, and financed under the direction of the British National Space Committee. Ariel has already provided valuable data on conditions in space not previously measured in combination. The second international satellite is Alouette, launched by NASA in September 1962. (See fig. 11–6.) This satellite was conceived, designed, financed, and engineered by the Canadian Telecommunications Research Establishment. This Canadian satellite is making the first measurements of the upperside of the ionosphere, which is an electrically charged layer of the atmosphere the understanding of which is essential for advances in radio communications.

Other joint satellite projects are in prospect with these and other countries. Perhaps the most ambitious and of broadest general interest is the Italian San Marco project. (See figs.

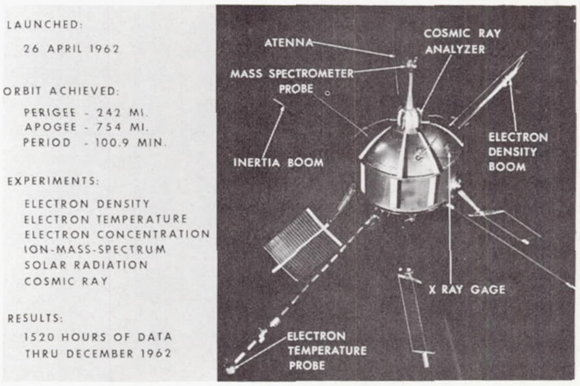


FIGURE 11–5.—Ariel (international ionosphere satellite, U.S.–U.K.).

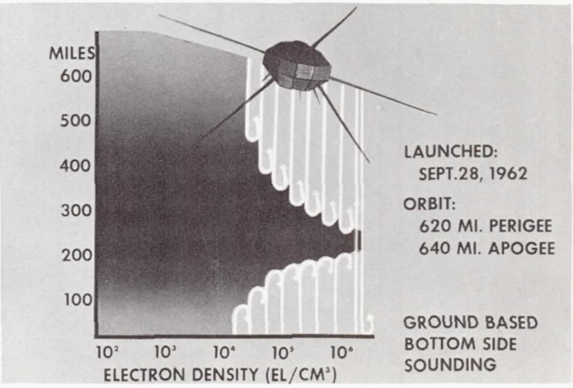


FIGURE 11–6.—Alouette, Canadian topside sounder.

11–7 and 11–8.) The Italian program calls for launching a satellite into an orbit around the Earth's equator in order to make observations of the density of the atmosphere. Because of the unique orbit, these observations will be of special interest technically and scientifically. To provide for the equatorial orbit, the Italian National Space Council is establishing a satellite-launching complex in the Indian Ocean on the equator off the coast of Africa. The complex will consist primarily of two large platforms resembling Texas towers which can be towed from Italy through the Mediterranean Sea and the Suez Canal down to the launch site. There retractable legs will be lowered to the ocean bottom to establish a firm footing. The elaborate instrumentation necessary for test and control systems for the launch vehicle and the satellite will be located on one platform and the launching itself will take place from the other. The Italian side is responsible for the concept, design, and construction of the satellite, for the launch platforms and instrumentation, and for much of the downrange tracking equipment. The Italian group will conduct the launching itself. NASA is responsible for technical training of many of the Italian team, for certain preliminary small rocket tests of the Italian satellite instrumentation, and for providing the Scout rocket vehicle which will be employed to place the Italian satellite in orbit. Special interest will attach to the technology of this launch operation in an ocean environment and to the scientific results to be achieved in the first equatorial satellite experiment.

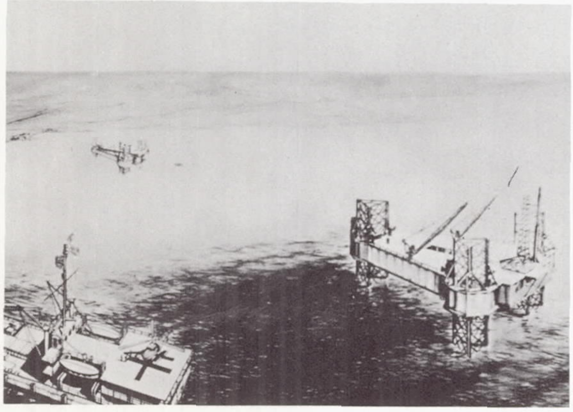


Figure 11–7.—San Marco project.

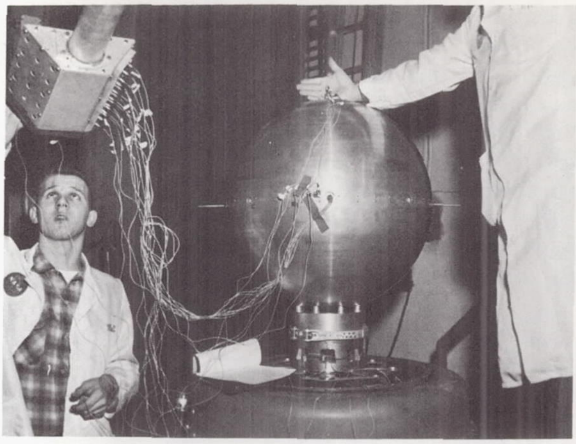


Figure 11–8.—Central section undergoing environmental testing at Goddard Space Flight Center.

Essentially, satellites give data for the particular altitudes above the Earth at which they orbit. It is just as important to obtain vertical profiles of conditions in and beyond the atmosphere. To get such vertical profiles, small sounding rockets which rise almost directly above the launching site for a few minutes only and then descend to Earth not very far from their launch site are used. In their few minutes aloft, they permit the taking of measurements at various levels in the lower or upper atmosphere or even in near space. These measurements apply only to the vertical section of the atmosphere which is penetrated, but the atmosphere differs at different latitudes, in different seasons, and at different periods of day and night. Therefore, the true potential of sounding rockets can be realized only if many such vertical sections are measured and the results correlated. This means that sounding rockets must be used repeatedly in many different parts of the world at the same times and at different times. Obviously, then, international cooperation is an essential ingredient for successful use of sounding rockets. (See tables 11–II and 11–IV.)

In the past year alone, NASA has in fact carried out cooperative launchings of sounding rockets with eight different countries. Many of the launchings have been overseas—in Sweden (figs. 11–9(a) and (b)), Norway, Pakistan, Italy, and Canada. Other countries have joined with us in experiments in the United States—

Australia, France, and Japan. Still other countries are even now approaching their first joint sounding rocket experiments with us—India, New Zealand, and Argentina.

The basic elements in such programs are the scientific instrumentation for the flight, the rocket itself, the ground instrumentation to receive data from the rockets, and, finally, the analysis of data. The cooperating countries divide responsibility for these elements according to the particular agreement. Already, such cooperative scientific sounding rocket arrangements have provided for us the first sampling of night-glowing clouds, a phenomenon of the Northern skies which may contribute importantly to our understanding of upper atmosphere processes. These programs have demonstrated the comparability of Japanese and American instrumentation for measuring electron density so that the observed results in both countries can be interchanged and correlated. They have permitted extensive probing of the auroral regions which are not accessible from our own territory. They have permitted correlations of seasonal phenomena such as warming and cooling at the top of the atmosphere in both arctic and temperate regions. Altogether, sounding rocket cooperation is slowly extending our knowledge of spatial processes and the connection between those processes and our weather and communications.

Further experiments proposed by foreign scientists for both satellites and sounding rockets have been approved on their merits and are to be carried out on a cooperative basis. Our debt to gifted foreign scientists in the past is so well known that it is not necessary to emphasize the importance of keeping open the channels between our communities.

International personnel exchanges also contribute importantly to these cooperative efforts through a variety of NASA fellowship programs. In general, opportunities for training are made available here; the sponsoring country pays for the travel and subsistence of its trainees. This requirement for investment on the part of the cooperating country assures careful consideration of the training arrangements, the personnel selected to be sent here, and their future utilization at home.

All of these international programs are conducted by NASA with civilian agencies abroad,

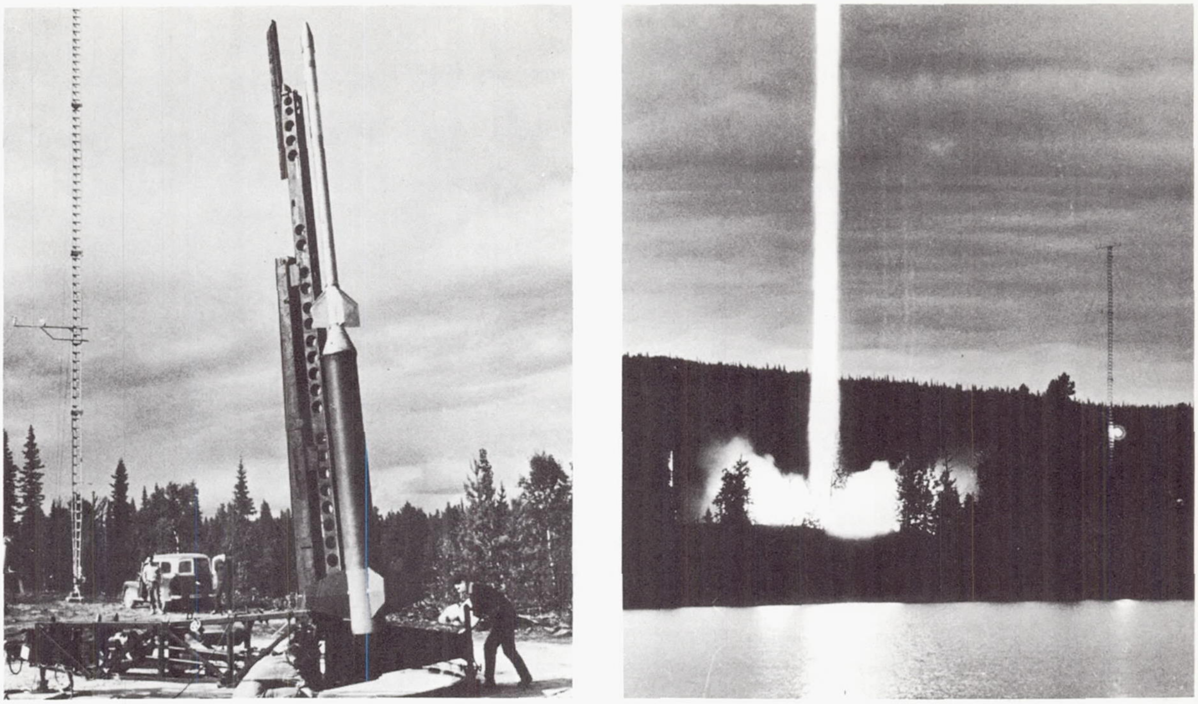
TABLE 11–III.—*NASA International Programs—Sounding Rockets Launched from Wallops Island*

Country	Rocket	Objective	U.S. participation	Foreign participation	Launch
Australia	Aerobee	Measure VLF radio noise	Rocket Launch Airborne telemetry	Experiment VLF ground equipment Data analysis	12/62
Canada	Black Brants (6)	Study vehicle and instrumentation performance	Launch	Rockets Instrumentation Data analysis	6/62 12/62
France	Nike-Cajuns	Test specialized optical equipment	Rockets Launch Experiments	Observation equipment Data analysis	1960–61
	Aerobee (2)	Study ionosphere irregularities	Rockets Launch	Experiments Data analysis	Early 1963
Italy	Shotput (1)	Flight test San Marco instrumentation	Rocket Launch	Experiments Data analysis	1963
Japan	Nike-Cajuns (3)	Compare resonance and Langmuir probes	Rockets Launch Langmuir probes Data analysis	Resonance probes Data analysis	4/62 5/62
Norway-Denmark	Nike-Apache (1) and Nike-Cajuns (3)	Study D and E region of ionosphere	Rockets Launch Experiments Data analysis	Experiments Data analysis	12/61 6/62 Early 1963

with valid scientific objectives, with actual sharing of the work involved, and without the exchange of funds or the export of a dollar. These activities, all evaluated and implemented by the competent NASA program offices and technical centers, represent a net contribution to our own space interests. But equally important, they stimulate other countries to efforts of their own. The European nations, among others, have been quick to recognize the inher-

TABLE 11–IV.—*NASA International Programs—Sounding Rockets Launched from Foreign Ranges*

Country	Rocket	Objective	U.S. participation	Foreign participation	Launch
Australia	Skylarks (4)	Measure stellar and nebular ultraviolet radiation	Experiments Data analysis	Rockets Launch	Woomera 9/61, 11/61
Canada	Various U.S. approx. 30/year)	Study auroral zone phenomena	Rockets Data analysis	Launch	Fort Churchill
India	Nike-Cajuns (4)	Study upper atmosphere winds	Rockets Launcher Launch training	Launch Experiments Cameras Data analysis	Thumba, 1963
	Nike-Apaches (9)	Investigate equatorial electrojet	Rockets Magnetometer experiments Doppler equipment Telemetry training Data analysis	Launch Supplementary experiments Ground experiments	Thumba, 1963
Italy	Nike-Cajuns and Nike-Asps (8)	Study upper-atmosphere winds	Experiments	Rockets Launch Data analysis	Sardinia, 1/61, 4/61, 9/61, 12/62
	Shotput (1)	Flight test San Marco instrumentation	Rocket	Launch Experiments Data analysis	Indian Ocean, 1963
New Zealand	Arcas (3)	Measure mesospheric wind drift and turbulence	Rockets Launcher	Launch Experiments Data analysis	Birdling's Flat, 1963
Norway-Denmark	Nike-Cajuns (7)	Study D and E region of ionosphere	Telemetry trailer Experiments Launch and telemetry training Data analysis	Rockets Launch Experiments Data analysis	Andoya, 8/62, 12/62, 1963
Pakistan	Nike-Cajuns (2)	Study upper atmosphere winds	Rockets Launcher Training	Launch Expermients Data analysis	Sonmiani Beach, 6/62
Sweden	Arcas (1)	Measure winds during occurrence of noctilucent clouds	Rockets Experiments Launcher Ground telemetry	Launch Supplementary experiments Recovery	Jokkmokk, 8/61
	Nike-Cajuns (4)	Direct sampling of noctilucent clouds	Training Data analysis	Data analysis	Kronogard, 8/62



(a) Before launch. (b) After launch.

FIGURE 11–9.—Sounding rocket launching in Sweden.

ent values of space activity in advancing national technology, security, and prestige. Most of them have established national space authorities and are conducting or planning programs of their own and in cooperation with us. Furthermore, they have recognized that the high costs of space activity require the smaller nations to pool their resources if they are to participate in the larger benefits of space work. Europe, therefore, is now establishing two major regional organizations for space activity. One, the European Space Research Organization, plans expenditures of some $300 million over a period of 8 years. The other, the European Launcher Development Organization, plans to spend some $200 million over 5 years to provide European boosters for European satellites.

Through these organizations, Europe is bringing into being a sensible, regional cooperation of a highly integrated character, with common technical centers and laboratories. This development in a very realistic Europe is clear evidence of the practical political and industrial attractions of space activity. The combined resources of Europe are formidable and could, if interest is sufficiently high, support very substantial space programs. But in a broader sense, the movement to establish space programing on a regional basis in Europe illustrates the unifying forces which are brought into play by the requirements and by the promise of the massive technologies of the future.

NASA has officially indicated to both European space organizations its readiness to enter into cooperative programs on the same basis as in our arrangements with individual countries. Actually, there are many reasons why we and the Europeans should prefer the multilateral approach. For one thing, far greater technical potential can be achieved with a broad economic base. For another, European regional collaboration with U.S. cooperation could contribute significantly to the cohesiveness of the Atlantic community.

What of the Soviet Union?

For a long time, the Soviet Union was a passive bystander as the increasingly successful cooperative enterprises in the Western and neutral world progressed. A little over a year ago, correspondence between President Kennedy and Chairman Khrushchev opened the way for a first serious effort to arrange some cooperative activity between the two space powers. Mr. Khrushchev, in a congratulatory message to the President after the successful flight of John Glenn, observed that it would be a fine thing if the two nations could pool their efforts in space activities. Such observations had been made before, but this time President Kennedy replied with specific proposals for such cooperation and suggested that negotiators be designated. Three major meetings have taken place over the past year in New York, in Geneva, and most recently in Rome, between teams headed by Dr. Hugh L. Dryden of NASA and Academician Blagonravov of the Soviet Academy of Sciences. Dr. Dryden and Academician Blagonravov reached agreement last June upon a three-part program.

The first part provides for the coordinated launchings by the two countries of satellites to obtain weather data. It also calls for a direct communication link to exchange such weather data between the two countries and between any additional countries which wish to tap into the link. The second part of the agreement provides for coordinated launchings of satellites to map the Earth's magnetic field in space. The third part provides for cooperative testing of the next passive communications satellite, Echo. The Dryden-Blagonravov agreement was later confirmed by the two governments. Joint working groups met two months ago in Rome to provide for the implementation of this unprecedented agreement. Their work, so far, provides details for carrying out the first and third projects.

It should be noted that this U.S.-U.S.S.R. agreement is based upon coordinated rather than integrated effort. Yet it represents a remarkable breakthrough, a tiny oasis in a vast desert. The establishment of joint working groups under the agreement carries with it at least a potential for closer association and understanding. It is important that such possibilities be pursued within the bounds of prudence and mutual interest.

It is only natural that the United Nations should mirror the concern among all nations that space activity be directed to peaceful purposes. For two years, efforts to explore a proper role for the U.N. in space were snarled in political maneuvers and cold war politics. But then, in 1961, the UN succeeded in putting together a new Committee on the Peaceful Uses of Outer Space. (See fig. 11–10.) The Committee set up technical and legal subcommittees with the hope that the technical group would do something to facilitate international cooperation, and the legal group would frame useful guidelines for space activity. To the surprise of many, the technical subcommittee agreed unanimously upon a modest program which, among other things, provides for UN sponsorship of an international facility for launching scientific sounding rockets on the geomagnetic equator. India promptly came forward to offer a site for such an international rocket range, a site now urgently needed for research which can be done in no other latitudes, a site where technicians of East and West might meet in space operations for the first time. (See fig. 11–11.) Access to the range will be open to any interested member of the United Nations and the data obtained will be available to all. Technical and financial arrangements will be made directly by each participating nation with India. Thus, no international bureaucracy will be required. These recommendations were unanimously endorsed by the General Assembly of the United Nations.

The legal aspects of space activity were not so easily handled in the UN. The U.S. at the outset of UN activity in the space field put forward two two broad principles which were unanimously accepted: first, that international law and the United Nations charter apply equally to outer space and the celestial bodies which move through it and, second, that no nation may appropriate outer space or celestial bodies to itself or deny other nations access to them. Then, in the legal subcommittee, the U.S. proposed practical measures to provide for liability for damages or injury resulting from the reentry of man-made objects from outer space and for assistance to astronauts and the return of spacecraft and their crews to the launching nation. The Soviet Union was more interested in very broad principles to govern activities in space generally, but there has so far been no agreement on the definition of such

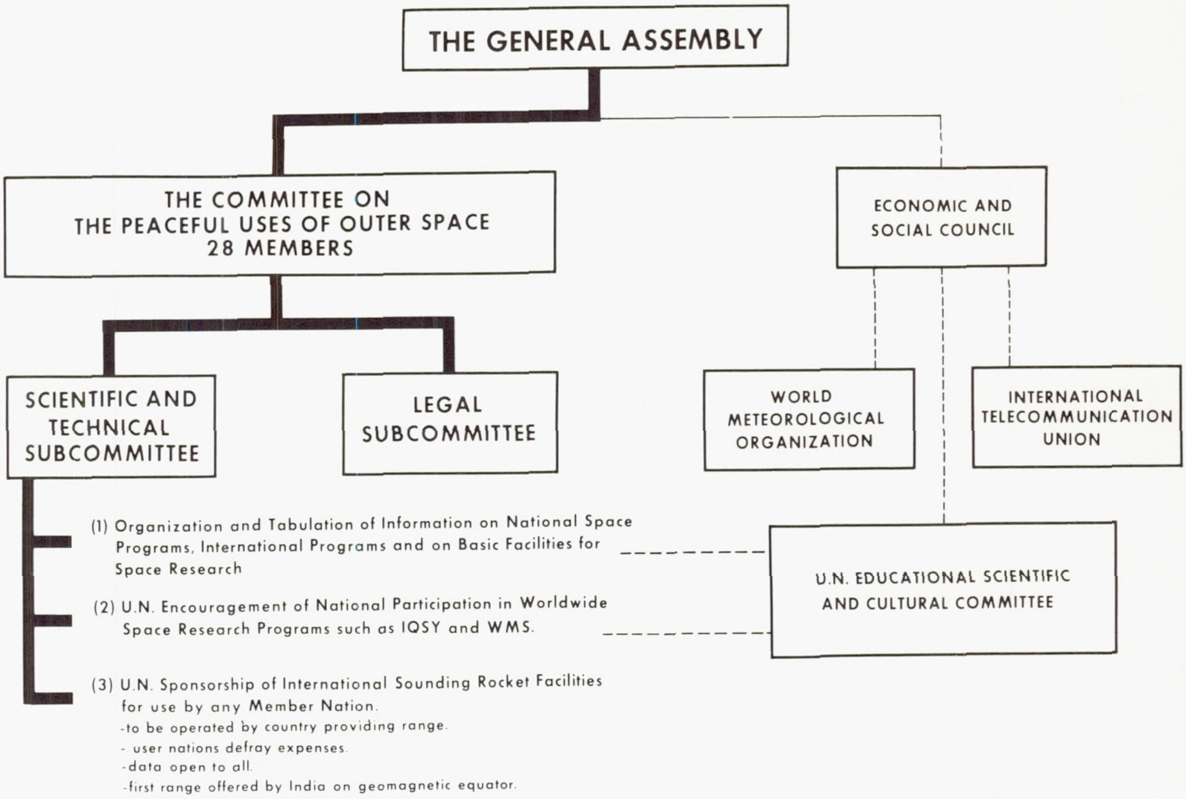


FIGURE 11–10.—United Nations Committee on the Peaceful Uses of Outer Space.

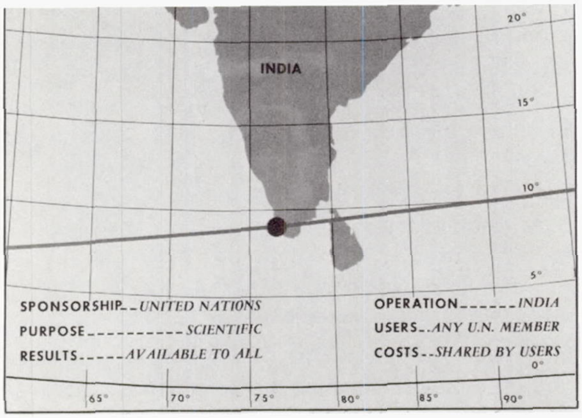


FIGURE 11–11.—International sounding rocket facility at geomagnetic equator (INCOSPAR).

principles. However, many more than one hundred satellites have now been placed in orbit and no legal problems have yet been encountered. Desirable legal principles may still be arrived at before real legal problems arise as a consequence of space activity.

By way of an overall conclusion and summary, one can say that very considerable progress has been made in only the past year in international cooperation in space through—

(1) The launching of the first international satellites, the joint planning and execution of scientific sounding rocket programs
(2) The participation of upwards of three dozen countries in cooperative projects relating to communications and meteorological satellites
(3) The establishment of regional organizations in Europe for peaceful space activity
(4) The achievement of a unique agreement between the United States and the Soviet Union for coordinated space activities, and
(5) The substantive UN action to facilitate an international range in India.

Nevertheless, the effort remains an uphill one.

We do and must walk a narrow line between considerations of national security on one hand and of maximum openness and cooperation on the other . The Congress recognized this in the National Space Act by giving due attention to the national security, and yet specifying that the space programs should be conducted in cooperation with other nations. So far, there has been success in carrying out this mandate, but basic solutions to the world's political problems must in all likelihood precede rather than follow any very great extension of international cooperation in space projects. Still, modest progress in cooperation can contribute to the general improvement in climate which is needed for a significant thaw.

The University-Industry Partnership in Projects

Auspices: *University of Illinois*

Presiding: **LYLE H. LANIER,** *Executive Vice President and Provost*, *University of Illinois*

Introduction

LYLE H. LANIER
Executive Vice President and Provost,
University of Illinois

The main purpose of this session is to focus attention upon some of the major aspects of university-industry relations that are being affected in important ways by the space program. Obviously, a scientific and technological enterprise as vast as that conducted by NASA—together with related activities in the Department of Defense and the Atomic Energy Commission—must necessarily have an enormous impact upon industry and universities—as regards both their independent functions and their mutual interests.

Industry looks to the universities mainly for educated manpower and for technical information in the broadest sense of that term. Its greatest concern—and it is a concern shared by universities, by responsible government at all levels, and by our whole society—is that the quantity of educated manpower and of technical information be sufficient, both for the newer Space Age tasks and for all other economic responsibilities of the industrial system.

There is also concern about the quality of the trained manpower supplied by the universities to industry, with special reference to the requirements generated by Space Age developments. Are the curriculums in university departments of science and engineering keeping pace with the rapid changes in technology and advanced research? Is the cross-fertilization between the fields of physics, astronomy, and the Earth sciences—which has been greatly encouraged by the space program—being reflected in the university training of students preparing to enter the technical ranks of industry?

Institutions of higher education—especially the publicly supported universities that cultivate the land-grant tradition—also have an obligation to provide continuing education, or adult education, where the public interest requires it. Should these and other universities offer advanced training to industrial personnel, to help them bridge the gap between their earlier education and the newer technical developments in science and engineering? If so, what kinds of arrangements can most effectively accomplish this purpose?

In addition to in-service training for individual scientists and engineers, can universities devise means whereby broad segments of industry can be assisted towards greater technological sophistication on an institutional basis? A program which has been proposed by Dr. J. Herbert Hollomon, Assistant Secretary of Commerce for Science and Technology, is designed to encourage more rapid advance in technology on the part of important civilian industries that traditionally have done little research and development. Is this a broad area of university-industry relationships that could be cultivated with mutual benefit, and with promise of substantial stimulation of economic growth in general?

One final question which may deserve consideration: Should the economic and social consequences of Space Age science and technology be subjected to systematic study by social scientists in universities—for the guidance and mutual benefit of industry, government, and the general public?

12

Contributions of Educational and Research Programs to Manpower and Advances in the Space Sciences

FREDERICK SEITZ

Head, Department of Physics, University of Illinois, and
President, National Academy of Sciences

The mobility of man throughout history exhibits a curious dualism in the sense that the species is distributed in essentially every part of the world that can possibly be inhabited, in spite of the fact that the average individual basically prefers to remain fixed. Most human beings spend all of their lives within a few miles of their birthplace, usually marrying someone from just around the corner. Yet, in spite of this, our species has managed to reach almost every spot or crevice of the world which muscle or machine can attain. Moreover, individuals from one region have managed to wander far afield in spite of hardships. The reasons for our moves from one region to another, either in small missions or in large groups, are quite varied. A few of the principal ones may be listed.

Perhaps the most important reason has been the drive for self-preservation. It is this, for example, which brought the Eskimos to the Arctic wastes, the Patagonians to the bleak tip of South America, and the bushmen to South Africa.

Second is the desire for trade, which, for example, led to the establishment of the "amber route" between the Mediterranean and the Baltic many thousands of years ago, and likewise led the Chinese to develop the caravan routes across the Gobi to Persia and Rome. This trade enriched the Roman West in silks but depleted it of gold. The same interests brought the Phoenicians to England and around Africa and ultimately brought Columbus to the new world.

A third motive is the desire for adventure or booty which drove Alexander across Persia to India, Marco Polo to far-off Cathay, and Pizarro to Peru.

Then there are the reasons of military strategy, such as those which caused Hannibal to cross the Alps with his elephants in order to attack Rome from the north and caused Henry The Navigator to seek a route around Africa and thereby outflank the Arabian citadels in the Near East.

Prestige may play a very important role; it influenced the national teams that have penetrated the polar regions and led Hillary to the top of Mount Everest.

Then there may be religious motives, such as those which impelled Livingstone to the heart of Africa, the Puritans and the Quakers to the new world, and the Italian Jesuit, Mateo Ricci, to the life of an expatriate in Peking 400 years ago.

Finally, the desire for unusual knowledge is one of the deepest driving forces among an exceptional group of human beings. This quest for knowledge drove many men to the heart of Africa to search for the source of the Nile, others across the Arctic wastes to the Poles, and still others in bathyscaphes to the bottom of the ocean depths.

Clearly, most unusual human journeys have been spurred by a combination of these motives and not by one alone. We know, for example, that the Celtic tribes wandered back and forth across the face of Europe in the millennium before Christ, goaded by a variety of motives which must have included all of these factors to some degree. Somewhat the same can be said of the majority of the expeditions to the Antarctic in the last 50 years and of the trips of the atomic submarines between the Altantic and the Pacific under the polar ice sheet.

The great exploration of the extraterrestrial space about us in which mankind is deeply engaged at present is a continuation of the pattern of migration that has prevailed throughout the history of man. The only remarkable thing which has occurred is that technology has now reached a point where our machines can attain sufficient velocity to overcome the Earth's gravitational field and hence has opened to us the possibility of exploring the outer hemisphere and the interplanetary regions. Fortunately, as long as we keep to the nearby planets the distances and speeds involved are such that these explorations can be undertaken in a time that is short compared with one human lifetime, and thus they can be comprehended in the same general framework of time as that involved in the great explorations of the past.

The motives which drive us into the exploration of space are on the whole complex, involving most of the basic factors listed above. In fact, the only one which might be said to be absent is the desire for wealth or booty, although in this connection Representative Gross of Iowa stated last year during the hearings on the NASA budget that he hoped we would find that the Moon is made of gold since he thought we would need it by the time the first men land there at the end of this decade.

We must view this period of exploration as an essential part of the human journey, tied to whatever meaning our own human existence has. The only major debatable issue seems to be the rate at which the exploration proceeds. Here our President has decided that nothing less than leadership will suffice. The investment in any year or decade must be decided by a complex balancing of all the factors involved and will continue to be a matter of public discussion and debate, but this investment will be high compared with that for most matters of scientific interest if we are to lead.

In considering the role that the university will play in all of this, we automatically focus on the issue of knowledge, for the university is one of the best places to generate new knowledge through research. It also has almost uniquely the role of transmitting advanced basic knowledge in a systematic way from one generation to the next. It is as unthinkable that the university can ignore space exploration in its broadest sense as it would be for the university to ignore the corresponding problems concerning terrestrial affairs. Conversely, as will be emphasized subsequently, space exploration cannot afford to ignore the universities. There seems to be no aspect of university activity relating to science or technology which is not involved in a fundamental way with space. One of the most active bodies in the National Academy of Sciences at the present time is the Space Science Board of the National Research Council which, historically speaking, played a key role in the organization of NASA and is now the principal outside advisory body for that agency. It is composed of scientists and engineers from essentially every discipline represented within the National Academy of Sciences. Most members are from academic life.

The principal areas in which we can hope to gain knowledge of the type with which the university is normally and justly concerned are easy to mention and discuss. I will begin with the applied arts and then turn to science.

In the area of technology there are, first of all, matters relating to the traditional fields of engineering. If we take the view that engineering is concerned with the practical aspects of power conversion, communications and control, the properties of materials, and structures, and, above all, that the highest art of genius in the field of engineering is associated with tying these together in specific applications through invention and design, it is clear that space technology offers an almost unlimited challenge.

Along the same lines, if man is to spend an extended period in space, it will be necessary to develop somewhat specialized knowledge concerned with man's responses to his environment that will become part of the traditional disciplines of the medical and behavioral scientist or engineer.

Finally, it may be recognized that the field of space exploration will have many sociological, legal, and economic problems associated with it. These will become part of the traditional discipline of our highly organized society and will be soon fitted into the body of academic knowledge.

Turning to the sciences, there are, first of all, matters relating to the upper atmosphere of the Earth, which is influenced very directly by the emanations from the sun (solar wind). Connected with this is the thin and highly ionized solar atmosphere through which the Earth travels. It is clear that we will not have a comprehensive and practical understanding of our atmosphere as a whole until there is a clearer picture of events a hundred or more miles above the surface of the Earth. Tied in with all of this, of course, are the Van Allen belts which are the focus of a variety of interests, both basic and applied.

Second are the matters relating to the inorganic composition of satellites such as our Moon and of the planets, that is, what might be called the local geology. In this connection, the term "geo" for earth is taking on a much broader meaning these days—the chairman of the Academy's Space Science Board is a geologist by profession. Geologically speaking, our own planet consists of a metallic core surrounded by a coating of less dense metallic oxides usually divided into the outer crust and the inner mantel. The basalts and heavier minerals lie nearest the metallic core. The continents are granitic in nature, representing islands which float on a basaltic base, and are in turn surrounded by the great oceans. The action of the water of the surface and atmosphere and the highly oxidizing atmosphere itself have produced highly individualistic features, such as the sedimentary deposits and the weathered and eroded features of the topography.

To what extent are all of these characteristics unique to our own planet? Since the Moon does not possess an atmosphere and probably lacks a metallic core, its features are obviously unique in their own way. Moreover, the Moon bears in a clear and evident way the imprint of billions of years of direct exposure to space, and thus it is in itself somewhat of an enormous fossil whose study promises to teach us much of the ancient past.

The information gathered by radioastronomy and by the recent Mariner probe of Venus has given us a much clearer picture of the topography of Venus. It has a dense, smoggy atmosphere and seems to be in a state like that which the Earth may have passed through at least a billion years ago, before the oceans formed and the inorganic carbides became involved in aqueous systems. The surface temperature is several hundred degrees above the boiling point of water. In contrast, Mars seems somewhat more like the Earth today in the sense that its atmosphere is transparent to light, and its temperature is closer to that of the Earth. However, we still wonder about the detailed features of the atmosphere and surface.

Related to all of this are questions concerning the composition of the atmospheres and the clues the physical features give concerning the formation of the planets.

The third great area of scientific study centers about the type of extraplanetary astronomical observations, normally made with telescopes and related instruments, that become possible once one is above the atmosphere rather than under or in it. The vistas for research are almost unlimited. The view is not only free of atmospheric turbulence but is free of all the absorption of the atmosphere which blacks out everything except a small region in the visible range and a few octaves in the radio range, normally termed the radioastronomy window. Once this type of observational astronomy begins in earnest, one can expect a vast extension of knowledge on all topics ranging from the study of the Sun's surface to the distant nebulae.

Fourth are studies of the basic laws of physics, particularly those covered under the designations of special and general relativity. Exciting new investigations become possible when one deals with variations in velocity and distance of gravitational field that are somewhat larger than the variations normally encountered on Earth, such as is possible for a terrestrial or solar satellite with a highly eccentric orbit.

Finally, we turn to the area of biological science which to my mind is by far the most intriguing of the fields involved in space exploration. If we find no significant signs of life anywhere else in the solar system, we can be fairly certain that life as we know it originated on the Earth and evolved, as is traditionally conceived, from complex molecules suspended in the ancient seas of the Earth a billion or more years ago. On the other hand, if we do discover signs of life elsewhere, a whole host of stimulating questions arise: First, is the form of life elsewhere basically like our own in the sense that it employs the same amino acid building blocks in its structure? If so, can we determine whether life originated elsewhere in the solar system or universe and was transported here? Or did it perhaps start on our Earth and become dispersed at an early stage in its development? If, on the other hand, it does turn out that life elsewhere in the solar system is inherently different from that on Earth—that is, uses radically different chemical building blocks—what will we be able to say about the ease with which life can be formed in other environments? At this moment, I can think of no serious problems except possibly those related to the origin and evolution of our own species that are even as remotely exciting as these. It should be emphasized that there is evidence which suggests that the hydrocarbons found in some meteorites are closely related to those found in archaic deposits of biological origin on Earth. This suggests, in turn, that some forms of life resembling our own may have existed outside our own atmosphere.

It is clear, then, that man's adventure in space will stimulate many branches of university work in a quite natural and automatic way. In some cases, this will mean no more than the addition of interesting new facets of a specialized kind to traditional disciplines; in others, it will lead to major research programs which may involve sizable teams of workers.

It may reasonably be asked at this point, to what extent the universities can expect rather radical reorientation. The answer to this question seems fairly simple. The effect on each institution will be somewhat individualistic, depending upon the local interests of the staffs and students, but, on the whole, will not be vast. In general, the major universities will not be conscious of major revolutions. Those institutions which are already well grounded in the fundamental aspects of the topics which underlie space science and technology will recognize the innovations quickly and adapt to them. Here and there, a faculty member will take on the problems in his field related to space science or technology as a specialty and evolve a team for development of a research program or a new curriculum, becoming deeply involved in a personal way. Occasionally, a large segment of a department involved in science, engineering, sociology, or psychology will decide that its department should become a major center for such study, just as the Department of Physics at the University of Iowa has devoted much of its attention to the instrumentation of satellites and the interpretation of the results obtained from the instruments. Still further, some universities will form interdisciplinary groups, perhaps connecting the biological, physical, and engineering sciences, in order to evolve programs which draw upon a diversity of talents.

Taken as a whole, I'm inclined to feel that the greatest impact of the space program will be on the engineering colleges—not so much because of the unique character of the knowledge which is being developed as because of an acceleration in the changing pattern of engineering, which would have altered much more slowly without the space program. While it is true that the basic equations of the engineer, such as Maxwell's equations or those relating to dynamics and statics, will not be altered, the new field has need for the most advanced and sophisticated type of engineering knowledge. There will be great emphasis on routine reliability, but there is also the utmost need for innovation. I am inclined to believe that those universities which take pride in their engineering schools will now have added reason to reexamine the relative emphasis which they placed upon work leading to the doctor's and bachelor's degrees. They will also have good cause to reexamine the traditional departmental structure, which represents an inheritance from the earlier days of engineering when specialization occurred at the junior level in college rather than at the graduate level and which may be poorly suited for the period ahead if the fields of engineering are to retain the maximum degree of flexibility in the face of challenges of a highly sophisticated type. Still further, it seems clear that almost any aspect of space research which is carried on within a university will require close cooperation between those in the engineering department and in the physical science departments such as astronomy, geology, or physics. This need should accelerate the development of interdisciplinary laboratories connecting engineering and science, to be used both for graduate and postgraduate research programs.

It is hardly necessary to add that the universities have an enormous capability to contribute to the space program. At the very minimum, the output of graduates is absolutely indispensable if the field is to accelerate and be sustained in the way which is envisaged at the present time. Moreover, these graduates must have the most advanced type of preparation our academic system is capable of giving them if they are to contribute.

Even beyond this, however, the history of science in the United States demonstrates quite clearly that strong university participation in a field of research, whatever it may be, helps to assure its health. There are many reasons for this. First, a certain fraction of the best minds find the type of freedom and flexibility peculiar to universities best suited for their work. Then, too, the presence of many inquiring young minds in a formative period adds a particular freshness and vitality to research. This is not to say that excellent work is not done elsewhere, such as in industrial, nonprofit, or inhouse laboratories. What is important is that any program which does not take maximum advantage of the capability within universities will not advance in the most effective way possible.

This brings me to a very major problem which is in the minds of all of us at present. What degree of interaction between the agency sponsoring our space program and the universities is most desirable if our national space program is to accomplish its best in the period of 10 or 20 years which lies ahead? The problem is obviously very complex and is not subject to any exact analysis. Perhaps one would like to ignore it, and yet it is not ignorable precisely because of the enormous demands the space program will make upon the universities for the most highly trained manpower as well as for subsidiary talent and knowledge. It is safe to say that in the coming generation a large fraction of our best-trained students in science and technology—perhaps at least one-half—will end up in some facet of the space program if we continue to make it the object of urgent national interest that it is at present. For their own good, the space agency must make certain that the universities are viable and that the students they turn out have been given the maximum opportunity to develop their capabilities, at least in the areas of academic work essential for the space program. This is elementary wisdom.

Let me make a side remark at this point. We all encounter numerous individuals who regard the national space program as an unmitigated evil which saddles our country with a heavy financial burden and diverts our best technical minds from more important tasks. I hope my earlier remarks made it clear that I feel personally that the general goals of the space program are a natural continuation of the human adventure. It is unthinkable that our society, particularly Western society, can ignore this challenge! The only debatable issue is the rate at which we proceed and the sacrifices we make for it. Having witnessed first-hand the colossal waste of technical manpower which took place in our country during the depression years, I must say that the present period of what is sometimes termed technical overemployment stands out in very healthy contrast, whatever else might be said.

I am inclined to feel that the overall evolution of our country in science and technology will be far better off with a healthy space program than it would be without it, provided we continue to focus reasonable intelligence in recognizing both the good and the bad effects it may have on our economy and social structure and mitigate the bad effects. The impact of the space program on our universities is one important facet which merits watching.

If we examine the policies of the various agencies which support science and technology in a way that has a direct effect on the universities, we find considerable variation. Some of the more important cases will be reviewed here.

First, there is the National Science Foundation, which is *not* mission-oriented and regards its key role to be that of providing support to universities in most major areas of science and engineering through grants. It is noteworthy that the National Science Foundation does not play a very direct role in guiding the flow of students into employment, although its indirect influence is enormous.

The National Institute of Health resembles the National Science Foundation in the sense that it has a broad responsibility for supporting research directed toward the improvement of the national health. It differs from the National Science Foundation in the sense that it also operates inhouse laboratories, which interestingly enough have suffered seriously from raids by the universities and nonprofit laboratories that are supported by grants from the Institute. Doubtless the money furnished for research by the NIH is having a significant impact on the choice between professional careers in the life sciences and in medicine. However, except for the extent to which the indispensable inhouse laboratories of NIH may be suffering damage, there is little doubt that the policies of NIH have done a great deal to bring the best minds and talents to bear on the essential problems of public health.

In the years immediately following World War II, various agencies of the Department of Defense, particularly the Office of Naval Research, felt called upon to support university research in both breadth and depth on the principle that a healthy intercourse between the universities and the research agencies and facilities of the Department of Defense would benefit both and thereby provide maximum support to the Department's mission. In the intervening years, the Department of Defense has interpreted its mission more and more narrowly, apparently adopting the general viewpoint that day-to-day association with university science was overemphasized in the past, and that the National Science Foundation and NIH are doing enough to maintain a healthy research atmosphere in the universities insofar as the needs of the DOD are concerned. There are a few areas in the DOD which have retained the original policies, but they are few and under growing pressure to reform.

It is still true, I should say, that a very large part of the output of universities ends up being employed by contractors of the DOD or in the inhouse DOD laboratories and agencies, so that the DOD inevitably depends substantially on the health of the universities.

Immediately after its establishment in 1947, the Atomic Energy Commission adopted policies toward the universities somewhat like those the agencies of the Department of Defense had at that time. That is, the AEC began to support the universities in both breadth and depth, recognizing that this policy would in the long run be of mutual benefit. Over the years, the Atomic Energy Commission has not deviated significantly from this policy. Unlike the Department of Defense, the AEC has on the whole tended to strengthen and reaffirm its original policy on a broad front. It is true that the contracting procedures of the AEC are rather more complex and cumbersome than those employed by some of the other agencies. This, however, is a detail about which adjustments can be made in the course of time.

Since NASA, DOD, and AEC are much more mission-oriented than either the National Science Foundation or the National Institute of Health, I see little point in expecting them to provide the same general type of support to universities that NSF and NIH do, unless evidence arises to show that certain specialized areas are being grossly neglected. It is clear that more appropriate bases for comparison are provided by the Atomic Energy Commission and the Department of Defense. It is particularly important that NASA make such a comparison at this time, while it is in the process of establishing its own policies, for two good reasons. First, NASA will depend significantly upon the quality of the product of the universities for the quality of its own effort, and second, the agency presumably has a long future life and may well determine the course of many aspects of science and technology in our country, not least the vigor and effectiveness of some aspects of university life.

Taken as a whole, I strongly recommend that NASA consider policies relative to the universities more nearly like those followed at present by the Atomic Energy Commission rather than by the Department of Defense. I realize that NASA, unlike the AEC, operates its own inhouse laboratories directly rather than depending upon contractors but this, I feel, is a detail in the larger picture since the large contract laboratories of the AEC are in a sense also inhouse laboratories. What strikes me as the most significant consequence of the differences in the policies now followed by the AEC and the DOD is that a very large number of university scientists and engineers have a sense of direct responsibility for the program and welfare of the AEC, whereas the trend is in the opposite direction for the DOD. I find very few scientists or engineers under 40 in universities who any longer feel the sense of close communion with the Department of Defense that my own generation did in the corresponding period. I believe an important part of this difference stems directly from the fact that the Atomic Energy Commission has continued to support university research broadly and in depth while remaining well within the framework of its mission, whereas the agencies of the Department of Defense have tended to become more and more selective and restrictive. This gradual withering of the bonds between the Department of Defense and the universities can be justified only if one assumes that the very indirect channels which now exist are adequate. Such an assumption strikes me as being exceedingly dangerous. In brief, I think the policy adopted by the Atomic Energy Commission is a far more conservative and reliable one for the long range.

In brief, then, it is my hope that once this period of organization and adjustment is over and the NASA has become established, it will adopt policies resembling those employed by the Atomic Energy Commission in as close a way as its own frame of reference permits. This, I feel, will assure a long and intimate period of communication between NASA and the universities which will optimize the benefits to both. I see no reason why the establishment of such a policy should affect the inhouse laboratories of NASA adversely. On the contrary, it seems to me that such communion will guarantee that the NASA laboratories will obtain appropriate fractions of the best talent graduated by the universities.

13 University Research Activities and Their Impact on the National Space Program

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In the preceding paper by Dr. Seitz, it was pointed out that the universities cannot afford to ignore space exploration and, conversely, space exploration cannot afford to ignore the universities. He has reminded us that the National Academy of Sciences through the Space Science Board has played a key role in our space program.

We all agree with Dr. Seitz that space presents a technological and scientific challenge which requires support from our scientific resources. Furthermore, the continuing growth of space and, indeed, of all our technological activities requires that the academic programs of the universities be enhanced and strengthened through a bilateral interaction with the national space effort.

For the success of our space effort, we need the ability to synthesize complex systems requiring contributions from the physical and life sciences. The universities provide the best sources now available for a multidisciplinary research capability. Their capability will therefore continue to be an important contributor to the success of our national effort in space. At the same time, we must remember that the universities are our prime source of new scientists and engineers. The problem which must be solved, then, is to use the university resources in such a way as to advance our national interest in space and at the same time strengthen the traditional role of the university in its academic function. It must not be forgotten that the basic responsibility of the university to society is to educate the young men and women who will conduct the affairs of the Nation tomorrow.

As a general background observation concerning the rate of growth of our technical activities in this country and, therefore, of the need for growing educational opportunities, it is instructive to note the growth of expenditures for research and development. For example, in 1940 the total national effort is estimated to have been $400 million, whereas in 1963 this had grown to $20 billion (50 times as great). It is also significant to note that in 1940 roughly one-quarter of the total effort was supported by the Federal Government; in 1963, three quarters of the effort is supported by the Federal Government. In other words, we are in an era of very rapid increase of research and development activities and an era in which the Federal Government is playing an increasingly important role in these activities. Therefore, not only must the universities establish their proper function and activity to support this growing scientific world, but also since the Federal Government is requiring such a large research and development effort, establishing the proper relations between the universities and those Government agencies which are responsible for large research and development efforts is equally important.

I was interested in the comments of Dr. Seitz regarding the Atomic Energy Commission and its policies towards universities. Clearly, the AEC (just as NASA) must depend significantly on the product of the universities for the quality of its own effort, and both AEC and NASA are equally concerned with understanding and working with the universities. Dr. Seitz states that he "strongly recommends that NASA consider policies relative to the universities more nearly like those followed at present by the Atomic Energy Commission rather than by the Department of Defense." Although I do not feel competent to compare in detail the operations of these two agencies with the universities, I certainly agree on the necessity of NASA establishing the best possible working relationship with the universities.

DEVELOPMENT OF "BIG SCIENCE"

The huge growth in expenditures for research and development has been accompanied not only by the growth of the purely technological aspects of research and development but also by a tremendous growth in the more "scientific" part of research and development. This has led to what Weinberg calls "big science." If I may hazard a definition of "big science," I would say that it refers to very large and expensive projects which have definite, pure scientific objectives. Examples include such things as the building of a bevatron by the Atomic Energy Commission as a scientific research tool and the launching of unmanned satellites and space probes by NASA to obtain purely scientific data. The significance of the growth of big science is that such projects, rather than being simple scientific projects, are largely engineering projects in the sense that they require the organization and management of extensive engineering resources in order to accomplish the project. The fraction of the cost associated with the purely scientific part of the project is usually very small. Of course, even though the project is largely an engineering development, nevertheless the controlling motivation and, indeed, the specifications of the project will be closely determined by the scientific objectives—hence, the term "big science" rather than "big engineering."

At the present time a large portion of the research and development expenditures of the Federal Government is devoted to such big science projects. Through these projects, the resources now available to scientists, in at least some areas of research, are many orders of magnitude greater than in the period before World War II.

NASA AND ITS SCIENTIFIC NEEDS

As far as the NASA is concerned, it is obvious that much of the NASA expenditures will be for projects which, by definition, I would call "big science." However, it is important that NASA also support work in the "little science" area. The NASA administration is well aware of this fact and actively supports a host of research activities in almost all fields of science. These "little science" projects are the seed for the development of "big science" projects in the years to come.

In order to carry out its mission, NASA has a great breadth of scientific and technological interest. Most of the NASA flight projects require the synthesis of all the physical sciences into an engineering system. Some of the projects, of course, also add the biological sciences to the list. It is therefore appropriate—in fact, necessary—for the NASA to support research in all these areas.

Much of this is quite properly being done at the universities, within the normal framework of university graduate student and faculty research. In fact, within the Chicago area, NASA is supporting research activities at Northwestern, Armour Research Foundation, the University of Chicago, and the University of Illinois, among other places. In a recent listing of NASA research grants and contracts, some 25 separate projects were listed at these institutions. At Armour, an Astro Sciences Center is being established; at the University of Chicago, the Laboratory for Astrophysics and Space Research will be one of the first interdisciplinary space research centers in the Nation. These activities are representative of the support which NASA is giving in the "little science" area. It is important, and the fact that universities all over the country are participating in this program is indicative of their recognition of its importance, not only to space, but to science in general.

It is extremely important that greater emphasis be placed on investigations into the engineering problems associated with space ventures. At the present time, engineering limitations and difficulties are the limiting factors in many of the flight projects which NASA is undertaking; therefore, development of new ideas and new techniques and new skills in engineering can be of enormous value to the program. The engineering faculties of the universities should not only recognize the new problems and new parameters which space has brought into their disciplines, but should also search for new solutions to old problems and indeed solutions to the new problems which will inevitably face our future space development. The NASA will certainly listen sympathetically to proposals in these areas.

This area of "little science" is obviously the most direct point of contact between the universities and NASA. Without the help of the universities, our program would be severely handicapped. For example, from the universities come most of the ideas for the experiments to be conducted in space. Many of the instruments are developed in university laboratories. University scientists conduct the analysis of flight data a specified time after the flight. NASA generally makes these data available to competent scientists. The study conducted by the National Academy of Science in Iowa last summer is indicative of both the interest and the imagination of the scientific community in this area.

But in addition to this direct association with space experiments, the university laboratories contribute to the general advancement of space technology. A glance at the list of NASA research grants will show such titles as the following:

(1) Investigation of the properties of gaseous plasmas
(2) Studies of the fundamental chemistry properties and behavior of fuel cells
(3) Research to establish methods of systematic structural synthesis
(4) Theoretical studies of the solar wind
(5) Studies of closed ecological systems

In the Chicago area, the Armour Research Foundation is conducting studies of lunar soil mechanics, and the University of Chicago is conducting experiments with image converter tubes for orbiting observatories.

These investigations are illustrative of the direct contributions of the universities. In a less direct, but equally important fashion, the universities contribute to the space effort through their academic programs. NASA is assisting by providing funds for fellowship grants and by helping finance summer study activities. However, space activities should go far beyond this point by being incorporated into academic courses of many kinds. Elementary physics courses are using satellite orbit problems in many schools now, and, as time goes on, there will be an increasing awareness of the relationship between most of the usual academic subjects, even economics, and space. This must be so for two reasons—first, space represents the scientific and technological frontier and, second, space is an important factor in national policy and the national economy.

Now, as far as NASA and its "big science" projects are concerned, by and large the universities are not directly concerned—the Jet Propulsion Laboratory being a unique exception. The Atomic Energy Commission has elected to use the universities a great deal more for conducing their "big science" projects. In fact, all their laboratories are operated either by universities or by industry.

ORGANIZATION TO DO "BIG SCIENCE" PROJECTS

First, consider the possibilities which the government has for carrying out its "big science" projects. Primary responsibility for the projects could be handled either within the government, within industry, or within the universities. In fact, examples of all three of these methods can be found. Before discussing the pros and cons of these choices, it should be noted that, in the last analysis, industry will always do most of the work as far as providing the actual hardware for the project. In other words, industry will supply most of the subsystems and test equipment for a project and, if the project requires a number of copies such as in the case of NASA projects in which a number of identical flights are being conducted, then industry will almost always be brought in to build the additional hardware. The question of responsibility for the project is therefore one of selecting a method for managing the project, including its overall design, testing, and perhaps building of breadboards during the development phase.

If the government manages the project itself, the principal advantage is that it is conducting the project with a staff which is thoroughly responsive to the needs of the government. On the other hand, the experimental evidence seems to indicate that the government has difficulty in obtaining and holding personnel within the Civil Service laboratories of a type able to manage the large engineering enterprise with which we are concerned. An argument for industry is that it is indeed well organized to staff and manage a large engineering effort. The contrary factors against this advantage must be considered—the fact that an industry conducting a large science project for the government within the framework of its other government and commercial activities is handicapped by its desires for developing proprietary interests and its need to make a profit. Furthermore, industry, in general, is not well organized to do "one of a kind" projects.

As far as the universities are concerned, the advantages lie with the fact that "big science" projects are closely allied to the interests of university staffs and, therefore, the personnel which the university can make available are well fitted through their academic background and analytical approach to work on such projects. Furthermore, the fact that the university is outside of the government and yet not motivated in the same way as industry permits it to advise and debate with the government in a manner which neither its own laboratories nor industry are quite able to do.

As arguments against the use of universities, the two most significant factors are probably the fact that a "big science" project is not a normal activity for a university and therefore there is the danger that the project preempts the university talent away from its normal activities with the consequent long-term damage to our national position in order to solve a short-term problem. There is also the concern that the university is not well equipped to manage a large engineering project and, therefore, it may find difficulty in properly and efficiently carrying out the government's objective when it attempts to conduct a big project.

THE JET PROPULSION LABORATORY AS A CASE HISTORY

The development of the Jet Propulsion Laboratory (JPL) since 1940 is an interesting case history of the growth of the university-supported government laboratory which is conducting major scientific projects. JPL was initially intended as a field station to conduct rocket and jet propulsion studies for graduate students in the Aeronautics Department of the California Institute of Technology. The coincidence of successful experiments by this group and military requirements engendered by World War II gave a great impetus to JPL, and support from the Army Air Corps was soon forthcoming. It was clear that the Jato developments of the Jet Propulsion Laboratory were of great practical value and a demand for these rockets grew rapidly. As a result, JPL assisted in setting up a commercial activity to manufacture and to continue development of these units. This corporation is now the Aerojet-General Corp.

With the unloading of this production activity, JPL turned to advanced research in the field of rocketry. Many of the present concepts of both solid and liquid rocket systems stem from work at JPL during the period of the midforties. Support for JPL continued to come from the Army Air Corps and also from Army Ordnance, who were interested in the possibility of long-range artillery rockets. The Jet Propulsion Laboratory was therefore invited to conduct research leading towards an understanding of the problems associated with such long-range rockets. Shortly after the war, support for the Jet Propulsion Laboratory was transferred primarily to Army Ordnance, and flight-test programs of research rockets were begun at the White Sands Proving Ground, which, incidentally, was initially established by the Army for the use of JPL.

In order to accomplish these investigations, the scope of the Jet Propulsion Laboratory had grown to include such technical areas as aerodynamics, structures, and electronics. By 1949 the status of these developments was such that Army Ordnance asked JPL to modify their research rocket, the Corporal, into an operational weapon system. This was done in the period 1949–1954. Development of the system was undertaken by JPL; production was handled by industry—in this case, primarily by Firestone and Gilfillan.

Again the technical skills at JPL expanded in scope to include abilities in guidance and communication. In all of the areas in which JPL was maintaining technical capability, research programs of a fundamental nature were carried out. In order to place the Corporal into production, it was necessary for the Jet Propulsion Laboratory to develop management and administrative skills pertinent to transferring our knowledge and information to the production contractors. JPL continued to conduct field tests of the Corporal during the development phase and, indeed, launched approximately 100 test vehicles at the White Sands Proving Ground.

Following the successful completion of the Corporal program, Army Ordnance invited JPL to study a second-generation weapon system to replace Corporal. After reviewing the results of this study, the Army elected to have JPL proceed with the development of the Sergeant weapon system. In this case, Army Ordnance selected the Sperry Corp. as the potential production contractor in the very beginning of the project. Sperry engineering personnel, therefore, worked with JPL during most of the development phase.

By this time, the staff of JPL had grown to about 2,500 and the technical disciplines needed to carry out the development of a complete weapon system of this type were well represented. Supporting research activities were an important contributor to our success in the Sergeant project.

With the coming of the Spage Age, JPL's talents were first exploited by the Army when, with the cooperation of the Huntsville team under Dr. von Braun, we successfully conducted the first Explorer satellite mission and the first Pioneer deep-space probe to escape the Earth's gravitational field. In a general way, the division of responsibility between JPL and Marshall Space Flight Center was that Marshall prepared the launching rockets while JPL prepared the upper stages and the payloads.

At the end of 1958 when NASA was established, the Jet Propulsion Laboratory was transferred to the NASA. Shortly thereafter, the role of JPL within the NASA was defined as developing spacecraft for lunar and planetary unmanned missions. At the same time, the supporting research activities of JPL were recognized and strengthened by the NASA and our capability in the field of space sciences was expanded. At the present time, we are responsible for three major projects: Ranger, Surveyor, and Mariner. Ranger is a project which is in the process of being transferred from an in-house to a contractor-supported project. Surveyor was initiated as a contractor-supported project. Mariner is conducted as an in-house project with heavy industrial support for subsystem work. We also undertake responsibility of operating a Deep Space Instrumentation Facility to communicate with these spacecraft. This facility is operated for us by an industrial contractor. We also continue our active program of in-house supporting research projects.

In retrospect, it appears that the initial growth of JPL was engendered by the exigencies of national defense. The personnel of JPL were first motivated by their scientific curiosity concerning rocket propulsion systems and then became motivated by the knowledge that they were contributing significantly to our national defense posture. At the present time, this has evolved into our contribution to the national space effort. Our motivations stem from the knowledge that we are making significant contributions and, furthermore, that we are working in a field of immense technical challenge. The morale and efficiency of the Jet Propulsion Laboratory is found to be exceedingly high. I believe you will also find that the government gets more from its dollar expended with JPL than it does in many other areas. Furthermore, about 80 percent of the JPL budget is expended with industry and here again I believe you will find that we are conducting a capable and effective management of these expenditures in the interest of the government. In other words, it seems to me that the JPL is an interesting example of the government-owned, university-operated laboratory which has grown into a national role in the field of "big science" where it is conducting large projects effectively.

This development has taken place with the full support of the California Institute of Technology. The Jet Propulsion Laboratory has been separated enough so that it has not diverted the Institute from its academic activities, but is close enough so that the Institute has provided scientific inspiration to the Jet Propulsion Laboratory and, conversely, the Laboratory has brought the instructive and research activities of the campus into close contact with advanced work in space.

In its present role, JPL has a responsiiblity to NASA to advise and assist in the formulation of the projects and research activities which it should conduct. When these are assigned to the JPL, then it has a responsibility to carry them out with the utmost efficiency. This requires the support of industry, primarily in the project area. As just stated, about 80 percent of JPL's budget goes to industry in the form of contracts or purchase orders. In addition, the Jet Propulsion Laboratory serves as a focus for many of the space-oriented activities of the southern California universities. We provide support for the California University Council on Space Science, and also provide opportunities for faculty and graduate students to spend time at the Jet Propulsion Laboratory. For example, last summer there were 65 graduate students and 13 professors working with us. Currently, there are 15 resident research appointments for faculty scientists. Many of these appointments go to overseas scientists.

The JPL is an excellent example of how a university can participate in "big science" without damaging its normal function. In fact, the association of the Jet Propulsion Laboratory with the California Institute of Technology is a definite asset to both, and thus to NASA and the Nation.

In conclusion, it should be stated again that the university, in both its research and its teaching roles, is an essential element to the success of our national space effort. The NASA is well aware of this important fact, and is doing its best to bring the universities into the program in a rational way. The universities, for their part, must reciprocate by demonstrating their awareness that they recognize that space is here to stay and that it represents the most advanced technological frontier, and, therefore, that they should develop their capabilities and interests in this area. The NASA-university team working together will not only strengthen our space effort but will lead the way to the technological triumphs of the next generation, in whatever field they may lie.

Panel Discussion: University Research Parks—An Example of University-Industry Cooperation

Leader: **WILLIAM L. EVERITT**
Dean, College of Engineering, University of Illinois

DAVID PACKARD
President, Hewlett-Packard Company

RALPH A. SAWYER
Vice President for Research, University of Michigan

GEORGE L. SIMPSON, JR.
Assistant Administrator for Technology Utilization and Policy Planning, NASA (remarks presented by **SIDNEY L. JONES,** *Assistant Professor of Finance, Northwestern University)*

ARTHUR M. WEIMER
Dean of Business School, Indiana University, and Codirector, Aerospace Research Applications Center

PACKARD: It might be of interest to review a little of the history of the university-industry relationship in the specific area around Stanford University. The part of this relationship which I wish to discuss was not influenced in any way by the Space Age. In fact the building up of this relationship occurred before what we now call the Space Age came about, but it should be remembered that the industry and the activity which have developed from this particular relationship with Stanford have, in fact, had a great influence on the space accomplishments to date. It seems certain that the firms being developed and the engineers and the scientists being trained in this area will continue to play a very important part in future space achievements.

When Hewlett-Packard first established its firm in the Palo Alto area, there were about five electronics firms around the San Francisco peninsula. The number of employees were somewhere between 200 and 300 altogether. In those days we looked to Chicago as the center of the electronics industry; after we had developed a few products, one of the first places we emphasized our sales effort was in Chicago. A few statistics on the situation today, some 20 to 23 years later, may be enlightening.

At the present time in the bay area there are well over 100 electronics firms, including the large effort of Lockheed in their Polaris program, employing approximately 30,000 people. If this one large firm is not counted and a count is made just of the electronics firms in the area around Stanford University, there are approximately 70 firms employing approximately

12,000 people, and the annual volume of production of electronic devices is almost three-quarters of a billion dollars annually.

Ten years ago Palo Alto had a population of 25,000 people; the population has more than doubled in this decade—to more than 52,000 at the present time. At the same time the assessed evaluation of the community has gone up from $42 million to $170 million, or approximately four times. This is one of the direct and important results for the community. There has been a threefold increase in retail sales as compared with a 2 to 1 increase in population.

Thus, the electronics industry which has developed in this area has had a very important and beneficial effect on the community as well as made an important contribution to the whole area of technology. The interesting thing about this development is that a majority of these firms were started by young people coming out of the university. In many cases they were started with very little capital and well over half of all the firms in this area are new ventures that were started as private enterprises by young people with some knowledge, with some help from the university relationship, and with a desire to get into the private enterprise segment of our economy.

Several conclusions may be drawn from this university-industry relationship that has developed over the last 2 decades or so in the Stanford area. In the first place, almost all the new businesses in this area are based upon new products which were generated in the laboratories at Stanford University. This same process has occurred at other universities around the country. As an illustration, one of our very important product lines is what we call an electronic counter. The original concept of the device which really underlies this whole line was developed by a young man doing his graduate work at Stanford University on a felowship which we sponsored there. We have many devices in the microwave field which were first conceived in the Physics Department at Stanford. More recently some of the work in what we call backward-wave oscillator tubes and traveling-wave amplifier tubes was the foundation of some additional instruments which have added to the product line and the capability of our organization. This process has been duplicated many times over.

One of the important firms in this area is the firm called Varian Associates. The Varian brothers invented the Klystron tube in the physics laboratories at Stanford just a little before 1940. Shortly after World War II they founded Varian Associates, attracted some of the other young people from Stanford, and have built one of the most important industries in the country in the field of microwave tubes. Also shortly after World War II, Felix Block, through his research, developed an understanding of nuclear resonance and from that came a whole new line of scientific instruments made by the Varian organization. More recently, research in high-energy physics has contributed some very important products to this firm again. This is duplicated many times, often by small firms. There are four or five firms that were founded on some of the work that was done in traveling-wave tubes—Huggins Laboratories and Watkins-Johnson among others. Studies at Stanford of the ionosphere and methods of measuring and developing wave propagation have led to a firm called Granger Associates. They have made some very important contributions in this area.

Although a great deal of this work has resulted from the activities in the departments of electrical engineering, the electronics field, and in the departments of physics, there have been other contributing sources as well. For instance, a program at Stanford Research Institute involves investigation of explosives. Dr. Poulter, in the laboratory that was established in his name, did some important research in the use of shape charges and various kinds of explosive devices, and a program was developed which is the basis of the United Technology Corporation program of solid fuel propellants. This pattern has been most effective. While these programs have contributed to "big" science, they have also made a very important contribution to the free enterprise segment of our economy; this is an especialy important characteristic of the development around Stanford University.

In addition to specific products, the university has contributed a very important resource of trained manpower—engineers and scientists and business leaders—and this trained manpower has, in many ways, been developed around some areas of specific technology not unrelated to these particular product areas already mentioned—microwave tubes and solid-state electronics, for example. The university has attracted a very strong group of faculty and from this has come the Fairchild semiconductor program; William Shockley was attracted back to the area from Bell Laboratories and he, too, has established a commercial venture in the electronics field.

Underlying all this there has developed over the years an important relationship between the university and industry. A number of times during these 2 decades, university administrators have come to us in industry and pointed out that they had a faculty appointment open, but did not have the resources to attract the person they wanted; they have asked if we would be interested in providing either a consulting job or in some other way supporting this appointment financially. Our firm has provided this support in a number of cases and it has enabled Stanford to attract some important people. In the field of aeronautical engineering, this same support was given through a cooperative program between Lockheed and the university. Lockheed wanted a particular man who was interested in the university affiliation. This worked out extremely well. The results of this effort can perhaps best be demonstrated by the fact that 2 years prior to the start of this program there were only two graduate students in aeronautical engineering and 2 years after this program was worked out in cooperation with Lockheed the university had over 100 graduate students in aeronautical engineering. In addition to that there has been a very effective use of the university faculty in consulting services. This consulting service is effective, not just in terms of having a conference now and then to talk about a program, but in bringing a university professor into a close association on a continuing basis with a particular program that is of mutual interest; this has been done in the field of microwave tubes and in many areas by a number of firms. It has been done by our own firm in more recent years in the area of some of the solid-state electronics work, and has been helpful in keeping some of our scientists and engineers upgraded in this vastly active, rapidly advancing field. Professors have been brought in to give specific courses so that we can be sure that our scientists and engineers have a current knowledge of the field.

Particularly effective has been a university-industry program in which industry hires graduates from various colleges and universities around the country and, in an arrangement with Stanford, allows these baccalaureate-degree holders to obtain advanced degrees by spending about half time working and half time going to school. This was worked out by Dr. Terman, who was then Dean of the School of Engineering. He offered to expand the engineering program if industry would pay half the cost of educating the students—since tuition covers only half. So many firms have underwritten the normally unpaid for cost of educating these youngsters that the firms in this area have been able to hire some of the most outstanding students from all over the country.

In summary, it might be reemphasized that this astounding growth in the technologically based industries in the San Francisco Bay area has been due in large part to the contributions from Stanford University. Much of the growth was initiated by new developments, products that came specifically from research at the university; the entire program has been strengthened by a very close cooperative relationship in this area. There is no question that one of the important responsibilities of our universities is to generate new knowledge; it seems, as well, that one of the responsibilities of universities and industry is to find ways in which this new knowledge can be converted into useful purposes as efficiently and as effectively as possible. The programs in the bay area, particularly those around Stanford University, have been especially effective in this way.

SAWYER: One of the striking developments of the post World War II period has been the rapid increase in expenditures for research and development activities both in the universities and in industry. Although these statistics have often been commented on, perhaps it will be interesting to point them out again. Figure 1 shows the rapid development in research and development funds over the last 10 years from $5 billion in 1953 to approximately $15 billion in 1962. Of this $15 billion, about $9½ billion was provided by the Federal Government and $5 billion by industry. Of the $9.6 billion provided by the Federal Government $6 billion went for the support of research and development in industry and about $1 billion for the support of research and development in the universities. A major reason for this rapid research development has been the large expenditures by the Department of Defense for the development of new weapons and new weapons systems and, more recently, by NASA for the space programs. A considerable part of the money, however, has gone into development of new industrial products and the improvement of old ones, and in the universities into the advancement of basic research. Figure 2 shows the amounts for the development of basic research as a part of the total R&D program. In spite of these large expenditures, there is criticism that our rate of growth of industrial productivity and civilian technology is too small and that we should be doing more for the development of consumer products and improvement of the standard of living. It is stated that we compare unfavorably with some of the European countries and with Japan in these respects. As a result, in many of our states, and particularly in the Midwest, the industries and the state governments are looking to the universities for aid in the industrial development of the state, whereas the Federal Government seeks university support for its defense and space work.

The expansion of research and development activities has taken place in various ways and in various places. A large part has been in the research and development and enginering laboratories of the large corporations which have expanded in connection with their manufacturing activities and at their manufacturing sites. On the other hand there have appeared many

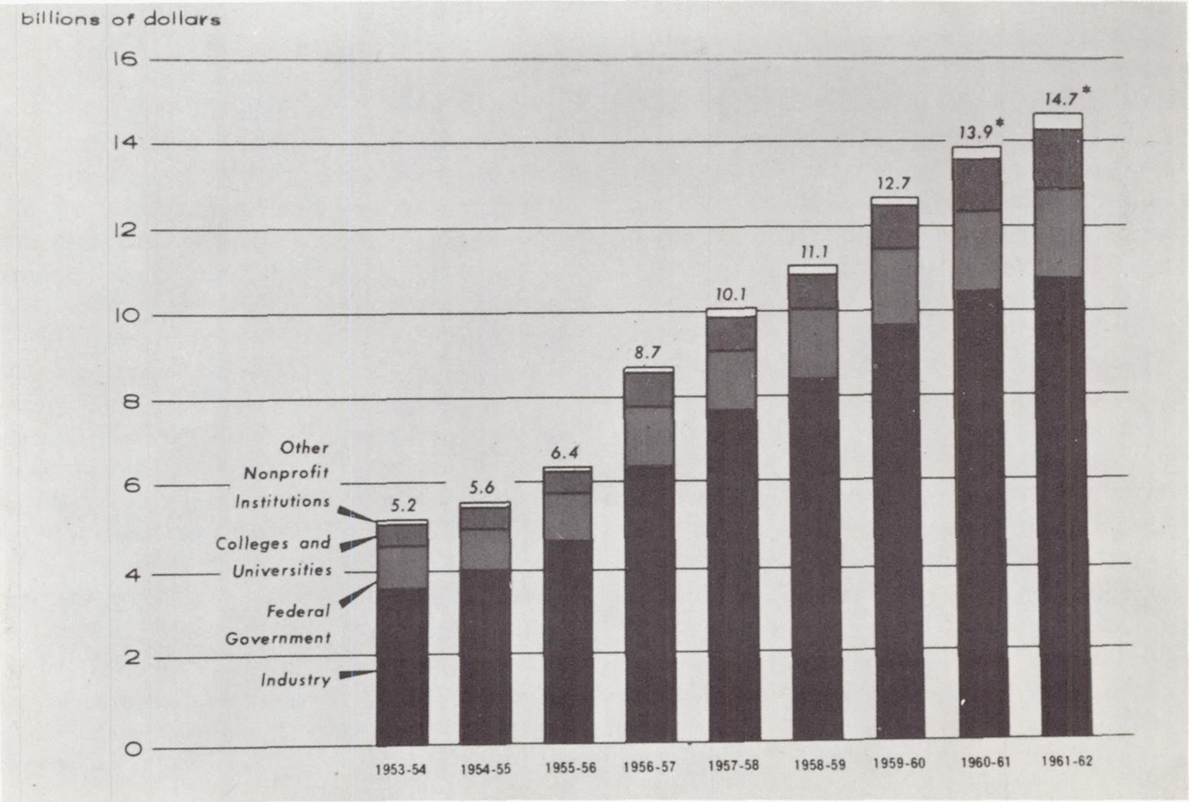

FIGURE 1.—Funds used for performance of research and development in the United States by sector, 1953–62. Asterisk indicates preliminary data. Source: National Science Foundation, 1963.

new research and development firms which are devoted to the exploitation of new ideas, new products, and new methods. An interesting example is the development of the laser with tremendous rapidity in the last 5 years. Over 200 new firms have been set up for improvement and production of lasers for various applications.

Some of the new companies have been established by scientists who have come from large industrial laboratories; some of the founders have come out of university laboratories. These new firms, and to a considerable extent the established firms which are going into new industrial development and new kinds of research, are looking for sites for the establishment of their research laboratories and of their new plants for light manufacturing. A new development of these past few years has been the establishment, in many places, of industrial parks as sites for new industries and of research parks as locations for research and development laboratories. I know of no accurate count or census of the industrial parks. Perhaps such a census is impossible since new ones seems to appear almost every week. The last estimate that I saw was that there were over 1,000. The number of research parks is very much less because of their highly specialized nature and requirements. The study published by Conway Publications in August 1962 entitled "Sites for Science," and which is the latest such census with which I am familiar, listed 53 research parks in 23 states and the District of Columbia. Of these, 12 were reported to be only in planning stages, 31 had advanced to the point of having located in them at least one research and development firm.

Although this research and development activity is scattered through many states, it tends to congregate on the east and west coasts and in the north central areas. Figure 3, taken from the industrial development study previously mentioned, shows the principal locations of research and development expansion. The Atomic Energy facilities are indicated by tri-

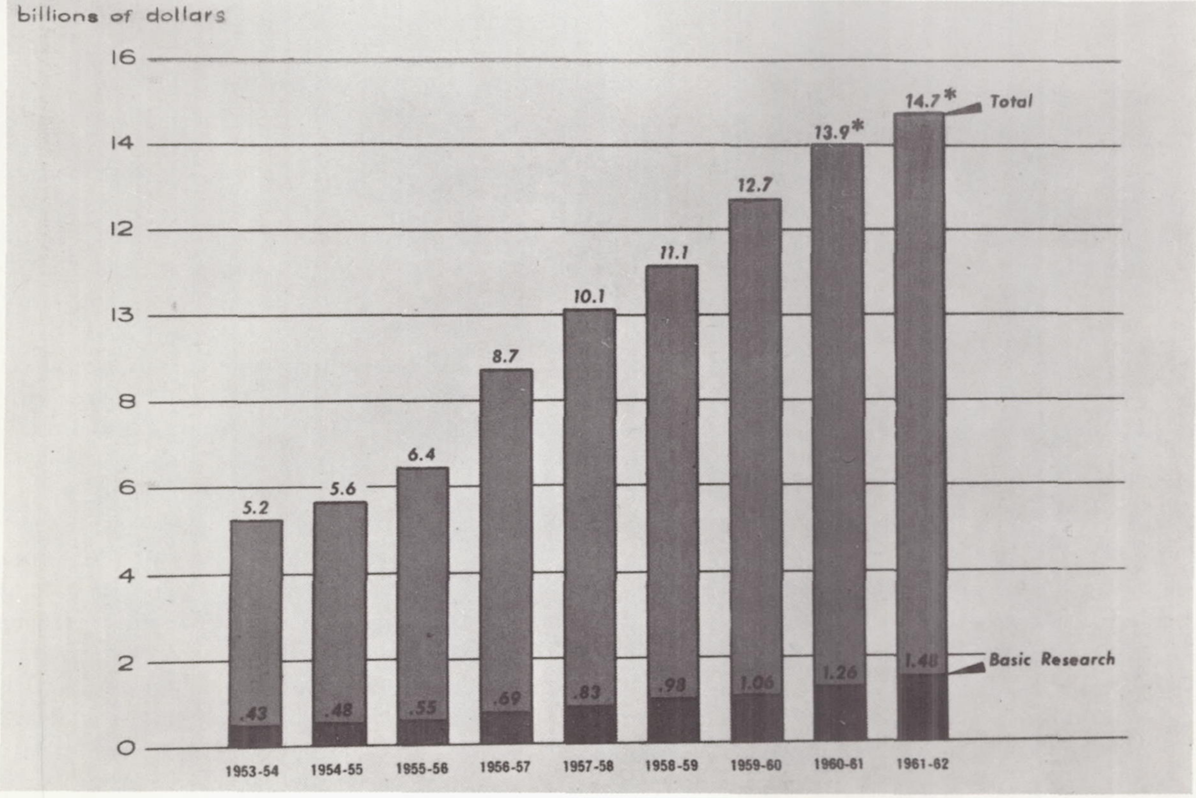

FIGURE 2.—Funds used for basic research performance and for total research and development in the United States, 1953–62. Asterisk indicates preliminary data. Source: National Science Foundation, 1963.

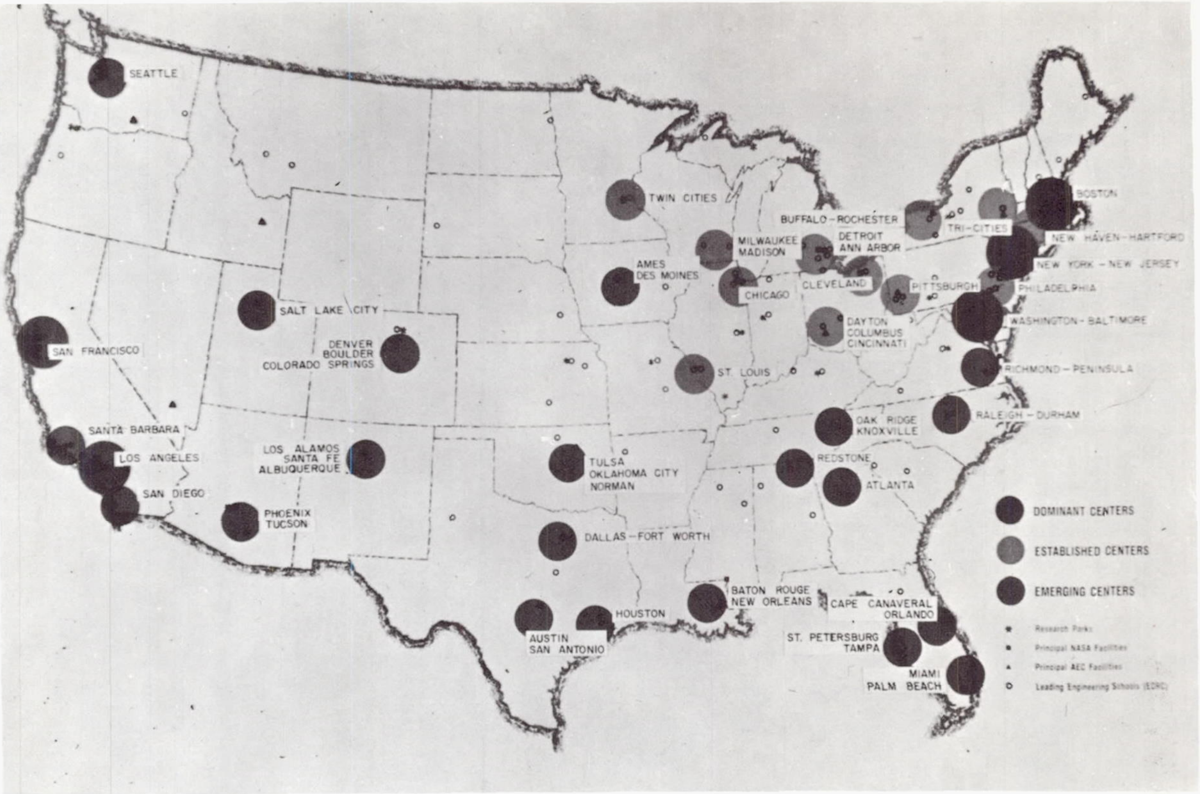

FIGURE 3.—Science centers where R&D expansion is particularly noteworthy.

angles, NASA facilities by squares, and research parks by stars. All of the well-established research parks are located in the neighborhood of large universities and have some sort of relation to the universities.

Research parks are of three types. Some are commercial developments established and operated by commercial realty firms; still others are set up by nonprofit corporations or by local Chambers of Commerce; and the third class are operated by universities. Ten of these university research parks have been established. In all of these cases the university has set aside land, which it makes available either by sale or lease, for the location of research and development laboratories, to which it offers in varying degrees, graduate schools, libraries, and other facilities.

In Ann Arbor, Michigan, I have been able to observe four different types of research laboratory locations. There is a greater Ann Arbor Research Park comprised of 209 acres which was set up through the cooperation of the Ann Arbor Chamber of Commerce and the city of Ann Arbor. There is a small Huron View Research Park of 20 acres which is a development of a local realty company. The University of Michigan from its holdings on its North Campus has sold land for research laboratory sites to the Parke Davis Company and to the Climax Molybdenum Company and has made land available to the Federal Government for the location of a Water Pollution Control Laboratory and for a commercial fisheries laboratory. In addition, there are located in the neighborhood of the university and on the outskirts of town about 20 other small research companies which have set up their laboratories on privately purchased land. There are reasons for industries settling on any one of these four types of sites: some want a developed park with utilities and landscaping already installed; some want to have the freedom given by purchasing their own site from the university or from private holders, subject only to the zoning restrictions, so that they can make their own arrangements free from limitations on site coverage, parking areas, or manufacturing activities to which they might be subject in a research park.

All these research parks have in common some expectations of association with a university. Almost all the research parks are close to a university. They have been located there in some cases because their founders were members of the university staff who wished to maintain their homes and their university associations. To a larger extent, however, they are located there because of the particular advantages that a strong university with a well-developed graduate school can offer. They want, first, the intellectual support of a university with its undergraduate schools and, particularly, with its graduate school facilities in science and engineering. They want the strong university library, the professional services which grow up around a university in the way of translation services, mimeographing, machine shops, and so forth. Second, they want the cultural advantages of a university town in art, music, recreation, and other cultural living conditions. Third, they want to be in a center of scientific activity, one to which scientists and their families will be willing to move because of the presence of other scientists, and they want the possibility of hiring personnel either from the graduate school directly or by the exchanges that are bound to take place with other companies. In general, these companies do not consider themselves competitors for personnel; in fact, I have heard the president of one of the electronic companies in Ann Arbor remark that the best thing the University of Michigan could do would be to attract another electronics research and development company to Ann Arbor because this would make it easier for him to attract new personnel from outside since there would be more than one employment opportunity for them. On the other hand, taxes, wage scales, and cost problems, which worry more competitive conventional industries, do not bother this type of industry so much. Finally, they want good accessibility—airlines, highway, and railroad connections.

The research parks which seek the advantages of neighboring universities are the newest example of the relations between the university and industry. Many universities maintain research institutes or stations which undertake both basic and applied research on contract for industry; most allow their faculty to devote 1 day a week to private consulting with industry; they provide an employment service to help industry interview students for jobs; they run specialized short courses as refreshers or on new technologies; they host or organize symposia and research conferences; they offer training courses for executives, and services in industrial health, group dynamics, industrial psychology, and other aspects of modern industrial activity, evening and off-campus courses for industry employees, library services, and numerous other direct aids.

This list may seem a long one and yet there are some activities not appropriate in a university-industry relation. A university is not a testing laboratory; production engineering problems should not come to it unless they involve basic developments; new products ordinarily do not come from its laboratories ready for manufacture although the new principles and phenomena which underlie new products and procedures certainly often and primarily do come from university laboratories.

The university and industry have long been partners. The land-grant colleges were set up 100 years ago to foster this partnership; the state university and the private universities carry it forward. The university's great strength is not in product development and service operations but rather in training students, in producing basic knowledge and ideas, and in solving new and difficult problems. The university-industry relationship in our economy is an important one. It has been fruitful in the past, and it seems certain to become more so. It should be a source of strength and development to both partners.

SIMPSON: The more I become involved with problems of university-industry relations, the more convinced I am that it is necessary to proceed from basic understandings about the nature of both a university and an industrial firm. We must not attempt to convert a university into an applied-research center. To do this would both damage the university and ask it to do those things which industry can do better. In the same way, we must not expect private companies to lose sight of their requirement to compete effectively in the marketplace. This also is a worthwhile function.

What is required is a new social mechanism that will allow these two great social institutions to support each other, not because it is a nice thing to do but because it is necessary.

The Research Triangle of North Carolina, about which I wish to make a few remarks, is determined by three universities: The University of North Carolina at Chapel Hill, Duke University in Durham, and North Carolina State College at Raleigh. These three institutions are situated close together, so that from a point in the center of the triangle it is no more than 15 miles to the campus of any of the three.

The Research Triangle was started in 1955 to develop around the university environment other research activities related to industry, and to devise ways in which there could be a fruitful interaction between industry and the universities.

Some substantial success has been achieved. A large park of some 6,000 acres has been developed in the middle of the triangle. Research facilities now include a very large industrial laboratory in the chemical field; three smaller laboratories operated by private industrial concerns that are national in scope; a disease-research laboratory of the U.S. Forest Service; the national headquarters of a textile research group; and a research institute now employing nearly 200 people and occupying four buildings.

In all of this, the three universities have cooperated fully for two very specific reasons: first, because the basic nature of each university was fully recognized; and second, because the universities were not asked to do more than was consistent with their wishes at any given period. University faculties consult with the private research laboratories and with the research institute; in some cases there is a sharing of facilities; a large number of the scientists in the private laboratories are receiving graduate instruction. Joint appointments between the research institute and the universities are possible, on invitation of the universities.

With reference to the Research Triangle Institute, which in many respects is similar to the Armour Research Foundation in Chicago, it is worthwhile to point out that this is in a real sense a creation of the three universities. Fifty percent of the governing board is composed of representatives from the universities and 50 percent from private areas. The Executive Committee, which is the governing authority, is composed of 50 percent plus one of university people, the remainder coming from private sources. Representatives on this executive committee are the graduate deans of the three universities and three other exofficio administration officials from the universities. I emphasize this structure because much of the present success of this undertaking rests on the fact that responsible, decision-making representatives of the three universities are really a part of the operating processes of this institute. This executive committee meets for a full afternoon each month to review and pass on both broad policies and specific projects for research.

Thus, the Institute, carrying on an essentially industrial research program, has been able to take strength from the universities in proper ways, and the universities are able to find ways of participating without harm to their basic functions.

All of this did not occur as smoothly as the description would indicate; nor is this development the total answer to the problem of how to begin stimulating a greater use of science and technology in an area where this was formerly almost nonexistent. Indeed, though this Research Triangle effort has accomplished much and has become a vital symbol and structure for the growth of science and technology in this area, it is not the ultimate answer. It is a first step, but only that.

NASA's view in regard to this problem of industry-university relations emphasizes that we are seeking a broader application of these principles to other situations.

The essential basis for finding a new pattern of industry-university relations is twofold: (1) The highest quality of fundamental work structured in strong, independent departments is the most valuable contribution that a university can make to this enterprise; (2) a receptivity to basic research and the willingness to do the hard, often expensive, work necessary to convert this basic information into usable form are the essential factors which industry must bring to the enterprise.

The problem is not so much to create these two sets of conditions; rather, it is to let them evolve in a strong self-perpetuating process. Stated another way, the problem is to call forth from the universities a regular presentation of those areas of basic knowledge that can become useful, and, on the other hand, to cause the industrial concerns to understand their needs and to be perceptive and positive in identifying those things that can be helpful.

As an illustration, it is clear that, in large part, we were able in North Carolina to begin a relationship in the area of science and technology because there was a local background of experience in other areas. For several decades the University of North Carolina had taken a great interest in the social and political problems of the state. This interest had grown out of, and was an integral part of, the academic work of several departments in the social sciences. It happened, therefore, that in such areas as the establishment and improvement of public education, in tax reform, in reorganization of government, in highway programs, in freedom of speech, in relations among groups—in these and in other areas—the university had written and spoken in ways that were highly effective. It should be emphasized again that this was a departmentally organized activity, not an extension or peripheral function. About 1930 the School of Medicine and the Duke Hospital were opened at Duke University. This complex began to have a direct, measurable effect upon medical care in every county of the state. Duke consciously assumed some responsibility in this matter; but, again, the effect was gained from the fact that the basic medical work was good and that this was not an extension service. At North Carolina State College, in a more typical pattern, there had been for many decades research into basic agricultural problems, not for the individual farmer, but for the purpose of striking at the basic knowledge that underlies the solution to broad problems.

In each of these cases there was a good reception on the part of the users. In social and political matters, the state's leadership, much of it trained at the university, was willing to accept forward-looking proposals; in medicine, there were the doctors and health services of the state; and in agriculture, there was the Extension Service and the farmers.

What, then, can be the mechanism for the university to act in similar ways with respect to science and technology? Probably there will not be a single pattern. A possibility that may be especially appropriate for the large universities located in metropolitan centers, however, is quite simply an emergence of interest by the university in the problems and enrichment of the region. It seems to me that there is sound ground for looking at this as a real possibility. For across the Nation there is evident a new interest in regional economic affairs. The reason is clear: the fast changes in technology, automation, the new requirements for training and skills—these and other factors have removed the economic stability that formerly existed. Every region must now act deliberately and with foresight to stay on top of this turbulent sea. Nor is this matter limited to industrial problems. Everywhere we have created great cities whose problems of water supply and contamination, of transportation, of government, of community life, and so forth require broad new studies and programs for action.

It is entirely possible, therefore, that a general national situation is developing in which the university, in proper ways, can begin to provide guidance to industry in those areas of basic knowledge and scientific advance that are useful in a practical way—and in which industry can achieve the motivation to seek out help, and support the university in its research program. It is the development of this or some other workable pattern of university-industry relationship that NASA is endeavoring to foster.

WEIMER: In a general sense scholarship relates to knowledge—including its production, transmission, use, and application. Universities have traditionally been concerned prinicipally with the production of knowledge through research and the transmission of knowledge through educational programs. Now we face increasingly the development of effective programs for the application and utilization of knowledge. In these areas the business school has already played significant roles, and it is destined to play more important roles in the future.

We are so close to the revolutionary developments of recent years that many of us may not recognize their significance. Not since the Renaissance has the human race experienced a comparable period of major advances in science, technology, economics, government, and business administration. We are in the midst of a tremendous explosion of knowledge. This explosion is a continuing one—a series of chain reactions, rather than a single event. To a degree it is unmanageable and perhaps should not be managed. But to some extent we must learn how to appreciate, nourish, and also harness this new knowledge.

The knowledge explosion is not of a balanced type. We are not moving forward nearly so rapidly in some areas as in others. But the lines of demarcation between many of the traditional areas of knowledge are being obliterated—and advances in one field soon influence others.

Those of us who are concerned with economic growth recognize that the existence of knowledge does not by itself improve the welfare of our people. The principles of the steam engine were known in ancient times but applied only for amusement—as an interesting toy. The principles underlying the flight of airplanes were understood a century before the Wright brothers.

What is it that brings the effective utilization of knowledge? The answer to this question is of major importance to everyone, and especially to those of us interested in business schools. In a period when knowledge was of a less sophisticated variety, the process of utilization and application happened almost automatically. To a degree this process continues. But with much research effort, especially that directed toward defense and space programs, application and the use of new knowledge for industrial and consumer purposes does not happen automatically. As Robert Solo pointed out in a recent *Harvard Business Review* article, we need what he refers to as "new social engineering," new institutional arrangements and imaginative programs, to assure that new knowledge will be applied and used in the processes of achieving economic growth. We are now trying to do some "new social engineering" through the Aerospace Research Applications Center recently established at Indiana University.

Another factor in the application of knowledge to practical purposes, undoubtedly, is what may be referred to as the "entrepreneurial mind." We are not certain about the elements that make up the entrepreneurial mind, but they would appear to include a restless creativity, not unlike the artistic mind, an interest in practical things, a desire for achievement, and a willingness to take risks—indeed, long risks—to try out new concepts and ideas in the hope of great rewards.

Not only capacities, but attitudes, are important in this connection. The taking of big risks requires an optimistic attitude, an almost blind belief in the desire and capacity of the human race to improve, and an eagerness to attack formidable problems and to solve them.

The Aerospace Research Applications Center at Indiana University is supported under a grant from the National Aeronautics and Space Administration, by membership fees from 28 business firms ranging in size from large to small and covering a wide variety of products and services, and by Indiana University as well as by the Indiana University Foundation. Of special interest is the fact that faculty members of the Graduate School of Business are working closely together with members of various of the University's science departments, both physical and social, in developing the programs of the Center. These programs fall into five major groups:

1. *Technical Library Service.* Indexes to all NASA publications are available through the library. All materials available in printed form from NASA are in this library, and where not available in such form are provided on microfilm. Thus rapid reference to all NASA literature is possible. Appropriate indexes to these materials are being computerized so that even more effective use can be made of them. This

system should be available to the Center by midsummer. Professor Nevin W. Raber is in charge of the Technical Library, and Professor E. W. Martin, Jr., who is director of the university's Computer Center, is in charge of the information retrieval system.

2. *Industrial Applications Service.* Information pertaining to potential industrial applications in the form of "flash sheets" and related materials are readily available through the Center. Some of this is privileged information and can only be made available at the Center under current conditions. Professor Howard L. Timms is in charge of the Industrial Applications Service and also the Engineering Service on Current Problems.

3. *Engineering and Technical Service on Current Problems.* Through this service of the Center, special provision is made for quick response to current company questions, problems, and needs. The Technical Library, general university library facilities, NASA Headquarters, and NASA Centers, as well as other sources of information, can be called upon to provide special information as may be required.

4. *Scientific Programs.* Through the Center, member companies have access to various of the university's faculty members who are specialists in one or another of the scientific areas. In addition, at the request of one or more companies, panels may be convened to provide an interdisciplinary approach to current research applications problems. If necessary, scientists may be brought from other universities and institutions for brief periods to assist in the work of the Center. Scientific Programs are under the direction of Paul Klinge, Associate Director for Science.

5. *Management and Related Programs.* NASA's experience in managing very large and highly complicated operations is contributing substantially to managerial and administrative knowledge. This information is made available to the Center's members. In addition, top management officials of the member companies have an opportunity to work with the Center in undertaking to solve current management problems. Panels including faculty members of the Graduate School of Business can be convened for these purposes through the Center, and management experts from other universities and from research institutions may be brought in temporarily as required to help solve these problems.

The effectiveness of the Center's operations depends to a considerable degree on the ability of the officials of the member companies to identify their specific current requirements for information and assistance. In addition, of course, much benefit accrues from the stimulation of association with university and other research personnel, as well as from the volume of information continuing to flow from NASA's programs. In some cases member companies are studying their internal organizations with a view toward improving the flow of techincal information and the research applications process.

It should be emphasized that the main purpose of the Aerospace Research Applications Center is to stimulate the economic growth of the Midwestern Region. Each of these efforts is designed to serve this primary purpose. Because much needs to be learned about the research applications process, the programs of the Center are necessarily experimental throughout its early stages, at least. Thus programs and procedures are being reviewed each quarter with top management officials of member companies in order to be certain that the most effective programs and procedures may be established.

EVERITT: Would the members of the panel raise questions that may have occurred to them as a result of these presentations?

PACKARD: There is one point which needs to be emphasized although it has been emphasized several times: it is very important to understand that industry should not look to the universities for specific help on specific problems. Industry should ask help on problems unrestricted as to the application or perhaps restricted to a general field of interest but without any end objective, and support the university over a period of time; I think the same approach holds for the government. I am not sure that it is as clearly understood as it should be that the government cannot look to universities to solve specific problems, or should not, but rather the government should provide support in broad areas and over long periods of time in order to utilize university capability properly.

EVERITT: One of the areas where cooperation with industry has been effective is where groups of firms have organized in some sort of an industrial organization and have been able to work with universities in areas in which they are not interested so much in competitive advantage as in advancing their general industry. For example, at the University of Illinois, for some 40 years we have been working with the two organizations in the area of home heating. The warm-air group and also the boiler manufacturers have supported over the years research programs at the university. A number of product developments have come out of these programs but these industrialists do not come to us with requests for a specific type of development. On the other hand, we frequently have requests from industry to initiate a research program aimed at a specific development for which they want patent rights. At the University of Illinois, we feel that this is not a function of a state university and I question whether it is a function of any university. We must recognize not only that there are some things that we can do which we feel we have not been called upon to do but also that there are possibilities of demands; industry must work with us and recognize that they should not hurt our major objectives of education.

PACKARD: It is important to recognize that these very points—the proprietary interest, patents, propriety for intellectual institution, and so forth—are probably the reasons why research institutes have sprung up, as sort of adjuncts to the ordinary departments of universities.

JONES: At the Universities of Illinois and Michigan, has the support from industry been constant and sustained during periods of economic downturn or has it risen and fallen with the economic tides in general?

SAWYER: We have had an industry program to do research for industry for about 40 years at the University of Michigan. This program has continued through good times and bad but it has not grown rapidly. Perhaps one interesting thing that has happened lately is that while government support of research has been growing very rapidly, industrial support of research in the universities, at least at Michigan, has not grown so fast. It has stayed rather stable. I do not know whether this is because industries are starting up research laboratories of their own or whether they are going somewhere else for help but industrially supported research has not grown rapidly at Michigan.

EVERITT: This has been our experience as well at Illinois—that the amount of support from industry has not grown since World War II whereas government support from a variety of sources and even support from the university itself have grown. The remarkable growth has been in terms of support from government—from the National Science Foundation and the Institutes of Health and from the Department of Defense, Atomic Energy Commission, and so forth. Industrial support provides a relatively smaller proportion. There may be a difference in this between the private universities and the state universities.

PACKARD: The situation at Stanford has been very much the same way. The amount of government support for research has gone up at a tremendous rate. Stanford has never had a very large amount of industry-supported research, in any case. Stanford Research Institute was set up to handle this problem, and they are involved in the more specific jobs for industry. The university has followed a policy of not taking on any specific job for a specific firm; only with rare exceptions does Stanford do this. The university tries to limit its research program to areas that are of interest to a particular professor and can be continued over a period of time. The figures for Stanford Research Institute are very interesting because an attempt has been made to keep a large proportion of research for private concerns there. The trustees would like to have not more than half of the entire Research Institute program supported by government funds, but it keeps increasing every year until it is almost 80 percent this year.

SAWYER: I have the impression that a large part of the work that Stanford Research Institue does for industry is in the economic field, and not in the technical field.

PACKARD: They have a large area of activity in economics. They have a strong program in engineering but, amazingly enough, the engineering program is largely supported by government funds, whereas the economic activity is not.

SAWYER: This has happened, I think, at Armour Research Foundation and Battelle Memorial Institute. They have also moved into doing government research.

EVERITT: I think there is a basic difference, too, between the objectives of the research institutes, as such, and the universities. In the university, the fundamental products are the undergraduate, graduate, and advanced graduate students. A university should be measured not so much by the number of dollars it spends per year, but by the number of students receiving Ph. D. and masters degrees. In the research institutes, where the main emphasis is placed upon the output of the research and perhaps upon a research product as well, then the production of graduate students is a secondary matter. I presume that Stanford Research Institute is not particularly involved in the production of graduate students except in regard to those employees taking graduate work at Stanford University.

PACKARD: I think that is correct. On that point there has been a very interesting development in this country over the last few years. Although it is a fact that the business and industry supported research in the universities is not increasing, the general unrestricted funds that come to universities have been increasing at a very rapid rate. One of the theories that has been used to justify this support is the fact that the main job of universities, especially some of the large ones, is to produce the Ph. D.'s who in turn are the very foundation of our whole teaching and research program in the country.

SAWYER: I do not think that there is any reason for a university to have a big government or any other kind of outside supported research program except to help its educational program. Last year, at the University of Michigan, we had 4,700 students who received some financial support from our sponsored research program and almost 500 of these were preparing doctoral dissertations supported by the sponsored research program.

PACKARD: I think that's right, and the encouraging development is that a great many people in business and industry are recognizing this. So far their support has been directed more toward the private universities than toward the publicly supported ones; this can be argued both ways, certainly, but at Stanford, for example, close to a million dollars a year of unrestricted money is being received from business and industry, on the theory that this helps the university generate more Ph. D. candidates and thereby contributes to the whole basis of our educational program.

EVERITT: There has been criticism sometimes of the amount of sponsored research the university has taken on; however, I remember that a few years ago Ross Martin, Director of the Engineering College Experiment Station, was making a study for the Engineering College Research Council and he found an almost direct correlation between the amount of sponsored research at institutions and the number of graduate degrees that were being produced. In fact, I think he found a formula on the order of $10,000 per year at that time, for masters degrees and $30,000 for Ph. D. degrees.

WEIMER: Dr. Sawyer, you mentioned four different types of research parks. What is the relative value to the university of the different types of parks? You happen to have several, and I guess there are probably several around Stanford.

SAWYER: I think that we would prefer to have this a private activity rather than a university activity. We think, as a state university, that probably it is not our business to sell land to research laboratories or to provide space for them under the ordinary conditions.

WEIMER: Why, then, did you decide to start a university research park when you already had a private one?

SAWYER: We do not have a university research park but we have sold five pieces of land for research activities. I think this is about the end of our activity. I think the situation at Stanford was somewhat special because they had some land and they wanted to get some income.

PACKARD: Yes, there was a special circumstance that caused the university to do this. Stanford had this very large amount of land, some 8,800 acres, which they thought was more than they were ever likely to need for academic purposes, and so they worked out a program to lease the land—fortunately, the founding grant of the university prohibited sale. They started out with a lease period of 99 years which was necessary to get any takers but this has been reduced to 51 years now. These leases are prepaid so that the tenant pays about the amount that it would cost him to buy the same quantity of land elsewhere. The tenant pays the money to the university; this is invested and the income is placed in an endowment fund. The interesting development in all this is that the industrial firms who lease this land contribute annually to the university a larger amount of money than the income generated from the prepaid leases so that the university would be ahead financially even if it had just given them the land and asked them to come.

How Space Activities Are Changing the Economy

Auspices: *Graduate School of Business, University of Chicago*

Presiding: **WALTER D. FACKLER,** *Associate Dean, Graduate School of Business, University of Chicago*

Introduction

WALTER D. FACKLER
Associate Dean, Graduate School of Business,
University of Chicago

There are a number of reasons why we at the Graduate School of Business are pleased to take part in this program. Though it sounds like a cliché, we are firmly committed to the idea that graduate business education should not teach the details of business practice today but should prepare students for executive leadership tomorrow and there is no doubt that tomorrow's business executive will face a bewildering world of enormous technological complexity. Part of this complexity is now before us. It is growing apace out of space research.

The business executive with an advanced education will be in a much better position to cope with technological complexity and the economic changes which are coming to pass. Some of America's new glamour industries are headed by men who have advanced degrees. The Ph. D. degree which has been a union card in academic circles is becoming a calling card for major executive positions in sophisticated industries. But all executives, those up from the ranks as well as those with advanced degrees, need to comprehend the scope of research and development programs, need to be able to convert new technological developments into new products, into superior methods of production, and need to understand the forces of economic change which will profit them mightily in the future.

14 Goals and the University

GEORGE W. BEADLE

President, The University of Chicago

A few words may be said concerning the interests of a university, such as The University of Chicago, in the basic and applied research effort underlying space exploration, for this is of vital importance to the future of the Chicago area and of the Nation as a whole.

Nearly 2 years ago, I moved from a confident, science-conscious California to a prospering but self-conscious Chicago. In coming "home" I was challenged by the opportunities offered by The University of Chicago, which for more than 70 years has been respected as a center for scholars and a producer of knowledge.

During a conference in Paris recently, arranged by the International Organization for Economic Cooperation and Development, several of us were examined by sociologists, physicists, economists, educators, government officials, and other representatives of a dozen OECD nations on the organization, functioning, and support of the system of higher education in the United States. I was tremendously impressed with the unanimous recognition of the prime importance of new knowledge for the economic and cultural advance of the nations of the world.

Our interest in research at The University of Chicago, as one example of the role of a university in space exploration, ranges from our investigators in the Enrico Fermi Institute for Nuclear Studies to the Graduate School of Business, from our Department of Geophysical Sciences to the Argonne National Laboratory, a laboratory serving especially the Midwest, which the university operates for the Atomic Energy Commission. In 1962, research and development contracts held by The University of Chicago, both on and off campus, totaled some $87 million in expenditures. These contributed in a large way toward making the university the 14th largest employer in the city, with some 7,500 persons on our payrolls. In addition, there is a staff of 1,000 scientists and engineers, plus 3,500 supporting personnel, at Argonne's sites southwest of Chicago and in central Idaho. These men and women are among the highest level workers in the Chicago complex—highest level, that is, in terms of intelligence and in terms of prestige productivity. Chicago needs more men and women like them if its research and development are to prosper as they should. We cannot do much about our Midwest climate, but we can do a great deal about our intellectual climate. We can, *and must*, work much harder to improve our schools, libraries, public services, and general orientation, if we are to lure and to keep the promising young men and women of our time in this area.

There is every indication that research activity on our campus and at Argonne, as well as on other campuses in this area, will expand greatly in the years ahead. To prepare for this research growth, we at The University of Chicago are planning for expenditures in the near future of some $41 million for new buildings and facilities on our Hyde Park campus. For example, on May 1 we broke ground for an NASA-financed, interdisciplinary space research center. At Argonne, a $48 million atom smasher, more formally known as the Zero Gradient Proton Synchrotron, will be completed this year. This will cost some $20 million a year to operate. Before it was planned, nuclear scientists moved to the east or west coasts to find such equipment. It is now keeping more of them in this area and helping to lure others here. Other research news also is being made at Argonne: Scientists and engineers there are supporting the nuclear energy phase of the Nation's space effort. They are designing new and more sophisticated power reactors. They are designing nuclear propulsion systems for space vehicles.

Meanwhile, on the main campus, some 280 members of our faculty are pursuing research spelled out in 516 Federal Agency grants totaling $23.5 million annually. Other universities are similarly involved in the "spin-off."

At this point a word may be said about what Mr. Webb, the NASA Administrator, has called spin-off from basic and applied research and development. This phenomenon has been known for a long time. For example: No one believed for half a century that Mendel's studies on the garden pea in his tiny monastery garden would revolutionize agriculture; or that discovery of nuclear fission in 1938 by Hahn and Strassmann would provide us with a great new source of energy, or that the work of Hanson and the Varian brothers on microwaves would make possible radar communication. One could go on listing great new industries that result from the spin-off phenomenon.

The Chicago area already benefits considerably in the spin-off from research on academic campuses. These benefits will surely continue at a faster and faster pace. For example, an estimated 30 to 40 percent of funds earmarked for constructing University of Chicago experiments on space flights results in spin-off to industrial activities. Many of the men and women presently engaged in space research in private industry in Chicago have been associated, in one way or another, with The University of Chicago or the Argonne National Laboratory.

Many people have been troubled by government support to academic institutions. There may be reason to be discouraged in particular instances, but all of us must recognize that this is a way of life that is here to stay. It is here to stay because academic institutions—and, indeed, industry in the case of space exploration—cannot possibly go on without large-scale government support. If we are intelligent enough, we need have no fear of it.

Government support will continue and will also surely increase. In fiscal year 1963, the Federal Government expects to obligate some $15 billion for research and development—sixteen times the amount allocated just 15 years ago. Research is indeed a growth business. As more industrial leaders become convinced of the wisdom of investing in research and development, the growth curve will shoot up even faster. Ours is more than the Space Age: it is an era in which human knowledge is expanding at an unprecedented rate and in which the frontiers are in ideas and applications, not in land or in rivers.

It is not too late for the Middle West to develop an intensive effort to achieve a capability in Space Age industry. Our universities, by and large, are carrying much of the burden in the pioneering work. Consider the research accomplishments of Iowa's Van Allen, Northwestern's Hynek, Illinois' Seitz, and Chicago's Simpson. The business community must reorient itself from the view that one engineer is employed to make 1,000 products to the philosophy that it might take 1,000 engineers to produce a single complex, miniaturized Moon probe. The talent is here. When The University of Chicago sought help for our series of satellite experiments, the winner in a competitive bid for miniaturized parts turned out to be a small, unorthodox company in suburban Bensenville—Paraplegics, Inc. In overcoming their handicaps to respond to the challenge of space, the members of that imaginative and risk-taking company are setting an example for many larger and more conservative firms.

The Big Ten and The University of Chicago together produce 26 percent of the national total of Ph. D.'s in the physical sciences and 33 percent of those in the biological sciences, not counting medicine or dentistry. Thus, it is evident that we turn out highly trained men and women who would consider going into industry here if the opportunities were available. The results of basic research at all universities are available to industry in the Midwest and elsewhere. The doors of Argonne and the universities are always open to industrial leaders interested in the frontier of ideas and research.

The business schools of the Nation, including that at The University of Chicago, play an important role as intermediaries in the translation of basic ideas into industrial production and sales. This role will surely become increasingly significant as both science and industry become more and more sophisticated.

The goals we have set in space and in other fields will be reached only if we all work together—academics, industry, government and the public.

15 The Economic Effects of the Space Program

ANTHONY DOWNS

Treasurer, Real Estate Research Corporation

The purpose of this paper is to discuss the economic impact of the amazing space program presented in the preceding papers. My function is to view the space program objectively as an economist so as to assess its impact upon the Nation's economy as a whole and upon certain regions in particular. In order to be objective, I will not take the extreme view that our entire lives will be changed by this program overnight—we will not all be wearing air-conditioned Moonsuits in 2 years and commuting to work by individual miniaturized Rocket-packs. An attempt will be made to avoid the other extreme of thinking that the space program is the greatest boondoggle since the Pyramids; it is not merely a form of scientific leaf-raking on a gigantic scale. My definition of the space program includes the program of the National Aeronautics and Space Administration (NASA) and some work of other agencies doing related space exploration, particularly the Department of Defense. In essence, I hope to answer the question: What will NASA's program mean to the participants in the Nation's economy?

OVERALL MAGNITUDE

The first step in judging the economic impact of the space program is to look at its overall magnitude—the total amount of spending involved and just how big that amount is in relation to other things. We are immediately face to face with the problem that no one really knows how much the program is going to cost us. There is too much uncertainty in forecasting budgets for research and development programs of this type. By the end of fiscal year 1963, NASA will have spent roughly $8 billion on its space programs, and other government agencies will have spent at least 25 percent more; hence, a total of about $10 billion will have been expended on all phases of space programs. Forecasting future budgets is extremely difficult because of what Secretary McNamara has called the "bow-wave" effect. Presently known programs call for a buildup of expenditures over the next couple of years and then a gradual decline beyond that. But as you move ahead, new programs arise, and the need for "just a few more billion" to finish off existing programs keeps moving ahead along with you like the wave ahead of the bow of a ship as it moves through the water. Moreover, experience shows that most government development programs actually cost much more than the initial estimates for them, sometimes double or triple or more.

Nevertheless, some estimates must be made; therefore, I have assumed that NASA will spend the $5.7 billion it requested for fiscal year 1964, and then spend $6.0 billion in each year beyond that through 1970. At this rate, NASA will spend $41.7 billion from the end of fiscal year 1963 through fiscal year 1970—or a total of about $49.8 billion from the beginning of the space program through 1970. Moreover, other government agencies will probably spend at least another 10 percent in addition to this and perhaps much more. Not all of this amount will be used directly to get a man on the Moon. About 65 percent of NASA's latest budgets are going to manned space flight programs; hence, about $27.1 billion will be spent on such programs from now through 1970.

A lot of numbers have been quoted; consider just two as indicators of the cost of the whole program. By 1970, approximately $56 billion on all phases of space exploration will have been spent. Our annual rate of expenditure after 1964, including both NASA and other agencies, will be about $6.6 billion. To paraphrase Churchill, we might say "Never have so many spent so much to send so few so far." It should be pointed out that the estimates are relatively conservative but they might turn out to be way too high if Congress changes its attitude about continuing support for the program.

These estimates are just numbers unless they are placed in some perspective. We are speaking of billions of dollars, but it is easy to forget just how much money a billion dollars really is. If you spent $100,000 a day 7 days a week, it would take you 27.4 years to spend $1 billion. Putting it the other way around, in order to spend $1 billion in 1 year, you would have to spend $2,740,00 per day. Thus, our space program will cost us about $18 million per day from now through 1970.

Clearly, the space program is extremely costly, but comparing it with other programs or spending shows that it is not quite as huge as some people claim. We will spend about $6.6 billion for space each year, but in 1962 we spent—

(1) about $19 billion for new cars
(2) about $15.8 billion in department stores
(3) about $5.2 billion in liquor stores
(4) about $5.9 billion for the Department of Agriculture
(5) about $9.2 billion for interest on the national debt
(6) about $17.5 billion for public schools
(7) and about $50 billion on national defense.

The whole program through 1970 will cost us about $56 billion if the forecasts are correct; in contrast the Interstate Highway Program will eventually cost $42 billion. It will probably have a far more direct and profound impact on millions more people than the space program will—certainly by 1970. Over $200 billion will be spent in the construction of private housing in the U.S. from 1960 to 1970, and over $50 billion in the construction of new public utilities in the same period. Thus, the space program is by no means the largest fount of spending in sight. In relation to our gross national product, the space program will comprise about seven-tenths of 1 percent of GNP in 1963, rise to a shade over 1 percent in 1965, and slide downward to about nine-tenths of 1 percent by 1970.

We can conclude our examination of the overall size of space spending by stating that the space program in itself, although certainly a large-scale one, will not be large enough in relation to the entire economy to cause any inflationary movements such as those stemming from our efforts in World II or Korea. The economy currently has too much capacity and too much ability to expand output to be pushed into any general price rise by a program equal in size to only 1 percent of the gross national product or less. The second major step in examining the economic effects of the space program is looking at the quality and type of activities it involves and estimating the more specific effects these activities will have on particular segments of or areas in our economy.

EFFECTS ON THE LABOR MARKET

Space activities are highly concentrated among a specialized group of industries which employ extraordinarily skilled workers. The actual output bought by all these billions of dollars consists of a relatively small quantity of objects, the costs of which are concentrated more in research and development than in production. The cost per pound produced is tremendous because of:

(1) Extremely high reliability requirements based on our fear of losing an astronaut's life and the need for several hundred

thousand parts to work at once for a successful mission.

(2) Difficulties of designing products because of the hostile environment of space and our ignorance of it. (For example, in 1960–61, 71 percent of North American's sales were in research and development, and production sales dropped drastically.)

(3) Need for extreme miniaturization to save weight.

The type of people employed in this business are primarily engineers, scientists, administrators, and other highly skilled, highly trained, and very well paid individuals. These are precisely the men who are in short supply because of the high demand for them in other fields; hence, their salaries will jump. Competition for such men generated by NASA's spending will stimulate entry into the scientific and engineering fields of young men of talent and thus, shift the allocation of brain-power toward these fields, away from business in general, social sciences, and other academic fields. Unskilled and semiskilled workers, with whom we are vastly oversupplied, have relatively little function in the entire space program, particularly since it has virtually no mass-production components. Some additional jobs for unskilled and semiskilled workers will be generated by production in so-called "spin-off" industries where new products based on space research will be built, and by the general increase in demand in those metropolitan areas where major space facilities or space contractors are located. Nevertheless, the net overall effect of the space program will be extraordinarily expansionary in a relatively narrow segment of the labor market, but not very expansionary in the parts of the labor market where expansion is needed most.

EFFECTS ON RESEARCH AND DEVELOPMENT

It is very difficult to separate out the portion of NASA's budget which will be spent for research and development, since the operational programs contain a great deal of research, but soon NASA will be spending a large proportion of all U.S. scientific research funds. Professor Robert C. Turner of the University of Indiana estimates that about $19 billion will be spent in 1963 for research and development of all kinds by government, industries, universities, and nonprofit institutions. About 40 percent of all these research funds are spent on military research and development, including nuclear weapons and military space activities. About 13 percent will be spent by NASA alone—and this value will rise to perhaps almost 20 percent by 1965. Thus, in essence, the NASA program functions as a giant shot-in-the-arm to a wide variety of scientific research activities, some of which will lead to applications outside the space program itself. NASA's own spending on nonoperational research is about 1 percent of its budget to stimulate universities, 13 percent for pure science research on space, and 2 percent for practical applications (including weather and communications satellites)—a total of $912 million in fiscal year 1964. Thus, most of the nonspace applications will have to be made by the industrial contractors concerned rather than NASA. The general effect of this research spending will be to shift further the allocation of U.S. research efforts toward scientific technology and to link further the financial support of our major universities to the Federal Government, which is now and will be even more in the future, a major support for our higher education and research.

EFFECTS ON VARIOUS GEOGRAPHIC REGIONS

Up to now, recent defense and space spending has been concentrated on states in the east and west coast areas and has been scanty in the Midwest, as is well known. The five Midwest states of Illinois, Indiana, Michigan, Ohio, and Wisconsin did 32 percent of defense production in World War II, 27 percent in the Korean War, and 12 percent in fiscal year 1961. Of both space and defense research and development contracts in fiscal year 1962, the west, gulf, and east coast states captured 75 percent of the pie and California alone got 41 percent but Illinois got less than 1 percent. But what is not so well known is that the Midwest is the slowest growing part of the Nation in employment altogether, primarily because it is the victim of poor climate, national decentralization of big mass-production facilities, and lack of interest in pursuing the government dollar. In the prespace era from 1953 through 1960, total nonagricultural employment in nine Great Lakes states rose only 1.2 percent in 7 years, whereas it went up 7.9 percent in the country as a whole. During the same period, of every 100 new jobs appearing in the U.S., 77 were in the South and West, and only 5 were in the Midwest, even though the Midwest has about 30 out of every 100 jobs in the Nation. It is believed that the great economic hose of defense and space spending, accounting for $25 billion or more in defense procurement and soon $6 billion in NASA funds each year, represents the only real hope for employment growth of any dramatic proportions in the Midwest. So far, this Federal hose has been sprinkling other parts of the Nation and has left the Midwest almost completely arid, a condition this conference is designed to alter.

It is often argued that Midwest manufacturers have avoided defense and space work because they believe that government work is unprofitable relative to civilian mass production, but the evidence does not support this assertion. In Fortune's list of the 500 largest industrial corporations in 1961:

(1) Median profits as a percentage of invested capital were 8.3 percent for all 500 firms.

(2) The 15 largest nondefense firms earned an average of 9.88 percent on invested capital.

(3) The largest defense-oriented firms earned an average of 10.7 percent on invested capital (excluding General Dynamics with its gigantic loss).

(4) The 47 Chicago-based firms in Fortune's 500 earned an average of 8.76 percent, less than the big defense contractors.

Profits as a percentage of sales are often lower in defense and space work, and the problems of red tape and uncertainty are great, but these are elements of riskiness rather than profitability itself, which is based on return on investment rather than return on sales.

Nevertheless, it is quite possible that there is a divergence between the legitimate private interests of Midwest manufacturers and the interests of the Midwestern region as a whole, a divergence which can only be resolved by a change in Federal Government policy. If Midwest manufacturers are earning satisfactory returns without government contracts and feel growth prospects for profits are just as good in their present pursuits, then they have no incentive for getting government contracts just to increase employment. The Midwest as a region, on the other hand, need gains in employment and therefore has an interest in its firms procuring contracts which cause this, regardless of the impact on profits. If the Federal Government wishes to stimulate balanced economic growth across the Nation instead of a continuous export of human and other resources from the Midwest to other areas, it should "sweeten the pill" by making it more profitable for Midwest and other firms to take such contracts—even if it costs a bit more for the outputs.

There are, certainly, limits to the added costs justifiable for this reason, but some added costs may be well warranted. The Federal Government should consider all the ramifications of its tremendous impact on regional growth rates—such as its pouring urban renewal funds into stagnant areas, its area redevelopment funds, and so forth; and perhaps it will find it less expensive in the long run to incur some added defense and space costs in order to maintain more balanced national economic growth. It is realized that the Department of Defense carefully evaluates the impact of its decisions on local communities in particular cases, but defense and space spending will be major determinants of America's regional growth rates in the future, and all the ramifications of this fact have not been fully considered by the Federal Government or anyone else. Thus, there are important values in life which should influence defense and space spending besides "more bang per buck"—values which can validly be expressed through political channels such as those which surely had some impact on the location of NASA's Manned Space Flight Center in Houston Texas.

OTHER MAJOR EFFECTS OF THE SPACE PROGRAM UPON THE ECONOMY

One economic effect which has been tremendously emphasized is the technical advance from space research which will lead to "spin-off" applications that will alter our everyday ways of doing things. Examples often cited are new ceramics for cooking developed from nose-cone materials, air bearings, small portable power packs, accurate weather forecasting, and countless other innovations. Undoubtedly, these will be important effects, but their overall magnitude cannot be forecast. We should remember that a great many of these products would have been invented anyway; space research merely speeds up the process. Moreover, the example of atomic energy shows that big scientific breakthroughs take a long time to filter down to the average man.

Another important economic effect is that the entire space program will result in greater Federal Government control over the resources in our economy. This control probably simultaneously increases both stability and inflexibility in the economy. If substantial deflationary forces cause a recession, the Federal Government may be tempted to use the space program as an expansionary economic spending tool independent of its scientific and strategic functions. However, as pointed out before, the narrow spectrum of the labor force covered by space programs reduces their usefulness as a "pure" economic stimulant compared with urban renewal, public works, or across-the-board tax cuts.

An effect which many critics of the space program point out is that spending so much money to land two men on the Moon reduces our ability to spend on humanitarian goals like education, mental health research, cancer cures, production of more goods and food for underdeveloped areas, urban-renewal, and a host of other significant needs which we have here on Earth. This criticism is certainly important, but it must be tempered by asking the question, "If we did not spend this money on space research, how much of it would we actually spend on these other worthy goals?" Probably most of the money for space research is diverted from consumption and investment in the private sector rather than from other social research programs, since the voters and Congress would not vote approval of these other programs even if there were no space program. Thus public acceptance of the entire space program in effect enables the Nation to divert billions of dollars from consumption and investment (and perhaps from nothing at all if the resources would be otherwise unemployed) to research which would not otherwise be done.

Another effect of the program related to the growth of the Federal Government's role in the economy is the pressure toward the creation of a few gigantic firms dominating the defense and space industries. Although NASA and the Department of Defense are heroically attempting to get small businesses into the act, the size and complexity of space projects and the need to have them all mesh perfectly because of the difficult "interface" problems means a pressure toward big-firm contracting and control. One of President Eisenhower's last statements in office was a warning that creation of an economically and politically powerful group of firms and government departments—even for purely patriotic reasons—in maintaining large-scale government spending for defense and space activities might have adverse long-run effects on our national policies and perhaps even our political structure.

CONCLUSIONS

The space program was undertaken by our government primarily as part of our life-and-death competition with Communism in the struggle for world power. Thus, our basic motives for this program are not economic or even scientific in nature, but the size and character of the space program mean that it will have important repercussions upon both our economy and science. Because the space program represents the intermingling of the most advanced modern technology with large-scale government and industrial planning, it must inevitably move our economy in the direction of more centralized control and planning; hence we are becoming more like our opponents in the struggle for world power, just as they are being forced to become more like us. However, in assessing both of these basic trends—the economic repercussions and the movement towards more centralized power—we should keep in mind that the space program represents less than 1 percent of our total economic output. Therefore, it will not revolutionize our life overnight or even in the next decade. Even so, the impact of this 1 percent can be and will be greatly magnified by its effects in speeding up technical research, and its employment effects in certain specific areas. Insofar as the direct effects of the space program upon us are concerned, those effects will depend upon our energy, imagination, and forcefulness in, first taking advantage of the opportunities presented by NASA's programs, and, second, pressing the legitimate political arguments for altering Federal policy so as to favor the Midwest more strongly.

16 Is There a Future for Small Business in the Space Age?

JOHN E. HORNE
Administrator, Small Business Administration

Since economic growth and freedom are strongly linked with our achievements in space, I believe that this Space-Age Planning Conference not only will have a significant impact on business, industry, and education in the Midwest but will contribute much to the progress and prosperity of the Nation as a whole. There is no doubt that the Space Age will have dramatic and far-reaching effects on our economy and our people. By-products of space research are resulting in new consumer products. Items about them appear every day in the newspapers. Space food experiments, for example, have resulted in better ways to preserve, can, and freeze food. Pressurized space suits for stroke victims who otherwise would be bedridden are also a result of space research. Medical achievements, such as retina welding in human eyes, have been announced. It has been estimated that at least 3,000 new products and methods have been produced for private enterprise as a result of our space efforts. These discoveries are piling up for consumers and industry alike. In all of this research, small business will have unprecedented opportunities.

At the same time, some assurance must be made that in the development of gigantic space projects and subsequent commercial adaptions that small businesses are not excluded from participation. Small firms should be given a much more equitable share of government contracts in research and development as well as in manufacturing. They should be safeguarded from restrictive and monopolistic practices that could develop because of the magnitude and complexity of these space programs. And, above all, they must be regarded in the light of their capabilities and their unique ability to meet certain demands in today's highly competitive market.

Nearly 95 percent of the businesses in America are small businesses—some 4½ million of them; they represent 40 percent of our total business activity, and approximately one of every two persons employed in the United States is an owner, manager, or worker in a small business. Collectively, small business is the biggest business in America.

Small business is also a well-spring of new ideas and new methods and new inventions. Typically, most people tend to think of inventions and innovations as being born in the research laboratories of giant concerns; however, many if not most of the important commercial inventions of the past half century—air conditioning, automatic transmission, cellophane, domestic gas refrigeration, kodachrome, insulin and streptomycin, to name but a few—were the products of independent inventors and small concerns.

Most importantly, there is the vast diversification of small businesses through the country. All are working for peace and are utilizing all our resources to avert World War III, but we cannot afford to be unrealistic about the time in which we live. Should war come, big industries would be hit first, and small plants would be expected to carry on.

One of the prime objectives of the Small Business Administration is to enable small business to use all its productiveness and inventiveness in the space program, as well as in other sectors of the economy. This objective is being accomplished in many ways:

(1) Money is loaned to small firms to help them finance and improve their operations, when such financing cannot be obtained from private sources
(2) Assistance is given to small firms in selling to or buying from the Federal Government
(3) Several programs have been initiated to help small firms improve their technical and managerial skills
(4) Many publications are published and distributed
(5) The Small Business Administration acts as spokesman for the small business community in the councils of government and works with other agencies to give small businessmen a strong and united voice.

In short, all our resources are being utilized to help small business to overcome the competitive handicaps under which they operate today. There is ample evidence that they can do so.

Experience has shown that there is no field, no undertaking, no new or previously unexplored area, that is too big or complex for participation by small firms. The Small Business Administration has seen many examples of the ability of small firms to provide highly specialized services and essential products and components.

I recall one case in particular. Some years ago, a Missouri metal worker decided to go in business for himself. He bought a lathe and installed it in his basement. Later he moved his equipment into a warehouse. As time progressed, so did this small businessman. He bought some land on which he intended to build a plant. Then he took a banker out to his new location with the hope the banker would approve a loan. The banker stood in the middle of waist-high weeds and asked: "Where is this land of your?" The metal worker told him he was standing on it, and the banker turned on his heels and fled. However, this enterprising young man managed to get his plant built. Today, he is turning out parts for the Gemini space capsule. The Small Business Administration had a hand in his success.

Another case I might mention is that of a small Pennsylvania plant that developed an ammonia-activated battery. The Small Business Administration assisted the company to obtain its first government research and development contract and suggested that other batteries it had developed might be used in meteorological rocket heads. As a result, the company sold the government additional batteries for extensive testing. Other government, as well as commercial applications, seem assured.

We also lend money and give technical assistance to small businesses known as research, development, or production pools. These businesses consist of a number of small firms that have pooled their resources in order to be in a better position to compete for government prime contracts and subcontracts. Most of them are engaged in space or other scientific projects. Actually, there is hardly a Small Business Administration activity that has not been stimulated by the space venture.

The lending program and the technical counseling given to small firms has already been mentioned. The more small concerns become involved in the space program, the more requests there are for Small Business Administration assistance. Indeed, as time goes by, the Small Business Administration is becoming increasingly space-oriented.

The Small Business Investment Program is another good illustration of a space-stimulated activity. In this program, we license, regulate, and help to finance privately owned small business investment companies, known as SBIC's. The SBIC's in turn, serve as a source of private equity capital and long-term loans for small business. The growth of these companies in the past 2 years has been phenomenal. We now have 655 SBIC's with nearly $600 million in capital to invest in small businesses. Of this number, 49 are in Illinois and the three surrounding states. Nationwide, the electronics or "glamour" industries seem to have attracted the interest of a great many SBIC's, and their investment in this field is relatively heavy.

The area which affords small firms the greatest opportunity to participate in the space program is in the field of government contracts. Although it is felt that much more can be done to utilize small business know-how in government contracts, generally speaking, the achievements during the past 2 years are encouraging.

There was a time—between 1954 and 1960, to be specific—when small businessmen were losing out at an alarming rate on the dollar percentage of purchases awarded by the government. Clearly, this was an inequity that called for a change. President Kennedy, a former member of the Senate Small Business Committee, felt that corrective action was imperative. Accordingly, early in 1961, he asked for a 10-percent increase in the small business share of the dollar value of military procurement. This was achieved. In October 1962 he similarly called on NASA, the General Services Administration, and the Atomic Energy Commission to increase contracting opportunities for small business. As a result of the President's action and the cooperation of the appropriate government agencies, a greater number of purchases were set aside for small business bidding.

There was a significant increase in SBA's joint set-aside program with NASA. In fiscal year 1962, NASA's set-asides for small business totaled $18.2 million. During the first 9 months of this fiscal year, the dollar amount rose to $20.7 million. The contributions of small firms who have been awarded prime contracts in the space program are too numerous to mention, but one example, I think, is particularly noteworthy.

The prime contractor for NASA's S–16 Orbiting Solar Observatory was a small Colorado firm which not only built the satellite but developed several new products in the process. Commenting on the firm's success, a leading magazine observed that "corporate girth is not essential for the long reach into space." This type of thinking is becoming more widespread as small firms continue to prove their worth.

In the field of prime contracts, the Small Business Administration feels that considerable headway has been made. In Illinois and its three surrounding states alone, the dollar value of small business prime contracts has almost doubled, increasing from $130 million for 1959 and 1960 to $238 million for the past 2 years. Similar increases occurred throughout the rest of the country for the corresponding periods.

There are, however, certain limitations. The growing technological complexities involved in producing military and space items for the government tend to curb the prime contract opportunities available to small concerns. Fortunately, this is not the case with subcontracts. Here, small firms have a broader area in which to operate. For this reason and at the direction of Congress, there is an intensive campaign to expand the share of subcontracts to small concerns. Under a law passed by Congress in 1961, prime contracts in excess of $1 million and subcontracts in excess of $500,000 must include provisions requiring the primes and subs to conform to a small business subcontracting program. Basically, this is a cooperative program. We cannot—nor would we want to—compel a prime contractor to award a subcontract to one business concern rather than another. He is simply being asked to explore all possibilities for utilizing the capabilities of small firms. Moreover, effort is being made to convince him that it is good business to seek out the small firms rather than wait for small firms to come to him. Whenever possible, our representatives visit the plants of major prime contractors to discuss the program with them. The results over the long haul appear to be optimistic. There has been excellent cooperation from many of the large prime contractors. This is true not only of contractors that have been visited, but of others as well. The small business subcontracting forums conducted in southeastern states by one large prime contractor, in cooperation with SBA, are indicative of the constructive attitude taken by many of the larger contractors.

In California, another large prime contractor's general purchasing agent cited one example of a first order to a small firm for pipe and supply items that meant cost reductions of $6,000 to his company. Moreover he said: "With generally lower overhead rates and a keen desire to qualify as suppliers, small business firms often offer competitive pricing that results in lower unit costs."

Another example is the contribution of small firms to the communications satellite, Telstar. According to the American Telephone and Telegraph Company, nearly 80 percent of its suppliers were small firms.

There is a strong likelihood that the development of the first commercial space communications satellite program will result in the creation of new businesses and the expansion of existing enterprises. It is particularly important that small business be afforded equal opportunities to utilize the facilities which will be made available and to act as suppliers to the operators of the new system.

There is an excellent medium to increase subcontract opportunities for small firms; that is the facilities inventory, which is a nationwide registry of small firms interested in and capable of bidding on government contracts and subcontracts.

A year ago the facilities inventory was changed from a regional system to a centralized system using electronic data processing methods. This system now enables us to produce automatically listings of the products that small firms can make and also indicates potentialities for other goods and services. At the close of 1962, more than 41,000 small firms were registered in five categories. New registrations are currently being added at the rate of 1,500 per month.

The regional office in Chicago has registered and coded nearly 2,700 production facilities in the past year and is building toward a goal of 10,000 such firms. This is about a third of the estimated 33,000 small businesses with production facilities in Illinois, Indiana, Iowa, and Wisconsin. This is a good percentage since it would be impossible to register and keep current the information on all small businesses.

Being on the facilities inventory not only may mean added income for a small business from government procurement but from private business as well. Small concerns in the Chicago area can—and should—speed up their efforts to get in touch with the regional and branch offices and be listed on the facilities inventory of the Small Business Administration.

As a further means of assisting small firms to share in the fruits of the Space Age, there are a number of publications that relate to the subject. One is a directory listing small concerns interested in performing research and development. Another is a survey presented in a booklet called "Small Business and Government Research and Development." The Small Business Administration also has financed a study made by the University of Maryland on "Small Firms in Research and Development Industries." These publications and about 400 others, including a Products List Circular listing new inventions, are available at all of our 61 field offices throughout the country.

The Small Business Administration is seeking any new and proper avenue that will lead the way to more small business participation in space and scientific projects as well as in other areas of the economy. This must be done if this country is to have a strong and diversified small business community and thereby maintain the private free enterprise system which is basic to our liberty and to our prosperity.

In accomplishing these objectives, the Kennedy Administration gives its strong support. The Administration has taken vigorous steps to stimulate not only small business but the economy as a whole. Particular attention, however, has been devoted to the small business segment. The President's action to insure small business an opportunity to participate in the prime and subcontracting areas has already been mentioned.

Both the tax credit for investment in productive machinery and equipment and the new liberalized depreciation guidelines include features particularly beneficial to the small businessman. In addition, President Kennedy's tax reduction program, if passed by Congress, has many features deliberately designed to benefit small firms. These measures, plus the safeguards established by Congress to assure the growth of the small business community, will enhance the future of small firms in the overall economy.

In conclusion, small business has taken on the challenge of the Space Age, and—in its own way—is meeting this challenge as effectively and dramatically as our industrial giants. It is to the advantage of large concerns generally and to the Nation as a whole to encourage and foster the existence of small business enterprises. No one can detract from the importance of large firms, but in meeting the future space needs, it is essential that more dependence be placed on the skills of small firms. Certainly, the success in the space program already has demonstrated that imagination, ingenuity, and inventiveness are not sparked exclusively by big business. Progress is not necessarily induced by size.

Any small company with good ideas and scientific know-how has the opportunity to get into the space program. In fact, in the last few years, there have been established many small, highly specialized companies that are now contributing greatly to all phases of the Nation's technical demands, including space exploration. Without these small firms which produce so many of the custom-made products needed for the satellites and other exploratory equipment, it is doubtful that the space program would be as far advanced as it is today. No one company has all the resources, all the brawn, or all the brains to produce a complete space vehicle. It still takes the combined talents, the initiative, and the drive of both small and large firms to piece together the intricate instruments needed to probe deeper and deeper into space.

If we ever disregard the necessity for small business in economic makeup, we shall destroy the basis for our industrial superiority. We must protect and promote this factor underlying our greatness.

I am confident that in the Midwest, in the great industrial heartland of America, big business, small business, and the government will unite for the common cause, and that, together, we will reach our goal in a world whose limits are still unknown.

17 Free Enterprise in Space

NEWTON N. MINOW

Chairman, Federal Communications Commission

"Here, on the prairies of Illinois and the Middle West, we can see a long way in all directions. We look to east, to west, to north, and south. Our commerce, our ideas, come and go in all directions. Here there are no barriers, no defenses, to ideas and aspirations. We want none; we want no shackles on the mind or the spirit, no rigid patterns of thought, no iron conformity."

Governor Adlai E. Stevenson once spoke those words about Chicago. In those memorable words, Governor Stevenson caught the mood and enthusiasm of this crossroads of America, and I often think of them when I come home. Governor Stevenson's description of Chicago is especially pertinent when we discuss our new venture into space communications—a venture which requires that all of us see a long way in all directions, with no shackles on the mind or the spirit. Dr. Jerome Wiesner, Science Advisor to President Kennedy, told Congress not long ago that our country will invest more public funds this year in research and development than the nation invested in research and development from the time of the Revolutionary War through the end of World War II. In the space program alone, the current budget of over $5 billion is more than 100 times what was spent on the space program only 5 years ago.

One assignment, Project Apollo, backed by resources of some $20 billion over the next few years is to send men to the moon and bring them back safely to earth. Our goal is to achieve this mission in this decade. For many years, explorations such as this—which are perhaps even more exciting than those of Columbus or Magellan—will of necessity be conducted by our government. While programs like Project Apollo call heavily on private enterprise for necessary know-how and hardware, this subject is one in which free enterprise will play a more dominant role of development and commercial operation.

First, where do we stand in the technology required for a global commercial communications system using space satellites?

The first active communications satellite, Telstar, which was launched July 1962, operates under an FCC experimental license, and points the way of the future. Those of us who were present at the Andover, Maine, ground station last July 10th witnessed a modern-day miracle: the first international communication through outer space. As dramatic and awe-inspiring as this achievement was, it is but a crude beginning of an ultimate, working system.

In developing a working system, there are alternative possibilities. One possibility is a high-altitude system, meaning we would send a satellite into orbit at approximately 22,300 miles. Project Syncom is an example. At that height and with the right speed and an equatorial orbit, the satellite travels at the same speed as the earth—so that related to points on earth, it appears to be stationary.

The first Syncom shot was not entirely successful. During the 5 hours required to reach apogee, the Navy ship *Kingsport* made repeated contact with the satellite, sending up and back tone, teletype, music, and voice communications. However, the communications system failed when the final stage onboard rocket was fired to put it in proper orbit, and Syncom has been silent since then. Through telescopes the satellite has been located, its orbit is good (this is a major achievement in itself at a height of over 23,000 miles), and two more launchings are planned for this year.

The synchronous system has obvious advantages. Because of its great height, only three satellites in use (spaced at 120° angles) could provide communications service to 90 percent of the Earth's surface—to all but the extreme and unpopulated polar regions. Because it is stationary with respect to points on the Earth, there is less need for expensive tracking equipment. This would be of great importance in the development of a global system, especially to provide service to many underdeveloped nations which can ill afford to construct and maintain elaborate ground stations.

However, we are anxious to move ahead, and today the launching of a high-altitude satellite of sufficient size and weight to do the whole job (approximately 500 pounds) is still in the planning stage. Syncom I, for example, has only a single two-way telephone circuit compared with the 600 in Telstar required for television. Moreover a high-altitude system introduces certain problems, such as a noticeable lag in voice communications as a result of the tremendous distances involved.

Low- or medium-altitude systems such as Telstar and Project Relay have proven capabilities. Telstar follows a random inclined orbit and is tracked by elaborate ground equipment at Andover, England, and France and, during its final stages, by the new facility in Italy. Relay is in a slightly higher orbit, and has been tracked by the big ground stations and also by the much smaller ones, such as the 30-foot antennas in Fucino, Italy, and at Rio de Janeiro, Brazil. But as you know, depending upon the Earth's rotation and the satellite's orbit, Telstar and Relay are in sight of the ground station for only a few passes a day. Some of these passes last much less than an hour. For round-the-clock global transmission, about 40 such satellites will have to be in orbit at all times to give continuous, reliable service so that as some dip below the horizon, others will be in sight to take their place.

Thus, a low-altitude system requires more satellites and more elaborate ground stations, while a high-altitude system offers advantages but poses a number of yet unresolved technical problems.

During more than 4 months of continuously successful operation, Telstar circled the earth 1,242 times and traveled a distance almost half that to the sun. Telstar became silent last February due to radiation effects on the command transistors caused by its passing back and forth through the Van Allen belt. Relay is currently functioning very well, although it is necessary to turn it off occasionally so that its batteries have a chance to recharge. Just the other day, Relay transmitted medical data for diagnosis across the Atlantic Ocean. The brain waves of an English patient at Bristol, England, were sent via Relay into a computer at the National Academy of Neurology at Minneapolis, Minn. A diagnosis was made and sent back to England, all in a few minutes.

These experiments have been far more successful than even the most optimistic hopes of our scientists. All experiments originally planned have already been carried out. Over 300 technical tests and some 400 demonstrations have been conducted through Telstar and over 500 communications tests and demonstrations (more than 50 operating hours) have been made on Relay. A tremendous amount of invaluable information has been obtained. We know, for example, that the delicate instruments containing some 15,000 components can withstand the initial shock of blast-off and the later beatings of particles in space.

Because of this information, a number of changes have been incorporated into Telstar II (launched May 7, 1963). While basically similar in design and capabilities to Telstar I, it weighs 5 pounds more (175 pounds) and will provide regular reports on 118 separate measurements (112 for Telstar I). New transistors, with substantially more protection against the effects of radiation, are included. It was put into a higher orbit which minimized, by perhaps as much as 50 percent, the radiation effects. And with this new height (apogee of 6,713 miles), periods of mutual visibility between the United States and Europe will increase about 50 percent for each pass although there will be a fewer number of passes each day (6 compared with 9 for Telstar I). In addition, there will be times when transmissions between Maine and Japan will be possible.

We know that satellites can relay all sorts of communications—two-way telephone conversations, telegraphy, data, telephoto, facsimile, television (both color and black and white). Telstar sent data across the Atlantic at the rate of 1.46 million words per minute—fast enough to send the entire King James version of the Bible in just 45 seconds. Shakespeare's works could have been transmitted in 25 seconds. The master clocks in England and the United States were synchronized to within better than 10 millionths of a second via Telstar. And millions of people here and abroad saw live the Ecumenical Council and the flight of Astronaut Schirra. They also saw a big league baseball game, the United Nations, and night life in Paris.

The performance of Relay has been equally impressive.

The television picture of the unveiling of the Mona Lisa in Washington by President Kennedy, carried live via Relay from Washington to France, was reported by foreign officials to be the best video pictures yet sent by satellite. Quality of the voice, facsimile, and teletype transmissions were equally excellent. And when President Kennedy recently awarded honorary American citizenship to Sir Winston Churchill, the 3-o'clock ceremony was specially timed so that this distinguished world leader and millions of his countrymen could watch, via Relay, this impressive ceremony live.

It is this thrill of 200 million people here and abroad simultaneously sharing the unfolding of history that makes your task and mine—of using this science for peaceful purposes—so rewarding. It has captured the imagination of the world. In addition to the ground stations already operational in England, France, Italy, and Brazil, stations are being constructed in Germany, the Scandinavian countries, Canada, India, and Japan. The German station in Munich is nearing completion and there is optimism that the Japanese facility will be ready in time to bring us parts of the 1964 Olympics as they take place.

In many ways our European colleagues are better prepared for international television than we in the Western Hemisphere.

In Eurovision, free men in 18 West European nations have joined forces to erase communication barriers to reach 30 million television homes in Eurovision countries. These broadcasters have conquered language barriers, standards conversion, political differences, and all the myriad characteristics of outworn European nationalism. News inserts, major events, and sports are carried live throughout Europe, in a market of service for and between nations. At the end of 1961, 2,275 Eurovision programs for a total of 2,366 hours had already given rise to 12,733 relays through the Eurovision circuits.

There are lessons for us to learn from the European Broadcasting Union. And as we learn, we can start to build worldwide Univision.

Several years ago, the Federal Communications Commission gave the challenge of space communications its top priority. We work closely with the White House, the Space Council, the Departments of State, Defense, and Justice, NASA and the USIA. We seek the advice and views of the communications industry and the general public. We testify frequently on progress and problems before Congressional Committees. We attend international conferences with representatives of other countries and consult frequently with the communications authorities in all parts of the world.

Of primary concern, at the moment, are the preparations being made for the Extraordinary Administrative Radio Conference to be held in Geneva next October. At this Conference, the vitally important question of frequencies to be allocated to this service will be considered. Without international agreement to set aside frequencies for this service, we could find ourselves in the situation of the man on skis without snow.

Preliminary discussions have been most promising. The Telecommunication Committee of the Conference of European Postal and Telecommunications Administrations, on behalf of the 19 countries composing that Conference, has already expressed support for the concept advanced by the United States of a single global satellite system. We have already developed a realistic set of frequency proposals to present in the fall, and we regard the successful conclusion of the Conference as one of the key elements in the early establishment of a truly effective global satellite system. I attended meetings in Geneva in February of this year where we had a number of encouraging discussions at the International Telecommunications Union.

Now what is the significance of all this in terms of the role of free enterprise in the space age?

In 1927, when we first put in radiotelephone service to Europe, there were 11,000 calls. In 1962, there were about 5 million overseas calls. By 1980, it is estimated that the traffic will reach 100 million. Today, there are about 700 overseas circuits. By 1980, it is estimated that at least 10,000 will be needed. Present-day cable and radio facilities will be used to full capacity by 1965. So unless we are to commit ourselves to an emergency program of providing greatly increased cable facilities with much greater capacity, the answer to our problem lies in putting microwaves to work via satellites.

New facilities will not replace or threaten to replace existing facilities. The satellite facilities will be needed in addition to the existing facilities in order to satisfy the rapidly increasing demand for communcations service.

This kind of situation has occurred before. Prior to 1956, practically all plant for overseas telephone service was radio plant. Yet beginning in 1956, hundreds of millions of dollars have been spent for undersea cables. Existing investment in radio facilities did not hamper adoption of more efficient facilities.

To meet this ever-growing demand, President Kennedy established the principle that the United States would favor development by private enterprise of the American part of a global, commercial space communications system if the public interest would be fully protected. The President and all of us in the government concerned with communications know that our American system of private operation of communications under government regulation has served the nation well. We set out to extend those same time-tested principles into the space age, and they are reflected in the Communications Satellite Act of 1962—an imaginative, responsible, and timely law. The law authorizes the creation of a unique form of American corporation. It is a private corporation for profit, subject to substantial governmental regulation. The Corporation will build and operate a commercial communications satellite system. It will do this in partnership with foreign governments and businesses.

Half the stock of the new Corporation can be owned by communications companies, the other half by investors from the general public. There will be 15 directors—6 elected by the communications carriers, 6 by public stockholders, and 3 appointed by the President of the United States.

To organize the Corporation, the President appointed 14 prominent Americans whose appointments were recently confirmed by the Senate. One of them, David M. Kennedy, Chairman of the Continental Illinois National Bank in Chicago, is Chairman of the Steering Committee of this National Space Conference. The Directors selected two distinguished, able executives, Leo D. Welch and Joseph V. Charyck, to serve as Chairman of the Board and President of the Company. We are co-operating with Mr. Welch and Dr. Charyck, and with many common carriers interested in investing in the company. And there are clear indications that the general public is eager, almost too eager, to participate in the development of the Corporation.

The government's role is carefully spelled out in the new law.

The President, of course, will coordinate the activities of the Federal agencies. He will supervise the relationship between the corporation and foreign governments and stimulate foreign participation in the system.

NASA, working with the corporation, will continue to explore and clarify the technical characteristics of the satellite system. The launching of the second Telstar and the plan to launch two more Relays and two more Syncoms during 1963 are illustrative of this program.

The FCC has a number of important new responsibilities. With the advice of NASA, we must decide the characteristics of the system—whether it will be high, middle, or low altitude or some combination of the three.

We must approve the rates. Here we will anticipate some excrutiating problems. "COMSAT" will be a common carrier's common carrier—that is, it will provide service to and interconnect with existing carrier facilities. The rates must be fair to all users. So we look ahead to some novel rate-making proceedings.

We must insure effective competition for both large and small businesses in the purchase of equipment for the satellite system and ground stations. Suggested procedures have been drafted. We are currently seeking comments on them and we hope to make them effective very shortly.

Where the Secretary of State advises that communications to a foreign nation by means of the satellite system should be established in the national interest, we must immediately institute proceedings to establish such service. This, of course, is a basic policy—because what we seek is a truly global service, reaching both large and small nations.

We are given the assignment of approving stock issues and borrowing by the Corporation. We must also insure that no substantial additions are made to the Corporation or to a ground station unless required by the public interest.

The New York Times was most perceptive when it called our assignment "the most exacting regulatory task in the Commission's history."

As citizens, each of us has a staggering stake in the issues. A basic question of our time is whether a free society or a totalitarian dictatorship can make the best use of the technological revolution. The future of each one of us and of our children is woven into our answer to that question. Yet this technological race is so explosive that it leaves little time to grasp its deeper meaning. Albert Schweitzer has written of the inability of science to give us guidance in the use of its marvels. As Dr. Schweitzer has observed, "Today thought gets no help from science . . . ."

In the new area of space communication, every effort has been made to keep thoughtful public policy abreast of science and to advance the philosophy of peaceful uses of space. Congress has provided the framework within which government and private enterprise in cooperation can meet the technical, economic, and operational challenges involved in the establishment of a global communications system. Senator Humphrey articulated our national purpose eloquently when he said during the Senate debates last year:

"I believe that we ought to demonstrate to the world that a free people, through their free institutions of Government and through their free economic institutions, can pool their resources without the loss of identity of either Government or private enterprise in the fulfillment of a common objective.

"I wish to afford the world an example of what can happen in this country when the Government works with the private sector of our economy and when Government and industry walk arm in arm toward a common purpose and with a common goal."

Within the next few years, this example of a joint venture of government and private enterprise will bear fruit through improved international communications. I believe that with vision, international communications in the next decade can become the common market of mankind—the market of the free exchange of ideas. One of the world's great historians, Arnold Toynbee, sees the communications satellite as "a great asset to mankind in its present struggle for survival . . . . A world-wide network of television broadcasting is going to expand the circle of everyone's personal acquaintances to a world-wide range; and this is the very thing that we most need in the dangerous chapter of history through which we are now passing."

History will record that the Russians were first to send a man into space. But history will also record that the United States achieved something more enduring. We were first to launch an idea into space—and ideas outlive man.

That idea is to use international communications for peace. That idea is to build, not a wall sealing in ignorance and prejudice, but a window opening toward truth and freedom.

Panel Discussion

Leader: WALTER D. FACKLER
ANTHONY DOWNS
RICHARD LASSAR
Regional Director, Small Business Administration
NEWTON MINOW

FACKLER: This panel discussion might begin by asking for comments on the papers presented at this session. Mr. Downs.

DOWNS: This question may betray my scientific ignorance. Mr. Minow, wouldn't it be cheaper instead of launching communications satellites in space to lay more cables or use microwave relay systems with airplanes or ships, or are there some advantages to the satellites which cannot be achieved less expensively by these other means?

MINOW: Most economists think today that it will be cheaper to have the satellites but there are many unresolved technical questions. The two most critical are: First, how long will a satellite last? If a satellite will burn out in less than 2 years, then the cost of launching it may be so high as to make it uneconomic. The best-informed scientists of the time think that satellites can be made to last a long time. Second, can more than one satellite be launched at the same time? If half a dozen satellites could be launched with one vehicle, this would amortize the costs substantially and bring it down. Furthermore, the expected demand for communications is such that even if all the cables possible were laid, there still would not be sufficient circuits to carry the load. A general answer to your question is that I do not think that anyone knows yet whether it will be cheaper to communicate by satellite over the next 10 years or by some other means. Also, new cables are being developed, transistorized cables, which may in some ways improve the technology; so actually it is a technological growth problem.

LASSAR: It seems, just by way of supplementing what Mr. Minow suggested, that there is already evidence to believe that putting up a satellite, even currently, has economic advantages over, for example, multiple relay stations. One system does not have to preclude the use of the other. In one sense we are just getting a sample of what might be done with the communications satellite. The extension of the use of the satellite certainly will be projected to a point where the economics, as we envision them now, will have no relevance 5 years from now in terms of the many possibilities satellites offer compared with ground based stations. It seems that with the possibilities of probing farther into space the satellite becomes almost mandatory whether or not it has economic relevance.

FACKLER: Mr. Minow, what if consideration of national prestige and the like should induce other countries to start building their own systems? What kind of an international traffic control problem would we have with space communications satellites?

MINOW: There is a danger that this may happen; for that reason this country is trying hard to persuade other countries to join us. In the field of communications there is a long and honorable history of international cooperation. The International Telecommunications Union is a 100-year-old organization. It was absorbed into the United Nations about 10 or 15 years ago. The basis of communications is agreement. If you do not agree, you cannot communicate. If you picked up the telephone now and called Moscow, it would cost you about $12. The revenue is divided among the government in Russia, the American Telephone and Telegraph Company, and the carriers in Europe who participate in the call, and there are no arguments.

In the Communications Satellite Corporation we have tried something that has never been tried before in American history. It is a mixture of many concepts. Some people object to the idea that the government is not running it, that business has a role in it at all; other people in business think that there is too much government in it. This new technology is going to require adapting some of our institutions as was done in this case to find a blend of public and private participation. Mr. Downs, have you thought much about the structure of this corporation or similar cases which may occur?

DOWNS: I have not devoted any attention to this particular corporation, but it seems to me that you are right in thinking that government and private enterprise have to join forces. In the defense programs, in general, it is difficult to distinguish the Defense Department from the contractors in many places, such as Cape Canaveral. It seems to me that some new types of cooperation must be found between government and business. In fact, development of these new technologies is both so expensive and so complicated that, in effect, the Federal Government or some agency under the Federal Government must extend its role in the economy. As our technology becomes more and more complicated, we must expect the role of government in the economy to increase. This need not mean unmitigated government control, but the general role of government is definitely going to increase in the future, it seems to me.

Mr. Minow, although worldwide television might be an important influence in the sort of international prestige race between the United States and the Soviet Union, there seems to be a big problem in that most of the people in the world (a) do not have electricity, and (b) do not have television sets. Now, would you, therefore, advocate buying a few television sets and giving them to people around the world as well as supplying them with rural electricity?

MINOW: Actually, television is growing faster outside the United States than it is inside the United States. As of this year, for the first time, there are more television sets outside the U.S. than there are inside the U.S. Each day, two new television stations are opening somewhere around the world. The foreign growth has been about a decade behind American growth, but it is beginning. In Africa and Asia there are very few television stations still, and most of these are government operated. I would predict, however, that television will expand over the next 10 years in other countries faster than it will in this country largely because we have reached a very heavy development level. Now, I am in favor of experimenting with education via television and radio abroad. I am, at the moment, more interested in radio because it is so much cheaper. People can be taught how to read and write by radio at a very low cost. The National Association of Broadcasters, at the moment, is examining a project in the Dominican Republic which would use radio and some television for education and I cannot think of a better thing for us to do in a foreign aid program than to use these great media to teach. In Philadelphia, a commercial broadcaster developed a literacy course. I would like to see that kind of enterprise and technique extended through our foreign aid program to other countries.

FACKLER: Mr. Laser, I'm curious why the Small Business Administration is so particularly interested in space as opposed to shoes, cereal, nuts and bolts, appliances, and so forth.

LASSAR: I do not think that our interest in the space program transcends our interest in other kinds of programs, perhaps with one exception. We have seen the small business community placed at an increasing disadvantage with respect to the dollar volume or percentage of volume of business that they are able to secure as a result of government purchases, either military or civilian. A dramatic change occurred during World War II that affected the small business role, and I think this has to be footnoted and understood in order to appreciate our concern with where the small businessman is going to fit in the space program. Along with the advent of World War II, the Department of Defense began to purchase systems of guidance, systems of missiles, systems of all types, as contrasted with the purchase of individual components previously. Because of this, the small businessman was placed at a disadvantage. A small business concern employing 10 or 12 people could hardly be expected to bid competively against Boeing or Hughes or North American for a billion and a half dollars worth of contract to produce the XYZ missile or aircraft. So, in this sense, we have been concerned. It is true that the dollar volume of prime contract which is available to small business has declined significantly. The way in which we have been able to cope with this is to work cooperatively with the prime contractors to assure that there is an interest in subcontracting to the small business community. It is a testimony to the larger primes, particularly in the aircraft and airframe missile industry, that they have voluntarily set up small business departments, have made and are making technical assistance available, and are doing everything possible to proliferate the growth of small businesses around them in order to make available increased sources of supply. This, then, is the reason for our interest in the space program—to insure that small business does, in fact, get its fair share of the defense dollar.

FACKLER: We have been preoccupied with fair shares for a long time—for example, in the farm program. It was the fair-share idea that brought about a situation that is, politically, extremely difficult; neither party can really solve the problem, which began with a concept of parity of fair shares. What criteria do you use to determine what is a fair share and a share that is allotted through the normal operation of the market?

LASSAR: The law does, in fact, suggest that the small business community have a fair share in the purchases that the government makes; this share was not, in fact, defined. It becomes an administrative function to try to give this concept some dollar value. I suppose, in one sense, the fair share might be determined by looking at the total picture at a given time and then hoping that the dollar volume will not decrease in terms of the allocation to the small business community. We could put the fair share in some statistical reference or give it a frame of reference. If the small business community comprises, as Mr. Horne indicated, some 4¾ million individual enterprises, does 40 percent of the commercial volume of business that is done in this country, and employs one of every two persons who are gainfully employed in the United States, then, perhaps, these statistics could be used as criteria—to insure that somehow small business would at least derive 40 percent of the dollar value of purchases, either directly, as prime contractors, or indirectly, as subcontractors. The one-out-of-two people statistic may indicate that 50 percent of the dollar value should be derived. I do not think that it can be very carefully defined or that a dollar volume or a percentage can be given which would accurately describe fair share. Rather, it is a direction that we take. For example, if the feeling generally is that big business is growing at too fast a rate and is restricting the efforts of the small business community, we would hope somehow to change this direction—not to the extent that we would favor small business over large, but at least in the sense of helping the small business community.

FACKLER: Well, there is no doubt that the space program and the defense program, in the long run, change the character of the economy, change the structure of our capital, change our techniques, and have an enormous impact. I find the problems of fair shares and proportions and so on very difficult to make meaningful.

DOWNS: There is no such thing as the fair share in small business.

FACKLER: That's right.

DOWNS: In the field of retailing, with which I am well acquainted, the small businessman is disappearing. Little stores are being replaced by the hundreds every day. The number of stores dropped approximately 18 percent from 1948 to 1958, whereas retail sales went up 25 percent. It seems to me that the idea of fair share is meaningless and that what we should consider are the costs and benefits to our society as a whole of technical changes and how we should guide them. The same problem appears in the question, "What is the fair share of the Midwest in space contracts?" I do not think that the problem should be stated in terms of fair share. It is not a question of justice; it is a question of what are the desirable social goals as evaluated by the political system of the country. If the people of the country decide that national growth should be concentrated on the coasts, then this is a decision which our present government policies are going to implement. However, if we decided, through political channels, that we wanted to maintain some kind of a share of our national growth in the Midwest, then government policies would follow the pattern. It seems so difficult to make any sense out of the term fair share that I would rather consider the costs and benefits of the various alternatives.

FACKLER: When we examine the situation in the Midwest and the flight of Ph. D's and government contracts, it would seem that there are fairly good economic reasons for this. We must start with a realistic assessment of our prospects for growth, and an evaluation of our comparative advantages.

DOWNS: I believe that the Midwest should be subsidized—because we have the votes. We want to live here and we wish to grow and have a political position. Our political system is designed to express noneconomic forces that are not felt in the marketplace. It seems to me that it was perfectly valid for the people of Houston, Texas, through their representatives, to express their desire to have the manned space program located in Houston, as opposed to ten other equally desirable cities; they were successful.

Now, I am advocating a subsidy—not an unlimited subsidy. I think there is definitely a limit as to how much it's worth to subsidize the growth of any particular area. What I am pointing out is that there is a tremendous impact on regional growth rates from Federal spending programs. In fact, I think that it has the single biggest impact, within discretionary control, of anything in the economy. If the Federal Government wishes to make the judgment that, in order to obtain the most for its space dollar, it will let California grow at the rate of 41 percent and Illinois at the rate of nine-tenths of 1 percent, in terms of research and development, and if the political system supports that judgment, we have no argument. However, if this is not the case, then we in the Midwest have two courses and we should pursue both of them. One is to get into action and start pursuing some of these contracts and start thinking of the future. The other action, which is equally important, is to go through political channels and advise the government, in effect, that it has stimulated all kinds of jobs and employment in certain narrow areas, while it has neglected other areas—particularly the Midwest; that although it may cost a little more to do this in the Midwest, it is worth it to us as taxpayers, as citizens, as participants in the political system to spend more money on defense in order to have a more balanced regional growth. This is a legitimate approach. It is a subsidy; but all subsidies are not bad. They are good if we decide that they are worth it.

FACKLER: It is not what we alone decide; it is whether the people in the rest of the country decide that it is worthwhile.

DOWNS: We have to work through the political system, as it is constituted, to influence the rest of the country to decide favorably. Apparently one good way to do it is to have either the President or the Vice President elected from Illinois and that might help us.

MINOW: I am not sure that I accept the basic premise, although I do not disagree with the argument. I believe that the Midwest can compete on its own terms without a subsidy. I think the talent and the capital and the enterprises are here; I do not think they need to be subsidized. The first nuclear reaction was created in Chicago and I cannot see that anything in the Space Age could be more involved than that. Great medical research has been done and is being done in Chicago. I just think it is a matter of not having had sufficient interest, sufficient sophistication, sufficient dedication to go after it.

DOWNS: I completely agree with that. We should pursue that course; but I believe that we should vigorously pursue all courses which will lead to growth of the Midwest.

Consumer Goods Opportunities From Space Research

Auspices: *Armour Research Foundation of the*
Illinois Institute of Technology

Presiding: **JOHN T. RETTALIATA,** *President,*
Illinois Institute of Technology

Introduction

JOHN T. RETTALIATA

President, Illinois Institute of Technology

Several months ago in addressing the Annual Meeting of the Chicago Association of Commerce and Industry, I commented that the Midwest needs to make no 'apology for its consumer-oriented industrial technology provided it does not let Space Age ideas go begging. The present corporate and economic well-being of the general Chicago area must not blind us to the necessity for getting in on the ground floor of the future. Today, many of the elements that will go into the making of America's industrial future are being evolved through space-related research. The industrial applications of space research, referred to as spin-off, result from the tremendous scientific and technological efforts called for in the space effort. Some of the results that already promise to have an impact upon industrial products, capabilities, and profits are discussed in the papers presented at this session.

I should like to suggest, however, that the new technological age, so vividly represented by space research, is even more revolutionary than is indicated by the image of a spin-off of useful applications from new knowledge. Our present age is one in which science and engineering, basic and applied studies, research and development are so closely allied and overlapping that we shall really need a new name for those who are engaged in the simultaneous work of discovery and application. It will be an age of greater engineering, as well as, I believe, greater and more productive science. Yet, most of us still tend in our thinking to draw a rather wide line of separation between pure scientific investigation and engineering application. We remain oriented toward the earlier decades of this century when the engineer was purposefully changing the visible face of the civilized world while the makers of modern science were functioning within what seemed to be ivory towers creating, almost unbeknown to themselves, the basis for the world which we and our children have inherited. This new world became visible with the burst of the atom bomb and the flight into space of sputniks and astronauts. These were technological achievements of a new order of sophistication representing the closest possible collaboration between engineering and pure science.

This new technological age is not just a matter of new wonders. What it really amounts to is a complete reorientation of the world in which we live. It is not only that we cannot separate pure and applied science from each other. We cannot separate them either from our social, industrial, economic, political, and cultural life. If we do, it will be at the cost of losing our place in the 20th century. The key to an effective role in the second half of this century is the ability to accept and participate in rapid change. To the backward glance the developments that have taken place over the past 50 years seem breathtaking. Yet, the pace was sedate when compared with what we must contemplate for tomorrow. Between the first successful airplane and the really significant growth of commercial aviation there was a span of a generation. If present predictions hold true there will be little more than a decade between manned space flight and manned flight to the Moon.

Studies over the past decades have shown 10 and 20 years elapsing before industry accepted a new development, depending largely upon the economics of the industry. Today, the necessities of world economics and world politics are forcing us to step up this pace immeasurably. Furthermore, the engineer is not sitting on the sidelines waiting for the scientist to come up with something that he can put into good use. He is working intimately with the scientists of every discipline as a partner in basic, as well as applied, studies. The scientist's "Why?" and the engineer's "How?" have become linked in a continuous dialogue. The papers presented in this session offer an exceptional opportunity to learn, at first hand, of some of the consequences of that dialogue.

18 Space Technology and its Potential From an Industrialist's Viewpoint

EARL P. STEVENSON

Consultant to NASA, Industrial Applications Committee, and
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The broad national problem to which the Industrial Applications program of the National Aeronautics and Space Administration is addressing itself will be sketched here. One of the conclusions reached by the American Assembly in its conference last year on "Automation and Technological Change" was that the rate and direction of technological change in the decade ahead will be determined by public policy in supporting government-sponsored programs, of which space demands increasing attention.

In reaching this conclusion, the concern of the Assembly was more fundamental than the distribution of funds. It was recognized that technological change involves a complex social process including many participants: science, education, research and development (under both public and private auspices) management, engineering, production facilities, workers, and labor organizations. All stages in this complex process must be improved, and all groups in the community have a contribution to make. To quote further from the Assembly, "To accelerate productivity is a challenge to our technical resources, our capacity to cooperate, our political ingenuity and our sense of national purpose."

Robert A. Solo, writing recently in the Harvard Business Review, expressed the challenge in these words: "A change of approach must be in the offing, a change from the approach that views the transmission of the results of space-military research into industrial application as a happy instance of automatic spill-over to one that views it as a part of an immensely difficult task of social engineering."

There is concern over the increasing percentage of national R&D expenditure supporting massive federal programs—defense; atomic energy; space; health, education and welfare; and science. The President's budget for fiscal year 1964 includes a request for almost fifteen billion dollars for government-sponsored research and development. The estimated investment by the private sector is five billion dollars.

This concern over the imbalance in the distribution of the national effort between the two economies is currently reflected in editorials in the metropolitan press and weekly news magazines, as well as in technical publications. Most recently these reflect the unfavorable bearing of this imbalance upon our future competitive position in international trade. It is claimed that other highly industrialized countries are spending a higher percentage of their gross national product in promoting the growth of their civilian economy.

Such comments, while not to be ignored, do not take into account all of the factors that are involved in the overall process of promoting industrial growth through technological change. The R&D effort is only one term in a complex equation. Plant design, production techniques, investment decisions, labor relations, market research, public relations, and managerial policies are all involved in the end result. Even Congress can get into this act by approving the accelerated write-off of new tools (both shop and laboratory) and by reducing the corporate income tax rate to encourage investment in new and improved plant facilities. This overemphasis of the role of the research laboratory also tends to overlook the contributions of engineering. Science and engineering are not put in their proper working relations. Product and process innovations, while increasingly growing out of new scientific discoveries and most frequently conceived in the course of organized industrial laboratory research, do not necessarily begin and surely do not end with the R&D effort as we now measure this in terms of dollars. The Apollo and other manned spacecraft developments are the primary concern of engineers (85 percent).

While an imbalance does exist, the relative expenditures for R&D in the two economies or sectors of our society can be overstressed. The two figures are not strictly comparable because of basic differences in bookkeeping practices. The government budget does not distinguish between capital expenditures and operating expenses, and in industry, items which government bookkeeping might charge to operations are capitalized. The cost of starting up a new industrial facility can be the most costly step of all and be charged to operations. I make no issue of these differences, but merely note them in passing as distorting our perspective.

We are living in a new era. Major government-supported research programs will have a decisive effect on the rate and direction of technological change. Acts of Congress in creating the Department of Defense, Atomic Energy Commission, National Aeronautics and Space Administration, National Science Foundation, and Public Health Institute have profoundly changed our way of life, but not our national purposes. The public and private sectors of our society, which may appear to be growing apart, must learn to live together in an atmosphere of mutual respect. Industry should fairly appraise the plus and minus values to be found in the competition of government programs for our most limited resource, manpower capabilities. Certainly industry cannot afford to decrease its support of research with any idea that this phase of its activities is now being subsidized by the Federal Government.

At the turn of this century, the individual inventor was responsible in a very large degree for technological change. Out of the experience of World War I emerged the idea that innovations could be accomplished through systematic organized laboratory research, and during the next 20 years the industrial research departments of our major corporations came into being and grew in stature with their productivity. Only time will give us the perspective for labeling this new era, but we certainly will not write off either the contributions of the individual inventor or the techniques which we have been evolving for industrial research over the period of the past 40 years. It is appropriate to note here that while 75 percent of our national R&D effort may be financed by the national government, 60 percent of these funds were spent under contract in our industrial facilities. Also, companies which a few years ago would not have considered a government-sponsored engagement now avidly seek such opportunities. Such participation can be mutually self-supporting, but where undertaken without proper regard for a company's objectives it is of questionable value; or otherwise stated, if work is performed by a contractor in fields related to its regular commerical interests, the likelihood of transfer of technology is substantial. At the same time, industry must adjust its objectives to the overriding demands of our national goals.

The mission of NASA is a national goal. In attempting to look ahead and try to anticipate some of the social, political, and economic consequences of our space program, both civil and military, perspective is furnished by studying the process of technological change in the past. From technological advances of World War II emerges the world of today. By way of examples, a few of these can be coupled:

Atomic energy→The Cold War and a new source of energy
The jet engine→A smaller world
OSRD→The National Science Foundation
Missiles→The exploration of space

Radar→Navigation, radioastronomy and television
Antibiotics→The population explosion
Chemical warfare→Pesticides and insecticides
Electronics→Automation and the high-speed computer

In solving our World War II problems we have created many more. An operations research model may be pictured as a quiet pool into the center of which a massive object is dropped. But the pool has an irregular shore, varying depths, and many islands. Possibly it is from some such analogy as this, as well as actual observations, that we use today the words "unpredictable" and "uncontrollable" when we venture to predict the consequences of our present engagements.

We are, however, not dealing with a single impact of momentary duration. I believe we can today take it for granted that the Federal Government, through its various programs, will not only maintain but increase the participation in and support of research and development, and that our advancing technology will become increasingly identified with objectives of national defense and space exploration.

There is ample historical precedent for anticipating both short-range and long-range industrial benefits. In appraising these possibilities it is certainly difficult to envision any impact of powerful rocket-engine developments that would have any comparable effect in the civilian area to that of the development of the jet engine in the field of commercial aviation. Also, the techniques which are being developed in the fabrication of rockets and space vehicles are not those of the assembly line and mass production, but rather those of the job shop. Small industry, rather than large, may therefore be the most direct beneficiary of the shop notes that are beginning to flow out of the NASA Centers.

One of the most significant aspects of the space program is that it spreads across the entire industrial spectrum—electronics, metals, plastics, fabrication technology, ceramics, machinery, automation, instruments, controls, materials, heat transfer, data handling—to sample only a few. In each case the space program is making new and exacting demands. In almost every instance its demands are at the frontiers of our existing knowledge and experience.

Possibly the most realistic view of the opportunities afforded by the NASA program for technological growth in the private sector is to regard the Agency as providing an initial market for new products and ideas. Space exploration has created a new industry—one presenting new demands and sales opportunities. It is a characteristic of the aerospace industry that the demand is for new materials, techniques, and devices on the boundary between science and engineering; that the potential user is pressing the supplier's "know-how." Pioneering in fields of advanced technology is necessary if we are to conquer space, survive in a military sense, or harness the new sources of energy.

Research ideas therefore frequently find a receptive audience in one of the government services, and contract support is obtained. An example from the experience of Arthur D. Little, Inc., will suffice to illustrate this point. In the field of cryogenics the company sought support for developing an electronic switch based on the behavior of superconductors in a magnetic field. A computer with a wholly new order of memory capacity was envisioned. A government agency shared the company's enthusiasm and gave support to the point where industry is now supporting the development. The next generation of computers may employ these principles. En route to this achievement it was necessary to develop a refrigerator capable of maintaining temperatures in the range of 15° to 20° absolute with the reliability of the familiar electric refrigerator. And so the whole art of cryogenics is years ahead of a normal development in the civilian field, where the demands of the market place and the opportunities for profit are determining factors.

Space, defense, and nuclear weapons make extreme demands on our technical knowledge; they force us to attempt things and thus accelerate the utilization of this technical experience in our commercial life. Apropos this statement, the following comment has been made on the subject of computers:

> There were other forces at work in our society to design and manufacture more powerful computers. Thus, the space program found, already in existence, computers large enough and fast enough to handle the problem from the ground. The current demands are to make computers of small size for use in space vehicles; this ultimately will have its design impact on commercial computers. Space technology can lead the way in increased reliability and size reduction. Space money accelerates new technology in our civilian economy.

With this prophecy, many possibilities come into view. Among these are certainly new sources of energy and new methods of conversion, notably thermoelectric devices and fuel cells. Also, the demands of the space age have given battery development fresh impetus. Since World War II, improvements in battery materials have led to the reduction in size of nickel-cadmium cells and have stimulated the development of rugged, compact, rechargeable power supplies. Cordless appliances are increasing in variety and power. Fuel cells, being designed for spacecraft, support a challenging development. A revolution of some kind appears to be in the making in the energy field.

Other areas of advanced technology can be cited. Electronics would appear to be a general beneficiary, with such specifics as telemetry, sonars, and instruments finding new opportunities in the civilian field as a result of advances occurring in the space and military applications.

Contemporary research and development has become extremely complex. The nice little compartments in which scientific knowledge could once be contained have broken down. Increasingly science has become an integrated whole. The development of aerospace technology is the outstanding illustration. Within its program, every branch of science and engineering finds a role.

A further feature of this new era is the extent to which the team approach has replaced the individual in many of the frontier regions of both science and engineering. This increasing dependence of the individual on his team has introduced new concepts in research management.

This growth complexity of research and development has been in large degree promoted by the creation of superior tools, most frequently conceived in connection with basic research. Robert C. Turner, in remarking on this fact, has proposed a Parkinson's law of research: "The complexity of research automatically expands to consume the capacity of the available tools for doing research." A visit to any one of the ten NASA Centers will serve to mark the role of the space program as a frequent pioneer in the use of new instruments. And new instruments or tools create new skills.

The preceding remarks will serve to introduce a concluding discussion of the unique position of NASA as a patron of technological progress and the more specific ways in which it is so functioning. In speaking before the recent meeting of the National Security Industrial Association, J. Herbert Holloman stated, "The most critical problem facing the United States is the more rapid development and diffusion of technology." NASA is addressing itself to this problem. In this undertaking, it has the advantage of being almost 100 percent open.

The first program to be discussed is that of the Office of Scientific and Technical Information. Here the primary function is the dissemination of information within the aerospace industry through the medium of a semimonthly publication, *Scientific and Technical Aerospace Reports.* To serve its own centers and thousands of contractors, the present issue is around 12,000. These reports will also go to the twelve government regional reference centers being set up by the National Science Foundation. This dissemination employs sophisticated data-processing equipment. In its broader implications this program is tackling the problems created by the information explosion—that of information storage and retrieval.

Secondary publications will also be produced to collate and organize the mass of material in the basic or original records into integrated packages. These will be in the nature of technical reviews and state-of-the-art monographs.

While designed for the primary needs of the aerospace industry, these documents are not so restricted. They can be a primary force in energizing the diffusion process through which technology spreads by a mechanism that can be likened to biological infection. The most effective carrier is through the transfer of personnel from one group, company, or area of interest to another.

While it is a characteristic of this new era that the labor force is more mobile, and technically trained personnel move more freely from region to region, from company to company, and from one field to another, there are forces at work that restrict such transfer from the public to the private sector. Thus the diffusion process may not continue in its historical pattern. Does in fact such a barrier exist? How can it be lowered? These questions and others of a related kind are being explored under an NASA grant to the American Academy of Arts and Sciences. If we understand the hazards, remedial action is a possibility.

The second activity, the Office of Technology Utilization, will be discussed only briefly here. Subsequent papers will deal with this activity at the working level. I should note, however, that the advisory committee, comprising a small group of scientists and engineers with active industrial associations, is concerned only with the identification and appraisal of innovations made in the course of NASA's "in-house" operations. The general procedure will in time include innovations occurring in the course of carrying out contract work. As soon as a disclosure enters the public domain, the present restrictions will not apply. Problems involved in the ownership of title and licensing of patents are being resolved and hopefully will soon be in the clear.

A third approach is in the making. One concept is that of a "middle man" with the competence and resources to serve individual companies on a regional basis. Such an experiment will be tried out at Indiana University with the School of Business as the agent. Thirty interested companies are cooperating in this experiment by collectively matching an NASA grant to the University of $150,000. In another approach, eight facility grants have been made to universities that have substituted on-going research programs in the field of the space sciences. The president of each of these universities has signed a "Memorandum of Understanding" with the Administrator of NASA which provides that,

> The University will undertake, in an energetic and organized manner, to explore mechanisms whereby the progress and research results achieved in space science and technology may be fed into industry and segments of the economy with which the university normally has close relations. This effort may include scholars from other universities and from industry. In addition to an intensive effort on fundamental scientific and engineering problems related to the national space effort, research is to be encouraged on ways and means to expand the search for useful applications and on the economic and social impact of our national involvement in space exploration. The university will undertake to make the scientific community, as well as the industrial and business communities, aware of new opportunities for application of specific developments or processes stemming from the space program.

A word of caution is in order. The Space Agency has a large and urgent primary mission. It has a limited statutory obligation, in the words of the President, "to make the byproducts of space research easily accessible to civilian industry." But its primary mission is space exploration. Private industry must therefore take some initiative in seeking opportunities for translating achievements in space technology into civilian values.

For the corporate representative assigned to this responsibility, NASA offers several opportunities:

(a) Participation in regional conferences
(b) Publications of the Office of Scientific and Technical Information
(c) Access to regional research institutes participating in its industrial applications program
(d) The Washington Office of Technology Utilization.

In the following papers these opportunities will be further developed. The challenge, to quote the President, is to find "new means of facilitating the use by civilian industry of the results of government-financed research."

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The NASA Program of Industrial Applications

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At these sessions, many discussions have been presented on the various facets of the vast space program. The resources of our great nation are being marshaled in the forward thrust to the Moon and outer space. It is an effort in which all of us have a stake. Our spectacular achievements are a source of pride in American know-how and enhance our prestige both at home and abroad. They attest to our ability to support and uphold Free World supremacy in science and technology.

The exploration of space, as noted in previous papers, delves deeply into every basic science; indeed, it has opened new vistas of challenge to our Earthbound minds and energies. We must now devise ways whereby human life can be sustained as man pulls free from Earth's friendly atmosphere. We must develop a whole realm of new or improved materials for rockets, capsules, and space ships, more sophisticated instrumentation to relay data back to Earth, and new energy sources and new propellants to insure man's safe round trip into deep space. It is a highly complex, extremely difficult, but challenging task.

The technical progress predicted for this decade may result in scientific and technological achievements which would normally span a 50-year period. Already we are faced with the problems of analyzing reams of data, of sifting through an endless and growing store of research results, and of groping through an increasing labyrinth of scientific and technical journals and periodicals. Indeed, it was Time magazine which recently noted that man, through his most recent endeavors, has already reached beyond the imagination of our science fiction writers.

Surely, in this great mass of information and new knowledge must lie the seeds of new economic growth, new concepts of management, and the answers to improving our sociological well-being. With the many new forces shaping our destiny, we cannot be content to let their effects creep into our lives and our way of living through the slow processes of evolution and osmosis.

What can we do about it? What are we doing about it?

At this point, a few passages from the January 1963 Economic Report of the President, particularly those sections which relate to the nation's vast expenditures for government-supported research and development, might be appropriate:

> . . . The defense, space, and atomic energy activities of the country absorb about ⅔s of the trained people available for exploring our scientific and technical frontiers. These activities also assert a strong influence on the direction and substance of scientific and engineering education. In many fields, they have transformed our understanding of nature and our ability to control it. But in the course of meeting specific challenges so brilliantly, we have paid a price by sharply limiting the scarce scientific and engineering

> resources available to the civilian sectors of the American economy.
>
> Since rising productivity is a major source of economic growth and research and development are essential sources of productivity growth, I believe that the Federal Government must now begin to redress the balance in the use of scientific skills. To this end I shall propose a number of measures to encourage civilian research and development and to make the by-products of military and space research easily accessible to civilian industry. These measures will include:
>
> . . . New means of facilitating the use by civilian industry of the results of government-financed research.

That is what our Technology Utilization Program is about. NASA, committed as it is to the peaceful uses of space, considers the results of its own research and development effort a national resource which must be utilized for the benefit of all mankind. NASA feels that it has a responsibility to the civilian industrial community in view of worldwide competition, economic growth, and changing sociological patterns to make such information available. In fact, NASA's obligation to disseminate and utilize the science and technology resulting from its research and development program is written into the Space Act of 1958, in the section requiring the Administrator to: "Provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

But, according to a previous paper by Earl P. Stevenson, the diffusion of technology is a complex process. In this age of automation, there is nothing automatic about the transfer of knowledge or the application of an idea or invention to practical use. There has always been a long leadtime, an average of 7 to 10 years in many industries, before the ideas developed in a company's laboratory filter down into its production lines. Another time lag occurs before the returns on the research dollars spent are reflected in the upward curve of the sales charts and in expanding profit margins.

Most companies engaged in industrial research recognize that there are barriers in the channels of communications even within a single company and these barriers are a major hurdle in translating research and development results into practical use. There is resistance, too, to new ideas and new technologies; part of this resistance is psychological, part practical when new expenditures have to be justified to stockholders, and often economic, since to implement a new technology may result in a tremendous impact upon a way of life or a major industry, for example, diesel versus steam engines, oil versus coal, transistors versus tubes, and so forth.

What the Office of Technology Utilization is attempting is the far more complex translation of the results of government research and development into industry's engineering and production talents.

In order to achieve this goal, NASA created an Industrial Applications Division late in 1961. More recently, its scope was expanded by redesignating it the Office of Technology Utilization, within the Office of the Assistant Administrator for Technology Utilization and Policy Planning under George L. Simpson, Jr.

This is a joint program with industry and in order to benefit from industry's experience, James E. Webb, NASA Administrator, has enlisted an outstanding group to serve as members of an Industrial Applications Advisory Committee (IAAC). In alphabetical order they are: James Hillier, Vice President, RCA Laboratories, Princeton, New Jersey; Malcolm Hubbard, President, Hubbard Associates, Boston, Massachusetts; Augustus Kinzel, Vice President of Research, Union Carbide Corp., New York; Emanuel Piore, Vice President of Research and Engineering, IBM, New York; Games Slayter, Vice President of Research, Owens-Corning Fiberglas Company, Granville, Ohio; Earl Stevenson, former Chairman of the Board, Arthur D. Little, Inc., Cambridge, Massachusetts; and Howard Turner, Vice President of Research and Development, Jones & Laughlin Steel Company, Pittsburgh, Pennsylvania. Dr. Stevenson is also a special consultant to James E. Webb.

The Committee is chaired by Walter L. Lingle, Deputy Associate Administrator for Industrial Affairs, who was formerly Executive Vice-President of Proctor & Gamble Co., Cincinnati, Ohio.

In the simplest terms, the basic objectives of the Technology Utilization program are: (1) identification of innovations, (2) cataloging, and (3) dissemination.

One thing to be stressed is that this program is not necessarily limited to *new* knowledge. In their endeavor to meet the severe environment of space, scientists and engineers take existing materials, techniques, and technology and extend their load-bearing capabilities, their range of endurance, their limits of use to much larger dimensions and, finally, expand their use to completely new areas. Often these adaptations tend to stimulate new thinking on how to utilize better what is available and, in many cases, provide a substantial contribution toward advancements in the state of the art. In fact, we define the term "innovation" as a "means of accomplishing a work objective either more effectively than before or for the first time."

The innovation flow is as follows:

(1) Innovations originate at NASA contractors and centers
(2) Documentation is forwarded to NASA Headquarters for cataloging
(3) Innovations are analyzed for industrial potential
(4) Dissemination to industrial users.

These points are discussed in more detail as follows. Naturally, we looked to our NASA Field Centers first to get the program going. Industrial Applications Officers, and, in the larger centers, his staff, were appointed and given the responsibility for reporting innovations promptly to NASA Headquarters. This program was launched officially in July of 1962 with the result that we are receiving an increasing number of innovations each month at Headquarters for evaluation. The preliminary screening for potential industrial applications is done by a staff of specialists in the Office of Technology Utilization. These specialists classify the acceptable submissions into five broad categories, namely, electrical, mechanical, materials, life sciences, and finally energy and propulsion sources.

Several nonprofit research institutes, a commercial research organization, and a university have also been asked to assist in the evaluation of industrial potentials. Included are:

Armour Research Foundation, Chicago, Illinois
Arthur D. Little, Inc., Cambridge, Massachusetts
Battelle Memorial Institute, Columbus, Ohio
Indiana University, Bloomington, Indiana
Midwest Research Institute, Kansas City, Missouri
Southern Research Institute, Birmingham, Alabama
Southwest Research Institute, San Antonio, Texas
Stanford Research Institute, Menlo Park, California

These research institutes work closely with our space centers and with industry to test these innovations out on potential users, to document and augment the material contained in the preliminary data received at Headquarters, to relate the ideas to specific industrial needs, and to prepare technical reports on industrial potential. The geographic placement of these organizations gives us an insight into the needs of the national industrial community.

Howard Gadberry, in a subsequent paper, will detail the work of the Midwest Research Institute and describe the many interesting applications which have initially evolved from the Space Program. An introduction to his discussion might be provided by a description of two space-developed techniques.

The retrometer.—A Langley research scientist, who was trying to solve the problem of communicating from a space capsule during reentry's radio blackout, came up with a rather unique visual short-range communications device, called a retrometer. (See fig. 19–1.)

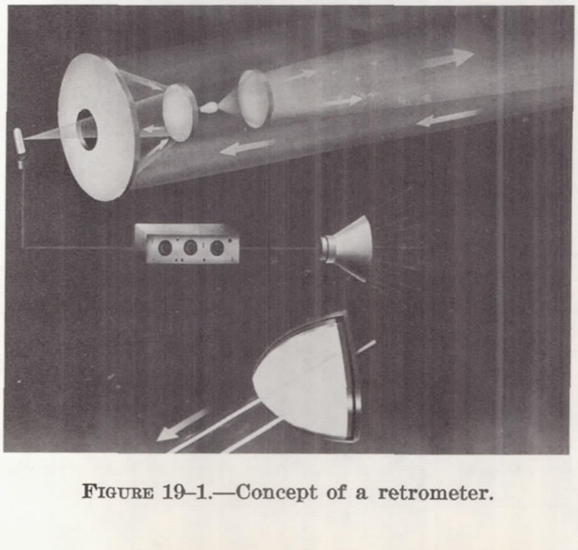

FIGURE 19–1.—Concept of a retrometer.

This device uses the well-known characteristic of a corner reflector, made up of three mirrored surfaces to reflect a light beam imposed upon it right back to the point of origin. He replaced one of the mirrored surfaces with a piece of tautly stretched aluminized Mylar, the same tough material being used for the skin of the Echo balloons which have done so well in space. By talking against this space-material diaphragm, he modulated the light beam with his voice and could now communicate back to the light-beam source. This light-beam source has a collector lens, a photoelectric cell, and a detector-amplifier to convert the light energy back to sound.

Such a device should prove extremely useful in large gatherings, in noisy steel plants, and in other areas where a cordless microphone would be useful and radio interference would be high. The idea has been brought to the attention of the Department of Defense in view of its potential military use in ship-to-ship and ship-to-shore communications.

Weld seam tracker and proximity control.—Marshall Space Flight Center was responsible for developing this improved method of guiding an electric-arc welding head along the seam separating two pieces of metal to be welded. (See fig. 19–2.) The proximity control, located at the base of the "eddy current" seam tracker, senses the distance between the arc-welding torch and the pieces being welded and automatically maintains the proper distance required for the best weld. Prior to the conception of this device, Marshall Space Flight Center had found that existing techniques available to them were not successful for following seams between heavy-gage aluminum work pieces.

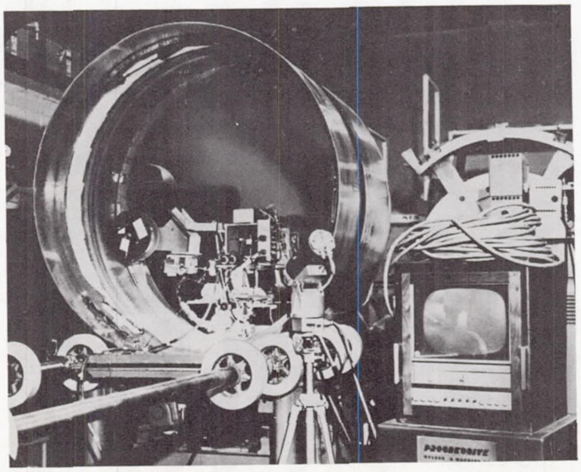

FIGURE 19–2.—Weld seam tracker and proximity control.

A leading farm machinery manufacturer is already investigating the use of this device for joining two channel sections into a wagon-tongue box beam; thus, the need for machining of the channel edges is eliminated and costs are reduced. Two leading welding equipment manufacturers have also expressed interest.

Up to this time, the more than 600 innovations sent in to NASA Headquarters have come primarily from the NASA Field Centers. However, the contractor effort, representing as it does 90 cents of each NASA dollar (only 10 cents is spent in-house) should provide a substantial source of ideas for evaluation and dissemination. Increased emphasis on retrieval from contractors is the next phase of the Technology Utilization Program. To accelerate such transfers, the Westinghouse Electric Corporation has recently received a contract to study the best techniques of motivating NASA's contractors to report technological innovations promptly.

In a subsequent paper, R. Bowling Barnes, president of Barnes Engineering Company, will discuss his company's adaptation of their space work to industry. Let me add that NASA endorses these fast and early applications of knowledge gained from space research and development. Such ingenuity and initiative help the Technology Utilization Program immensely.

The discussion now turns to dissemination, communication, or transfer effort. Solutions to the problem are being explored by the Aerospace Research Applications Center recently established at Indiana University under an NASA grant. Through a close cooperative effort between local industry's engineering and technology competence and the University's managerial and multi-disciplinary talents, various techniques and methods for accelerating the transfer of NASA's research and development results to industry will be studied. Seminars, oriented toward specific industries, are also being planned. A computer facility will be used to store the data not only from the Technology Utilization Program but also from NASA's catalog of space science knowledge maintained by our Office of Scientific and Technical Information. An attempt will be made to match this information to industry's needs. Every effort will be made through a quick feedback of results to NASA to extend new techniques for transfer, thus developed, to our nationwide program.

We are also looking to the University of Chicago for assistance. Its staff, along with the staffs of Iowa State University, Massachusetts Institute of Technology, Rensselaer Polytechnic Institute, Stanford University, University of California at Berkeley, University of Minnesota, and the University of Pittsburgh, have been requested to study ways and means to make the scientific community as well as the industrial and business communities aware of new opportunities for application of specific developments or processes stemming from the space program.

To determine what has already been transferred from the government's missile and space research and development program to industry, the Denver Research Institute at NASA's request surveyed 3,500 aerospace companies. This study, which will be released in June, shows that transfers have occurred mainly in terms of technology rather than in new products. In fact, Denver Research Institute identified 33 broad technological areas which benefited.

Among their findings to date is the interesting story of filament-wound plastics, a material which was first evolved in 1947. Its unusually high strength is due to the orientation of single epoxy-resin-impregnated glass filaments. The filaments neither twist over each other nor criss-cross at right angles to each other, and thus yield maximum strength. Filament-wound plastics experienced a real impetus from our missile-rocket research and development as rocket chambers or rocket motor cases because of their high strength-weight ratio, their high heat resistance, their resistance to corrosion, and their outstanding shock-absorbing characteristics.

A particular Northeast manufacturer, who gained his experience through the manufacture of rocket motor cases, demonstrated his ability as a true entrepreneur by his wide range of industrial applications. On one end of the spectrum, he is fabricating 8,000 gallon tanks for railroad tank cars which weigh 5 tons less than their steel counterparts. On the other end of his transfer spectrum, this same manufacturer produces filament wound brassiere supports which far outlast other supports.

The Denver Research Institute survey also confirmed that a considerable time lag exists between the development of technology and its commercial application. The complete report should also provide additional background and guidance on how a more effective job of space research and development transference can be accomplished.

Although we have used the term "industrial application" almost exclusively, the benefits of space research may reach into the public health sector as well. It is possible that solutions to such metropolitan area problems as water and air pollution, sewage disposal, safety, and sanitation may ultimately be found in the corollary work being done by NASA in its development of closed-cycle life-sustaining systems for long space voyages. However, NASA has one particularly difficult problem to solve—the conversion of waste to life-sustaining constitutes. Fortunately, we have not reached this state here on Earth.

Now we come to our final objective, dissemination of our findings. Existing channels of communication to industry will be used, including publications, trade journals, direct contacts, contacts through trade associations, professional societies, coordination with state economic development departments, and area development groups. We are also coordinating our activities with the Department of Commerce (Office of Technical Services), the Department of Defense, the Atomic Energy Commission, Area Redevelopment Administration, the Small Business Administration, and other government agencies.

NASA and the American Institute of Aeronautics and Astronautics have jointly undertaken a very comprehensive program in abstracting all aerospace literature on a current basis. NASA, in its STAR publication, includes abstracts of report literature, whereas the Institute's "International Aerospace Abstracts" includes all published material on aerospace sciences.

Based upon the input to the Office of Technology Utilization, the NASA Office of Scientific and Technical Information (OSTI) will prepare a series of Applications Notes and Applications Reports to be issued periodically. In addition, the useful properties and values of each innovation reported will be catalogued by OSTI and stored in a computer facility for ready retrieval in response to industrial inquiries. Monographs, covering NASA's specific contributions to the state of the art in various special fields of technology, for example, sensors, instrumentation, computer techniques, electric-arc technology, and so forth, are also being planned.

NASA's Technology Utilization Program is separate and distinct from our manned space flight and space science efforts. The space exploration program stands on its own merits; our nation must occupy a position of preeminence. The benefits from industrial applications are not now and never will be the justification for the high costs of this major effort.

Whenever this great nation of ours has marshalled its resources to achieve major scientific and technical goals, the nation's industrial community has reaped benefits. The concentration of effort during World War II on radar, sophisticated gun laying, and target seeking spawned the electronics industry which has grown into today's sprawling economic giant. The Manhattan project gave rise to a multitude of opportunities, including the whole field of radioiosotopes, new medical techniques, irradiation of foods, and nuclear power, among others.

We believe that the application of space technology will have the same stimulating effect. In fact, some recent studies predict that the economic growth in the next 2 decades will be more dependent on the contribution of new scientific knowledge than on any other factor; but, this will occur only "when and if applied."

How quickly this new space technology is utilized is closely allied to the initiative of business in performing market research, cost analyses, and industrial engineering studies. These are the necessary sequential steps beyond our Charter.

We promise no cornucopia of new products and consumer goods. We can only promise that we shall do our utmost to cooperate and make the knowledge gained from the space program available in understandable language and at an early date.

The thought expressed by Martin Goland, President of Southwest Research Institute, in a talk before a group of aerospace medical research specialists, appears to be applicable:

"So considerable is our intellectual and material investment in space that we cannot judiciously ignore its by-products, the opportunity to transfer knowledge and capabilities from space technology to other portions of our national effort. Each one of us must act as a catalyst in this diffusion of ideas."

20 How Companies Have Turned Space Technology Into Industrial Profits

HOWARD M. GADBERRY

Assistant Director, Chemistry Division,
Midwest Research Institute

For more than a year, Midwest Research Institute has been disseminating to industry ideas derived from the Nation's space program. NASA has given the Institute the job of conducting an experimental pilot effort to speed up the commercial application of space-related technical developments.

Institute scientists have visited the technical field centers of NASA to identify space-related ideas and sort out the industrially useful ones. The reports of space research work are continually monitored. We have talked to about 4,500 Midwestern businessmen and engineers to find what ideas were of greatest value to them. Field teams have visited the plants of over 300 firms to determine how space-related ideas can be put to use.

This practical operating experience has sharply illumined many facets in the process of transferring technology between various segments of the economy. Some of our findings, a few examples of practical results, and some of the problems involved are outlined as follows.

At the beginning of our project, there may have been some question whether space-related developments could effectively be transferred to nonspace industry. The answer from our own direct experience is a resounding "Yes!". Practical, profitable transfers to general industry *are* taking place.

Our task involves translating many of NASA's scientific findings into forms which can be of direct benefit to industry, broadening the range of applications of these ideas, and reducing the time lag to practical use.

What exactly is space age technology? And what kinds of ideas have been of greatest interest to manufacturers?

We define a space-related by-product as any device, material, process, or technique which has a nonspace use, and has either resulted from or received impetus from the rocket, satellite, or aerospace effort. It can be an innovation or new discovery, or it may be an old discovery made commerically feasible because it was needed in the space program.

In the broadest sense, space technology comprises the methods used by the most advanced aerospace engineers to accomplish their jobs. The nonspace firm can strengthen its technical capabilities by employing the useful developments of NASA, the defense agencies, and their contractors.

After a year of working with businessmen and engineers, we find that four kinds of ideas are of the greatest interest and value to industry:

(1) New materials
(2) New or improved processes
(3) New product opportunities
(4) Management aids and techniques.

An important point may be indicated by examining a few cases in which space-related developments have been applied to industrial problems.

Echo skins.—Most people have probably seen Echo, our first communications satellite, passing overhead. (See fig. 20–1.) It is made of vacuum-aluminized polyester film only 0.5 thousandth of an inch thick—the strongest thin plastic available. Its uses as a packaging material should be obvious.

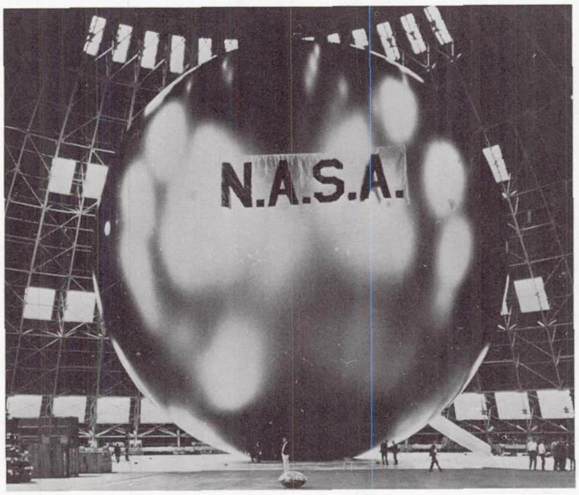

FIGURE 20–1.—Echo.

Less apparent, perhaps, is its use as a low-temperature insulation. (See fig. 20–2.). National Research Corp. of Boston, who metallized Echo film for NASA, announced that they have found this type of film to be the best insulation yet discovered for extremely low temperature use. Other companies have tried to use thin reflective foil insulation. The secret is to deliberately "crinkle" the film as it is wrapped around the vessel to be insulated, thus creating thousands of tiny cells which minimize radial heat conduction. It is important to note that National Research has patented this particular use and has licensed Standard Steel to use it on large tanks and Hoffman Laboratories to use it on laboratory Dewars.

Emergency call box.—The firm that provided the solar cells for many of our satellites has combined three separate space concepts to make possible the emergency call box (fig. 20–3) for the freeway—solar-cell power, nickel-cadmium rechargeable batteries, and digital pulse-code modulated signaling. The motorist in trouble

FIGURE 20–2.—Thin film cryogenic insulation.

FIGURE 20–3.—Emergency call box for freeway.

pushes the main button and the exact location of the box where help is needed is flashed over Citizens Band radiofrequencies to patrol headquarters.

Test installations on freeways show that the system costs far less than a telephone network, help for the motorist arrives twice as fast and traffic jams are cleared up more quickly. The investigating officer can then relay any of 14 specific messages by setting the selector on the pulse-code unit.

Polysulfide printing rolls.—Out of research to improve the casting of large solid propellant rockets, Thiokol has developed simple and economical procedures for casting poly-sulfide printing rolls which are superior ink carriers plus being tough, wear-resistant, and easily repaired if damaged. Rollers of this type have been found particularly useful for can printing and other high-speed press operation.

Printed cable.—Printed cables—flat, flexible, multiconductor wiring—first proved successful in the stringent area of missile systems. (See fig. 20–4.) Dr. Von Braun's group at Huntsville has developed the applications of printed cable to reduce the weight and improve the reliability of launch vehicles. Printed cabling weighs only one-tenth as much as conventional cables while the current-carrying capacity is twice that of equivalent size round wires. A rugged but neat installation is obtained by cementing the flexible ribbons to walls or structural members.

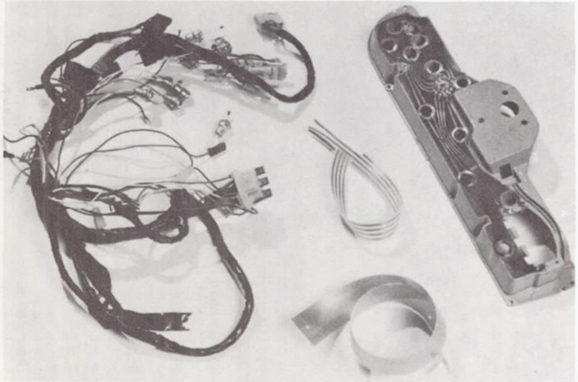

Figure 20–4.—Printed cables.

The Chicago firm of Methode is one of NASA's leading suppliers of printed cable. Last year Methode provided the printed cable dashboard wiring used on the Buick. The complex hand-laced wiring harness was replaced by flexible cable cemented onto the plastic dash insert. Note that both the wiring and the lamp sockets are provided. The savings in installation time and freedom from service trouble makes printed automotive wiring harnesses very attractive.

What is the key point in each of these cases? It is that the firms which developed these applications of space technology were themselves active participants in the aerospace program. They already had the basic concepts and technical experience. Based on their own appraisal of commercial needs, they were able to find profitable applications in the civilian economy.

This feature characterizes most of the space transfers that have taken place to date—applications have been made mainly by firms involved directly in space research.

Through the NASA Technology Utilization Program, vast resources of space-related technology will be made widely available to nonspace industry. The extent to which these new ideas benefit the industrial economy will depend upon the imagination and entrepreneurial ability of U.S. manufacturers. The nonspace applications of space technology are seldom obvious. Considerable ingenuity will be needed to take maximum advantage of these opportunities. In fact, the very words that are commonly used to describe space applications are misleading. Transfer needs to be a purposeful activity, yet the terms "fall-out", "spin-off", and "by-product" imply that the transfer of space-related ideas is somehow automatic or accidental. New ideas always need champions who are willing to risk trying to do something better.

Our experience in seven Midwestern states shows that industry is willing to try new ideas—and that NASA's technical findings provide an excellent source of useful ideas. We have also learned that very few industrial organizations can take a raw idea from a nonrelated technical source and put it to work in their business. An intermediary is needed which has both the broad scientific background on one hand and an appreciation of industrial needs and problems on the other. The industrial research institutes have worked in this intermediary position for years and are well suited to perform this activity for NASA's industrial applications program.

In the course of this work we have provided some 200 different ideas derived from aerospace sources to Midwestern industry. The response by about 600 companies (most of which are not in the aerospace business) has been most enthusiastic. Their greatest interest centered on fabrication processes, chemical sciences, materials, and management techniques. Cost reduction is of prime concern. Technically improving existing products is also attractive. The marketing of radically new products is approached with more caution.

We asked over 2,000 industrialists what kinds of ideas were most valuable to their firm. By a consistent 2:1 factor, they tell us that they are more interested in new materials and processes than in new product possibilities.

Most firms initially had little concept of how to put space technology to use. Few manufacturers identify themselves as potential users of ideas associated with the space program.

It may be helpful to look at a few of the applications that have been made by firms not primarily associated with the space program. How have these companies turned space technology into industrial profits?

Sintered Oxide Ceramics.—The new high-purity sintered oxide ceramics are usually considered in terms of their high-temperature refractory properties, which are useful for nose cones and rocket nozzle inserts. Unlike the usual brittle glassy materials, oxide ceramics are strong and tough. Figure 20–5 shows a ball of sintered aluminum oxide used as a check valve in liquid oxygen systems. Alumina was chosen for this use because it could be ground spherical at room temperature and stays that way from –450° to +1,000° F. In check valve use, it outlasts hardened steel balls five to one.

A manufacturer of miniature wire wound resistors was suffering 20 to 25 percent breakage of steatite rods in pressing on the metal end caps. With the help of NASA's Lewis Research Center, we suggested the use of sintered alumina rods. They now report that breakage has ceased to be a problem.

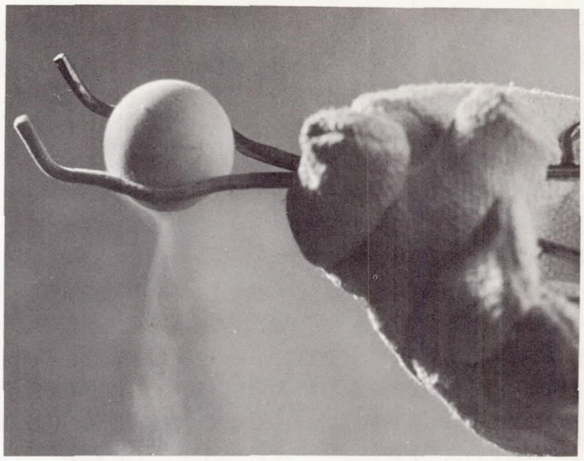

FIGURE 20–5.—Sintered alumina ball check for liquid oxygen valve—strong and spherical.

Magnetic pulse forming.—On the Saturn program at Huntsville, the use of magnetic fields to shape metal has been extensively developed. (See fig. 20–6.) The intense magnetic

FIGURE 20–6.—Magnetic fields used to shape rocket tanks.

field created when stored electrical energy is pulsed into the coil forces the metal to expand or contract against dies or against a mating work piece.

The method is particularly suited for expanding or shrinking tubes to make pressure-tight joints. (See fig. 20–7.) For swaged fittings, magnetic pulse working shrinks metal with less springback than any other method, giving a stronger, safer joint.

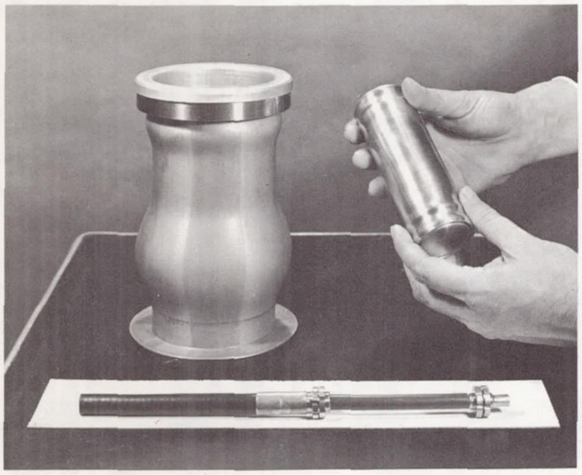

FIGURE 20–7.—Magnetically swedged tubes and cable.

A firm in Springfield, Illinois, has found magnetic swaging to be the only satisfactory way to fasten terminals and connectors onto low impedance coaxial cable without damaging the thin insulating sheath.

Air bearings.—Air bearings (fig. 20–8)—the lubrication of bearing surfaces with a thin film of gas—are used in the space program for high-speed gyroscopes, frictionless supports, inertial guidance, and stable platforms. This space impetus has made possible the design of predictable, low-cost air bearing devices. This air bearing supported platform at Huntsville is used to simulate one of the problems that will be encountered in performing mechanical repairs in space (fig. 20–9). The engineer in this slide has learned that ordinary wrenches are difficult to use in tightening a fitting—one firm twist and the nut stays still while he goes sailing away!

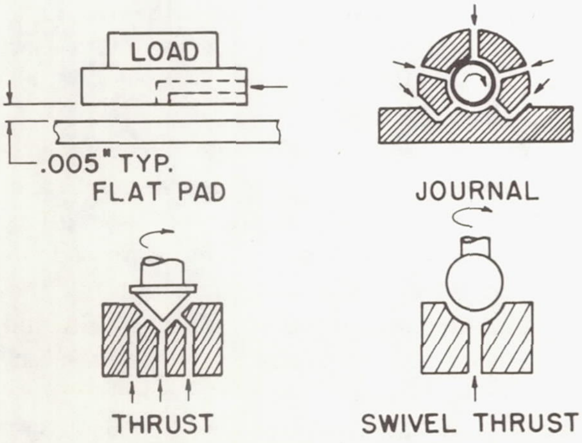

FIGURE 20–8.—Various types of air bearings.

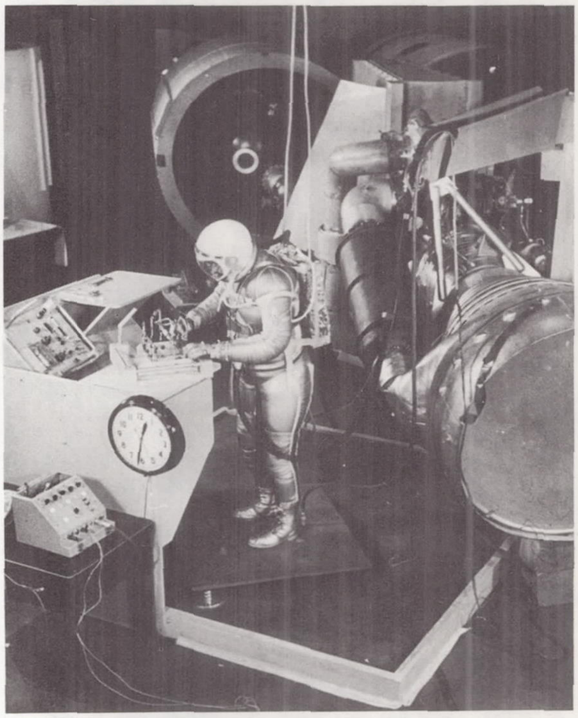

FIGURE 20–9.—Frictionless air bearing platform used to study maintenance operations in space.

There are numerous industrial applications of air bearings. One Midwest transistor manufacturer found that air bearing pads completely isolated his delicate microbalances from the vibrations of nearby machines. A Kansas firm producing heavy industrial equipment has incorporated air bearings into one of their large machines, thereby eliminating a bearing contamination problem that had plagued them for years.

Soldering reliability.—The reliability of electrical equipment depends to a large extent upon the soldered connections. To get the quality of soldering needed by NASA, a special training course in soldering has been developed. (See fig. 20–10.) The methods, standards, and visual aids developed for this highly sophisticated program can be used by manufacturers to train their key personnel and obtain reliability in electrical production. A poor soldered joint is almost impossible to inspect—the trouble is buried under the solder. Only proper training will insure trouble-free operation of a product. One of the Nation's largest oil prospecting and well logging companies obtained copies of the NASA soldering manual from Midwest Research Institute and carried on their own training program. This has virtually eliminated their previous trouble with soldered electrical connections in the field.

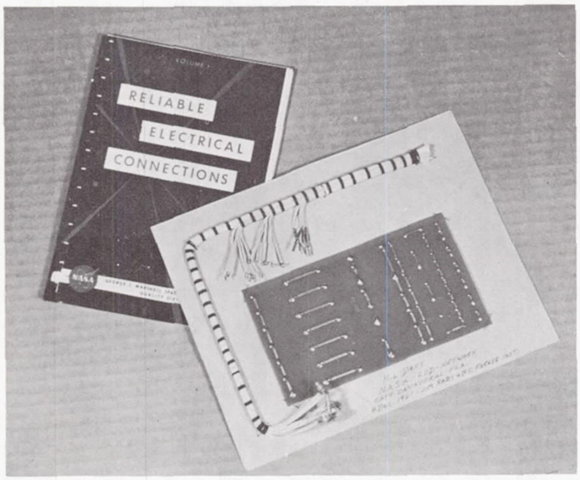

FIGURE 20–10.—Advanced training methods yield reliable soldered connections.

Refractory weld backup tape.—Welding is a major problem in the assembly of space vehicles. Much of NASA's welding technology has obvious industrial application. On the Saturn program at Huntsville, it was necessary to weld the circumference of large tanks with smooth, continuous, single-pass welds. They have found one answer in the use of refractory, pressure sensitive tape as a weld backup. (See fig. 20–11.) A Tulsa producer of heavy-walled pressure vessels finds that this innovation completely eliminates a costly manual closure weld. In addition, he now obtains smooth welds, free of scale and inclusions.

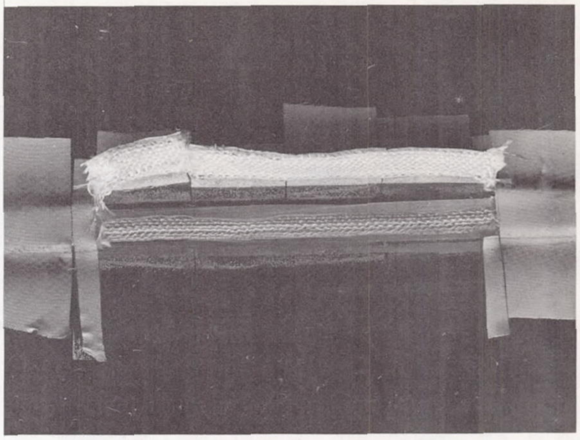

FIGURE 20–11.—Pressure sensitive refractory tape used as weld backup for smooth, uniform welds.

Pert-Cost.—In the area of program management, PERT-COST can be used to control any sequence of development events to disclose the least costly path.

PERT (Program Evaluation and Review Technique), was developed to help complete Polaris ahead of schedule. As originally developed, PERT was largely confined to complex government programs where time is of the essence and cost is secondary. Through the efforts of the Navy, NASA, and other agencies, PERT-COST has been developed to be useful in almost any special production or construction program. PERT-COST is particularly valuable in development projects. (See fig. 20–12.) John Deere and Company has tried it and found that it saved 28 percent of the costs in its development work. Deere now requires the use of PERT-COST on all developments of 200 man-hours or more.

Rogallo wing.—The Rogallo flex-wing concept developed at the Langley Research Center will be used for booster recovery or for the glide-landing of space capsules. This compact folding, lightweight wing is aerodynamically stable even at supersonic speeds. While NASA and various aircraft companies are putting the concept to sophisticated uses, the small firm of Flight Dynamics has capitalized on its use by sportsmen. (See fig. 20–13.) They offer sev-

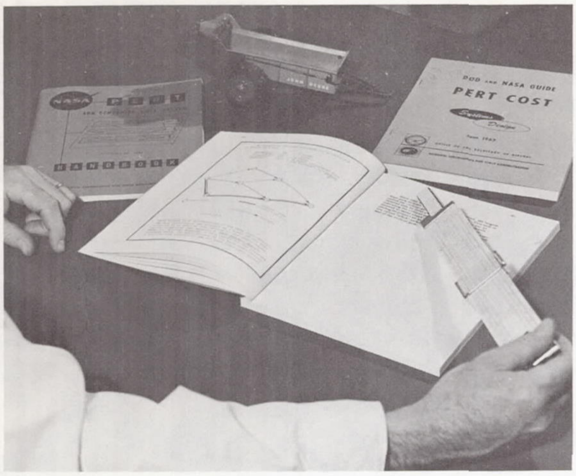

FIGURE 20–12.—PERT-COST management in new product development.

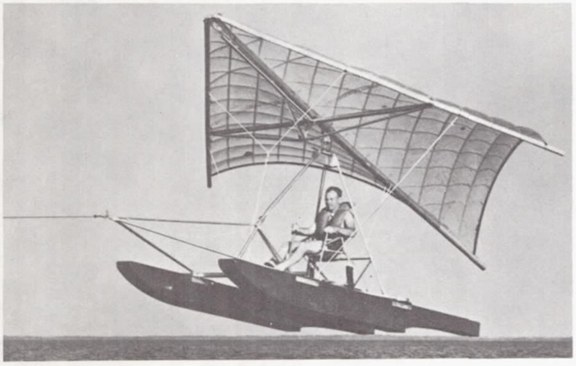

FIGURE 20–13.—Inexpensive space-age sports glider.

eral complete build-it-yourself kits. For about $150 anyone can assemble and fly this space age sports glider.

Explosive forming.—The shaping and forming of large metal parts by means of explosives is not wholly new. The aerospace industries use explosive forming as a regular tool (fig. 20–14); but the process is not common among metalworking firms.

A company in Kansas City wanted to make 20-foot-diameter dished tank heads. The management had approved the construction of a $4 million facility to make these heads by conventional means. Midwest Research Institute furnished the NASA report describing the production of 160-inch dished heads (fig. 20–15) by explosive forming and put them in touch with the men at Marshall Space Flight Center who directed this work. The company is now enthusiastically planning toward making these heads by explosive forming, since their costs estimates show that they will save nearly $2 million in capital costs by using explosive forming.

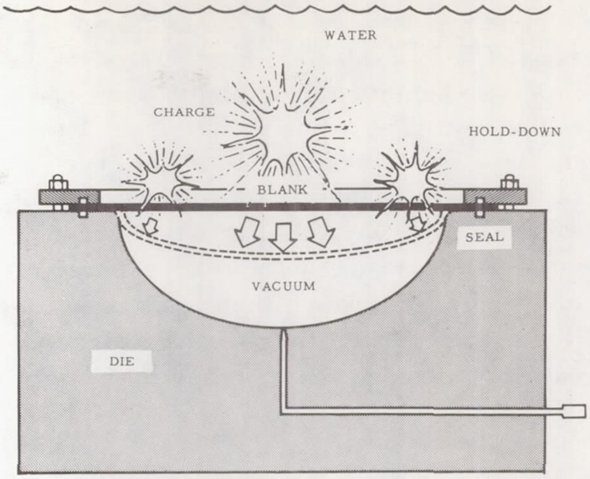

FIGURE 20–14.—Explosive-forming principles.

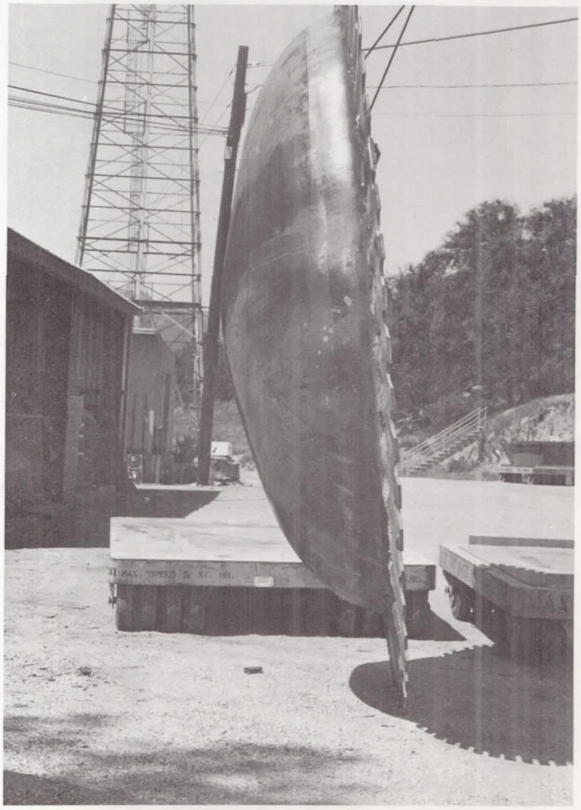

FIGURE 20–15.—Complex shapes formed in heavy metal by explosive forming.

These are but a few of the useful applications of space-related concepts. The size of a firm is no indication of its ability to use space technology. The major problem is a conceptual one—only a small number of firms are accustomed to looking at nonrelated outside sources of technological information. It takes imagination and ingenuity to see applications of new ideas. Someone with enthusiasm and authority must shoulder the responsibility of evaluating new concepts and putting them profitably to work. These attributes are found in firms of all sizes.

Making maximum economic use of our scientific potential is important enough to justify an organized, purposeful, continuing program. This effort must include three steps—to identify, to document, and to make available knowledge about innovations that have industrial significance. NASA has taken an important and forward-looking step in recognizing its responsibilities to insure widespread economic application of its research and development.

21 An Industrial Derivative From the Space Program

R. BOWLING BARNES
President, Barnes Engineering Company

This paper discusses briefly some of the efforts of a small company to create products for industry which are direct derivations of our defense and space work. Barnes Engineering Company, formerly called Olympic Development Company, was founded in January 1952, and today employs in excess of 600 people. Since its inception, it has actively participated in the defense and space programs of the Nation, including, among others, Polaris, Damp, Project Mercury, Tiros, and Mariner II. Throughout this time, and at present, approximately 90 percent of the company's sales have been made to various agencies of the government, including NASA, and its reputation in the field of research and development and as a producer of infrared systems and products is well known. These products are in widespread use today and have performed well under the rigid conditions imposed by the military services and by the unfriendly environment of space.

The successful performance of this type of R&D and the creation of a line of sophisticated instruments and products requires the combined skills and talents of many interrelated technical disciplines. These include optical design, optical engineering, electronics, mechanics, general fundamental physics, and many others, for, in most cases, the very nature of the work undertaken presents a real challenge to advance the state of the art or to achieve still another technical breakthrough. Major technological advances are made by pioneers, by those who are capable of utilizing the knowledge of the past, by those who are not satisfied with the knowledge of the present, by those who are able and anxious to challenge the future, and certainly not by those who are content to do tomorrow no more than they did yesterday.

To solve the technical problems of the future and to meet the instrument specifications which are now being imposed involves the diversified capabilities of many scientists and engineers, and requires teamwork of the highest order. Whether it be in the field of radiometry or spectrometry, of reconnaissance or tracking, of detection or communication, of space navigation or the attitude control of spacecraft, the problems themselves, as well as their solutions, have become so complex that the combined knowledge and skills of a technical team or task force are required. To use an old cliché, "success breeds success," and with the successful completion of each project more knowledge becomes available for use in tackling the problems which are still unsolved. The overall capabilities of such technical teams improve with each task completed either by itself or by any other such group with which it is free to communicate. It is to be expected, therefore, that the productivity of any scientific group will increase rapidly as the pool of technical information available to it expands and grows.

So long as our nation continues to desire a better life and a still higher standard of living, we will continue to face new technical challenges and to require new and improved products. Not only in connection with the problems of national defense and of space exploration, but also in connection with the problems of increased industrial production and of our own individual needs and desires, we will face an ever-increasing demand for improvement, inventiveness, and creativity. The end products of tomorrow will be derived from the research and development efforts of today, which, in turn, are largely based upon the totality of facts proven in the past.

How, one might ask, can a small company such as Barnes Engineering expect to build up a technical staff of sufficient strength and breadth to enable it to participate importantly in such a complicated field, and to aspire to create and produce significant industrial products for the future? There are many answers to this type of question, and, of course, no one answer will apply in all cases and situations. Our answer, I believe, is simple—we elected one highly specialized field of activity and then diversified broadly within that field. We chose to build our company as a leader in this one broad field, a field in which we have confidence, and not to scatter our financial and manpower budgets in too many unrelated or only marginly related directions. We have been fortunate in having been selected by the government agencies to undertake R&D contracts in connection with many important and vital programs. Most of these have been extremely challenging and thought-provoking, and they themselves have caused technical people of high caliber to wish to join our staff. We have carefully selected the fields of our interests and have avoided undertaking work for which we were not qualified, in regard to both personnel and facilities. We have in many instances made the transition from R&D, through the construction of a sufficient number of models and prototypes, to the hardware or product stage. Frequently, however, these transitions were made possible only as a result of our own company-sponsored research and product-development efforts. As a result of this overall approach, we have developed a highly diversified staff skilled in all phases of our chosen field of activity and backed by wealth of technical knowledge. To the extent that this "know-how" is not classified or restricted by any other limitations, it is now available for application to problems of our own choice.

The broad field of activity which our company chose was the field of infrared. Although it had been discovered as early as 1800, it was not until the late thirties that its value as an important tool for the analysis of chemicals was recognized by the major chemical companies, and gradually an infrared instrument industry began to emerge. These instruments were very largely spectrochemical in nature, and were welcomed for their ability to perform accurate qualitative and quantitative analyses of complex mixtures of industrial samples. The fact that both the time required and the amount of specimen needed for these analyses were usually very small compared with other methods gave this industrial use of infrared a tremendous boost.

During the Second World War, many uses for infrared in ground warfare became apparent and led to the creation of a new dimension in night vision and warfare. Infrared systems were ultimately perfected for surveillance, for reconnaissance, for communications, for fire control, and for night viewing. The sniperscope is familiar to almost everyone. During the next period of time, more sophisticated infrared devices emerged in keeping with the more stringent requirements of the times. Illustrations of these instruments are radiometers, trackers, thermal scanners, and heat-homing missiles, including the accurate and deadly air-to-air missile, the Sidewinder.

The advent of the Space Age brought still additional challenges to the infrared scientists and here, too, they have been able to make significant contributions in such areas as reconnaissance, space navigation, the stabilization of spacecraft by means of horizon scanners, and, more recently, the radiometric and spectrometric studies of our neighboring planets. Infrared is a fundamental science and will continue to rise to the challenges of the future.

Every object whose temperature is above absolute zero emits infrared. This fact can be illustrated with a simple experiment. If you will bring the palm of your hand close to your cheek, but not in contact with it, you will feel an immediate rise in the temperature of both your hand and your cheek. (Or you may try the experiment by bringing the palms of both hands close together.) You are in a sense detecting and measuring the infrared energy being emitted by your hand and your cheek. The results of the experiment would be the same if it were conducted in a dark room or even in a vacuum chamber. Every object emits infrared as a function of its absolute temperature—every object, if you will, behaves like a transmitter and broadcasts infrared information in a steady stream. This fact, plus the fact that we can capture this energy optically, transform it into electrical impulses, amplify and process these impulses into usable voltages and currents, and finally utilize these processed signals to perform desirable tasks, is the reason that infrared is so fundamental and has so much to offer. Its usefulness appears to be limited only by the imagination of those of us who are devoting our energies to its exploration, and at Barnes Engineering Company, infrared is our business.

It is our job to know and to be familiar with the facts about this field that have already been established and proven, and to explore the areas which are still unknown. Where the work which we are selected to do for the government leaves fundamental facts still in question, we must make every effort to fill in these gaps through the medium of our own company-sponsored research and development programs. We consider it our duty to create instruments based upon the knowledge gained through research and development, and to make these instruments available just as broadly as possible to government agencies, to other defense and space contractors, and to industry. Only in this manner can we be of maximum service to the Nation. The mere acquisition of knowledge is pointless unless this knowledge and the new truths which are established in the process are put to immediate use. We are striving to do just this through the creation of new products.

A brief description of three such industrial products, or rather groups of products, which we consider to be direct derivatives of the work that we have done in the past in connection with defense and space contracts may illustrate the point. The first of these is the Infrared Micrometer. In industry, many objects need to be measured which, for one reason or another, cannot be touched. In some cases they are too fragile to be touched; other cases they may be too far away or inaccessible, or moving too fast, or too dangerous, or too hot to touch. We were asked by one industry if we could devise a method of locating precisely the edge of a piece of red-hot metal while it was being worked. We reasoned that the edge of this hot metal would show a sharp thermal gradient against the colder surroundings of the factory, just exactly as the horizon of the warm Earth does against the cold backdrop of the sky. The situations are fundamentally the same, and the desired information was exactly the same, namely to locate a hot edge. As early as 1958, we had already proposed and constructed infrared horizon scanners for locating the Earth's horizon and providing electrical outputs which could be used in connection with the stabilization of missles and rockets. Subsequently we had constructed the horizon sensors which formed part of the stabilization system for NASA's Project Mercury spacecraft. We were able to show experimentally that the scanning systems we had developed for this purpose were exactly what was required for locating the position of the hot-metal edge. Further refinements were made, and the concept of locating two edges of a hot body simultaneously, and thereby establishing a diameter, was developed.

Red-hot steel rods emerge from the rolls of a rod mill at linear velocities which in many cases exceed 60 miles per hour. A knowledge of the diameter just as it emerges from the rolls is highly desirable, but in view of the danger involved and the motions which the rod undergoes, conventional means of micrometering cannot be employed. An infrared micrometer, however, which scans across the rod at right angles to its forward motion, can measure the diameter of the rod with an accuracy of about two-thousandths of an inch. The electrical output of the micrometer may, if desired, be recorded or used for control purposes. The scan rates used are fast, and accordingly the diameter of any given section of the moving rod is measured at frequent intervals. Such micrometers are being evaluated at a steel mill.

The gaging of hot glass tubing and rods as they are formed presents a similar problem. A somewhat different infrared scanner was required for this purpose, and it too is currently undergoing exhaustive tests. Other industrial applications for this type of noncontact dimensional gaging are expected to arise.

The second instrument to be described is the Infrared Radiation Thermometer, which is the ultimate outgrowth of a request made of us by the U.S. Navy. We were asked to deliver a hand-held instrument capable of indicating the surface temperature of the ocean when pointed towards the water from the deck or the bridge of a ship. Such a radiometric device was built, using knowledge much of which had been developed under defense contracts previously completed. Many other applications for this general type of temperature measuring instrument immediately came to our attention, and since the first model was delivered, several other versions have been completed. These have been tailored to meet the specific requirements of individual applications, and thus vary appreciably in their overall complexity and in the accuracy with which the desired temperatures can be determined. Among these instruments is the Airborne Radiation Thermometer, developed for the U.S. Navy Hydrographic Office, which records the surface temperature of the ocean to a fraction of a degree from a fast-moving patrol plane.

In industry, there are countless situations where noncontact temperature measurements are required. To satisfy certain of these needs, we have developed several Infrared Radiation Thermometers which have already found acceptance in a variety of diverse situations. To cite just a few, they have been used for measuring ocean temperatures, studying problems of stream pollution, locating hidden fires, and determining critical process temperatures in the glass, aluminum, plastics, steel, and textile industries.

One specific model, known facetiously in our company as a "mousemeter," appears to offer great promise in the fields of biophysics and medical research. A direct descendant of the original ocean-temperature radiometer already described, this thermometer is designed to record the temperature of a very small area of the skin of human beings and of animals.

A third illustration is the infrared camera, or Thermograph. Originally developed for the U.S. Army, this device scans the scene being studied, collects the self-emitted infrared radiation from each object in the scene, converts this energy into suitable electrical signals, and in turn converts these into a beam of visible light. This beam, whose brightness is caused to vary in proportion to the temperature of the object being observed at each instant, is then scanned across a photographic film in perfect synchronization with the infared scan. The result is a photograph, or thermogram, wherein hot objects appear white and cold objects appear black, from which the temperatures and temperature differences of all objects in the original scene may be determined quantitatively. Each thermogram contains 60,000 bits of temperature information and constitutes a true thermal photograph.

Originally used for mapping the thermal patterns of terrain and targets of military interest, for determining heat distributions of vehicles and installations, and for studying the effectiveness of camouflage, thermographs have more recently become generally recognized as an ideal tool for nondestructive testing. If a thermal gradient is set up across an object, the presence of certain types of subsurface flaws and imperfections will reveal themselves as temperature differences upon the surface. In the electronics field, the subject of reliability is becoming more and more important, and here again thermography has been of considerable value. Electronic systems, when under normal load, develop very distinctive thermal patterns. It is readily possible to recognize in a thermogram any undesirable deviations from a normal heat pattern which may have arisen as a result of localized overheating or underheating. These deviations may usually be traced to some one of many causes, including material failure, poor circuit design, faulty wiring, the accidental use of wrong components, or actual component failure. This valuable application of thermography was highlighted in a recent edition of *Fortune*. Still other types of nondestructive testing of current interest to NASA centers and NASA contractors include the thermal testing of spacecraft models and the study of rocket motors for locating inhomogeneities in the solid rocket propellant and faulty adhesion between the propellant and the motor shells. Each such application introduces new requirements and new parameters and, accordingly, the thermograph itself, as well as the techniques for its use, is constantly being improved.

Since all objects radiate infrared, and since the thermograph does not know or care whether it is detecting an overheated transistor on a printed circuit board or an abnormally hot area of the human body, it is only natural to consider how it can be used in biological applications. During the past year, over 1,000 thermograms of human subjects have been made, and the results so far obtained have been extremely gratifying. Thermography appears to offer a new dimension in the field of clinical thermometry and to provide a new and exciting tool for medical diagnosis.

If the proper clothing is removed and the subject allowed to remain at rest in a cool room devoid of air currents for a few minutes prior to being scanned, the resulting thermogram constitutes a quantitative thermal map of the skin. In general, the thermal contrasts which appear are the result of thermal discontinuities which lie beneath the skin, and already a high degree of correlation has been established between these contrasts and the metabolic dynamic state of the body. Bruises, contusions, fractures, infections, inflammations, and malignancies may all be recognized on the thermograms as areas of elevated skin temperature. On the other hand, necrotic tissue and areas where the blood circulation is poor or impaired, cysts, and benign inactive processes appear as areas of no temperature elevation or in some cases as areas where the skin temperature is actually lower than that of the surrounding skin. The hope that thermography, in conjunction with other diagnostic methods, including X-rays, may aid in the early detection and diagnosis of cancer definitely exists. It must be emphasized strongly at this point, however, that the thermograph itself does not detect cancer. Human skin is opaque to infrared of the wavelengths which must be used, and the thermograph therefore cannot "see through" this opaque layer. Its capability lies in its ability to present pictorially a quantitative thermal map of the body. From the limited medical infrared research so far done in Canada, in England, and in this country, it appears, however, that cancers do tend to elevate the temperature of the skin areas which lie above them. We have thermographed many such temperature elevations which have definitely been correlated with the presence of cancers which were subsequently identified at operation. What now remains to be done is to have this new technique evaluated on a broad scale, not only for the detection of cancer but also in the many other fields of medicine where it also seems to show promise.

We are proud of the role we have played in connection with defense and space programs, and look forward to the creation of still additional instruments for industry.

Panel Discussion: How to Accelerate the Application of Results of Space Research in Industry

Leader: HALDON A. LEEDY
Executive Vice President and Director,
Armour Research Foundation of Illinois Institute of Technology
EARL P. STEVENSON
LOUIS B. C. FONG
HOWARD M. GADBERRY
R. BOWLING BARNES

LEEDY: Although the papers presented in this session detail many different existing and potential applications of the results of space research, probably the most important benefits to industry and our economy from our space research program have not yet been imagined. Scientists are inclined to be a bit conservative, and perhaps it takes science-fiction writers to use vivid imagination to produce some far-out ideas. One idea which occurs to me is this: In our efforts to explore space, it is expected that within the next decade we will have a man on the Moon and will be able to bring back some samples of the crust of the Moon's surface. Hopefully, in the period following, samples of materials will be obtained from the planets Venus, Mars, and the other planets in our solar system. Most of what we know about materials is obtained by studying and analyzing and trying to synthesize and improve upon the materials that we find right here in the thin crust of the Earth's surface. As an example, it is doubtful that, if we did not find diamond existing naturally on the Earth's surface, we would have as yet been able to synthesize this extremely hard element. What are we likely to find when we examine some of the materials on the surface of the Moon or Venus or Mars, which, perhaps, were formed under greatly different conditions of temperature and pressure, and perhaps with a different atomic mixture? I think it is very likely that we will find a number of new materials totally unknown to us, with properties that we cannot even imagine from the materials which we have so far studied. Would you agree that perhaps we have not hit upon some of the most significant aspects of our space research program as far as their effects on our industrial applications are concerned? What are some of the far-out ideas which may have occurred to you?

STEVENSON: Mr. Barnes, in his paper, discussed uses of infrared. The story of infrared illustrates, in a classic fashion, time lapse. During World War II, we, in the Office of Scientific Research and Development were just becoming aware of infrared. Now, 20 years later, Mr. Barnes and others are beginning to see applications that we could not have anticipated. So my comment is that we must not be impatient in our search for applications of research. There is a certain cycle in human events, and technology is like any growing organism; it has to be fed; it has to develop naturally; growth can be forced only so fast. Also, Mr. Barnes made another significant point—that is that his company, a small company, identified itself with something in which it was greatly interested and in which it was competent. I have observed that other companies have bid in fields in which they were not particularly qualified. Even if they are successful, they do not have any urge to expand into new fields.

FONG: In the space program a considerable amount of work is being done in the field of dry lubricants and the potential for these is obvious. I think that you are familiar with the fact that graphite, which is such a good lubricant here on Earth, becomes an abrasive in space under high vacuum.

LEEDY: Any further comments?

BARNES: The greatest assets in all this space and defense work are the intangibles. The papers in this session focused on some of the more tangible results that we can point to today. The totality of all of the incidental technical knowledge that is being built up in the thousands of companies of contractors and subcontractors is enormous. If one industrial company tried to do all this alone in any one field, there would be a big lead time between conception of an idea and a marketable product. I think that this lead time can be and is being speeded up by virtue of the fact that NASA and the defense agencies are now having so many different companies share in this knowledge and build up increments of knowledge. If these increments can be put together so that an industrial company wanting to use the knowledge has it available in a form that they can use, I think this will cut down tremendously on the lead time.

STEVENSON: I think this reduction in leadtime is one of the characteristics of this new era. A good example is the laser. The principle was conceived about 14 months before the first commercial model was put on the market; normally this time lag would have been 20 years. The laser and the maser found rapid use because the defense and aerospace industries spurred the development and have provided the first market for these devices. We cannot claim that these devices were a direct by-product of space, but space has entered into the process of their technological development if in no other way than by providing a market.

LEEDY: There are a number of people who say "What good is all of this space exploration? Who cares whether we get to the Moon or to some of the planets? Don't we have enough problems right here on Earth?" The implication is that space research involves too many impractical studies. My own belief is that perhaps our space research program is too practical. For example, Dr. Stevenson mentioned in his paper that in the Apollo program and in the other manned space flight programs about 85 percent of it is strictly engineering. This implies that around 15 percent is research and development. My question is: Are we tackling space research too much by the straight brute-force method and engineering our products based on existing information? Should we be devoting more funds to long-range fundamental research to try to leapfrog some of these problems, and hence make greater progress? Mr. Fong, do you think that NASA is spending enough on long-range basic research in the space program?

FONG: I don't believe that there is an imbalance between our long-range planning technical efforts and our current engineering efforts to get to the Moon. Defining the line between the two is difficult but those familiar with the programs find, I believe, that we are not de-emphasizing the need for basic R&D to achieve our missions in space.

STEVENSON: We are underestimating the contributions of the engineer. When we say that 85 percent of the manned space flight effort is engineering this does not mean that only 15 percent of the total effort can be considered creative. Practical application is the business of the engineer. We talk too much about the scientist being responsible for the trip to the Moon. The scientist has very little to do with putting man on the Moon. It is the engineer who is going to design the systems and build the equipment. Now, the demarcation between the role of the scientist and that of the engineer is not as sharp as it used to be. There are certain individuals who can be called either engineers or scientists. It merely depends on how they happen to be looking at their problem. They are capable of looking at a problem either as a scientist or as an engineer.

GADBERRY: I think that in considering the question you must concern yourself first with what you are trying to engineer. It makes a great deal of difference whether you are carrying on the Mercury program to orbit a man or whether you are carrying on the Ranger program to land an unmanned capsule on the Moon as to whether you approach this within the state of the art or whether you attempt to use advanced technology. If you are concerned with a fast response program to orbit a man, then using the present state of the art is the safe conservative approach and that was the history of Project Mercury. On the other hand, with longer leadtime and more background to work with, Gemini and Apollo will involve many more advanced concepts. In the scientific satellite program, far-out concepts are being studied and NASA is doing a good deal of basic research.

With respect to the question of tangible as opposed to intangible benefits, I think that one of the greatest intangible benefits, but very important in the long run for the industrial community, is a new way of looking at scientific advances. There is a fundamental difference between the approach of an industrial problem-solving group and the space scientist who, very frequently, is working at the ultimate limit of his capabilities within the art as he knows it or at the limit of the capabilities of the materials at his command. The space scientist is stretching the very limits of what he can do. On the other hand, many industrial people are much more concerned with what they can afford to do this year. I believe that the interaction of these two modes of approach will have a very significant impact on industry.

LEEDY: It is now time to turn to the written questions submitted by the audience.

QUESTION: Mr. Fong, is there any space research which is applicable to agriculture?

FONG: I think that I might say there is, although it is the kind of agriculture that you will find inside a closed capsule—for example, algae production to get rid of the carbon dioxide. As far as any practical benefits to agriculture, as such, at the moment, we do not see too much in this area.

QUESTION: Are government or NASA funds available for financing development of NASA technologies into industrial products?

GADBERRY: If the end product is widely beneficial to mankind and to the public here in the United States, perhaps the government would undertake to develop a technology to the point of industrial feasibility. I think that the government cannot afford to take a product or a technique or a material which is narrowly oriented and spend public funds on its development. I think we are looking to industry's cooperation, initiative, and ingenuity to help us in this area.

STEVENSON: There is some debate in Washington at the present time as to whether the Federal Government should not be actively subsidizing this development. The Department of Commerce has discussed the idea of a plan modeled on the agricultural experiment stations so that the Federal Government could serve industry within the pattern that the Department of Agriculture has served agriculture.

QUESTION: Mr. Barnes, would you explain the term "unfriendly environment" a little further?

BARNES: When you leave the Earth you leave everything behind except what you take with you. This includes protection from all manner of radiation, from all the forces of vacuum, from cold, and so forth. It is cold and void and most unfriendly. I think that's a good word to describe space.

QUESTION: Do you believe that the profits from spin-off products and activities could successfully pay for the costs of the space projects now underway by NASA and the government?

STEVENSON: I very definitely do not, and I think that the two are not related. The conquest of space is a national goal. I think it is a reasonable aspiration for our society. It is an end in itself. No attempt should be made to try to balance this in an accounting fashion by saying that for $5 billion that we spend next year we are going to receive $5 billion worth of benefits.

Placement and Management of Research and Development Projects

Auspices: *Northwestern University*

Presiding: **J. ROSCOE MILLER**, *President,*
Northwestern University

Introduction

J. ROSCOE MILLER
President, Northwestern University

In February 1963, at the annual meeting of the Chicago Association of Commerce and Industry, I joined with other university presidents of the Chicago area in issuing an invitation to Midwest business and industrial leaders to utilize more fully our university resources in the space-related research and development programs we have in progress. Many have accepted that invitation. Participation in the Midwest Space Month is further evidence that the Midwest will soon be taking a more significant role—not only in the Nation's space race, but also, of even greater importance, in the peaceful uses of space and the potential contributions which this program can make to man here on Earth.

With the observance of Midwest Space Month, we have seen a tremendous effort through our press, television, and radio to acquaint the public with the challenges and promise of this Space Age. Our universities have presented various technical aspects of our space programs. In these sessions, we are going to discuss the practical problems of the space business.

It is not necessary to recite in detail the history of space exploration which has been short in time and almost incredible in progress. It was only 5 years ago that the Russians put Sputnik I into orbit. In those 5 years, the United States has established a National Aeronautics and Space Administration which has become our fourth largest Federal activity and is spending more money than the entire government budget of less than 30 years ago.

The three stages in the Moon-race schedule are Project Mercury, Project Gemini, and Project Apollo. Project Mercury, which is to end shortly, has been concerned only with the flight of man in a low-altitude orbit around the Earth. Project Gemini will concentrate on putting two men in larger and heavier space vehicles in low Earth orbit and will consider problems involved in joining two space vehicles in orbital flight. Project Apollo, set for 1966 to 1970, will take three men in a still larger spacecraft to the Moon for landing, reconnaissance, and return.

Meanwhile, we must not lose sight of the peaceful aspects of our space effort, the most important of which is finding the answers to some of the environmental hazards which have plagued man since the beginning of his career on this planet. For in putting man on the Moon, we are placing him in the most hostile environment he has ever encountered. We are involved in solving complex problems in biology, medicine, astrophysics, mathematics, communications, materials, and management. When we solve them, and solve them we shall, we may find ourselves living a new kind of life, one which may make our present life appear primitive. This solution, however, depends on how resourceful and energetic we are in applying to peace the discoveries made in the interest of defense.

In the Midwest, we have two industrial alternatives in obtaining economic benefits from the business of space. The first is to participate directly in the research and development activities of our space program. This is a business of more than $6 billion annually with an anticipated growth to $20 billion during the next 4 years. Currently, this money is being spent largely in the western and eastern coastal states which received over 75 percent of the defense and space research and development contracts in 1962. California alone drew 41 percent of the total. Illinois, in 16th place received nine-tenths of 1 percent. The declining position of the Midwest has now reached the point where only 2 of the top 50 prime contractors working on government experimental, development, test, and research contracts have their research facilities in this region. The following papers will outline the details of NASA operations and contract procurement, whether your interest be that of a prime contractor or that of a small subcontractor.

Despite the lateness of the hour on our space clock, there is no reason why the superb engineering and production knowledge of Chicago and the Midwest cannot get a larger share of this space development business. The essential factor in securing and making profitable such business is staff competency in research and development and in the management of such operations. The advance of technology is swiftly increasing the fund of knowledge and stimulating economic activity, but it is also creating many new problems for managers of modern industrial organizations.

As research has become a major factor in corporate growth and diversification, the size, scope, and cost of research and development organizations have increased rapidly. Even more significant than this growth in quantity is the increasingly important role of research in assuring competitive survival and in exploring opportunities for expansion into new fields. This problem of research competency is relatively easy to solve. In the Midwest, the universities are capable of providing the manpower needs through their current graduate programs and through making research facilities available on a consulting basis. All this area really needs for strong research and development staffs are the job opportunities.

A much more difficult problem, however, is that of management. The Midwest has something of an advantage in a late start in the space business for it can profit from many of the management mistakes that have been made elsewhere.

In a research organization, the source of production is the creative mentality of the individual researcher and the units of output are the ideas generated. The different professional goals and working techniques of researchers, combined with the intangible nature of research results, make the application of traditional management policies unusually difficult.

Chicago industry is well-known for its competence in mass production—but the techniques of the assembly line generally do not work well in the research laboratory. Many studies show that the research scientist and engineer, hired at a high cost to perform creative investigations, are often hampered and frustrated by management practices. In order to be successful, greater knowledge of the management needs of the professional staff is required. There are two principles which must be balanced to achieve success in this kind of business. Researchers must be free and managers must manage. These principles may appear contradictory in the management structure for mass production, but their balance is essential in the management of research and development.

Again, the universities may be of some assistance not only in providing training programs for space business managers through available courses but also because of the practical experience they already have in balancing the need for faculty-conducted research with faculty teaching.

The most significant benefit from our space effort will come in the form of new knowledge. Scientists tell us that we are currently doubling our total knowledge every 7 years and the problems of keeping up with the educational impact of this constantly increasing knowledge is one of our most pressing concerns.

The electronics industry, in particular, needs to be constantly informed of what is going on in the space program not merely because of the emphasis on miniaturization but also because of the new developments in electronics, such as biomedical engineering, which combines the special knowledge of the biologist, the medical man, and the electrical engineer to solve problems in the life sciences. Here is a new industry—medical electronics—that is just getting started and that has a tremendous potential for mankind. In solving man's biological problems in the hostile environment of space, we can already forecast important applications in the field of health.

In summary, our space efforts are too important to ignore. They will continue to absorb a growing amount of our financial, industrial, research, and educational resources and they will, within our lifetimes, affect our individual welfare and existence.

22 How NASA Selects and Manages Programs

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Associate Administrator, NASA

The purpose of this paper is to describe the placement and management of research and development projects, and in particular to discuss the manner in which NASA selects and manages its programs. Before making a decision to initiate a new project it is essential to investigate the technical feasibility of the project, its costs and proposed schedules. However, this is not sufficient since we have the capability in this country of performing many interesting experiments in space. We must provide the decision makers, and there are many in a democratic society, a yardstick by which to evaluate the overall importance of particular projects.

How do we decide whether a particular project is important? The basis for decision is: A project is important if it enhances our ability to achieve the goal of preeminence in space. What is meant by preeminence in space? Preeminence in space includes: (1) the acquisition of scientific data, (2) the development of technology, and (3) the ability to operate in space with all types of payloads. In the discussion to follow each of these elements will be described more fully. The discussion will also include a description of several specific projects already approved, some future plans, and certain management aspects of our overall program.

In the scientific area, the advent of the rocket has given us the ability to carry out scientific exploration in a manner impossible 10 years ago. The rocket allows placement of experiments and testing beyond the atmosphere—in a space laboratory. Information can be obtained on magnetic fields, radiation belts, and cloud formations; measurements can be made of the Sun and stars, measurements which are impossible through the cloudy window—the atmosphere—that surrounds the Earth. Spacecraft—eventually carrying men—can also be sent to the Moon and planets. Such missions will lead to many startling discoveries.

From the standpoint of launch vehicle technology and capability, we still are second best. We still do not have by a factor of several times the capability that the Soviet Union has had for the past 4 years. The Mercury spacecraft weighs approximately 3,000 pounds; the Soviet Vostok payload weighs some 10,000 pounds. Moreover, the Soviets have the capability of placing 15,000 pounds in orbit, a weight we cannot match at the present time. Thus, the first order of business is to develop a larger series of vehicles for placing payloads into orbit. We must also develop the equipment to be sent into orbit and the stabilization devices and power supplies and sensors necessary to the execution of scientific experiments. In addition, we must develop a viable communications system, meteorological system, and navigation system. For the future, we must develop new kinds of propulsion and new kinds of power supplies so that we will have an on-going program which builds upon the science and technology we learn over the next 5 years.

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Where flight operations are concerned, we must learn to launch on schedule; we must learn how to inject into specific orbits; we must achieve the capability necessary to enable orbital rendezvous and docking. Above all, we must learn how to develop more reliable equipment which is necessary not only for manned operations but also for economically viable communications, meteorological, and navigation systems.

If we are to be preeminent in space, we must enhance the competence of the institutions upon which the success of our whole program rests, Competence of the various agencies of the government must be improved: NASA for research and development, the Department of Defense for national security, the Department of Commerce for weather forecasting, the AEC for development of nuclear power, and so forth. The skill of industry must be brought to bear upon the technical problems of space flight and open up opportunities to use this technology for other than the space program. We must also so work with universities as to encourage the training of more scientists and engineers than we have today and to support the basic research that will be so important to us in the future. It is our feeling that the training and the research naturally blend and work well together. We want to administer NASA grants and contracts with universities so that we are building additional interdisciplinary competence on the campus, not decimating the university and pulling people away from it.

Finally, we want to be sure that not only are we preeminent in space but that we know we are preeminent in space—that our citizens truly feel that the institutions we have in this country can do the kind of job that is needed to attain superiority in space—that people in other countries feel that the United States is a country with which they want to be allied in the years ahead. We feel that developments in space have become synonymous with progress in this technological age and we must conduct our affairs with this in mind.

A brief description of some of the NASA programs may indicate the direction in which we are moving. First, the lunar program involves investigation of the Moon by means of instruments before men are landed on its surface. Figure 22–1 shows the three spacecraft which are part of our unmanned program, a program that has been underway for 2 to 3 years. The Ranger, designed for hard impact on the lunar surface, weighs approximately 450 pounds and will give us our first TV pictures of the Moon; the Surveyor Lander is designed to land gently enough on the Moon to allow TV transmissions to continue after landing and to make other measurements on the lunar surface; the Surveyor Orbitor will be able to map large swaths across the Moon and tie together the information obtained from the two landing spacecraft.

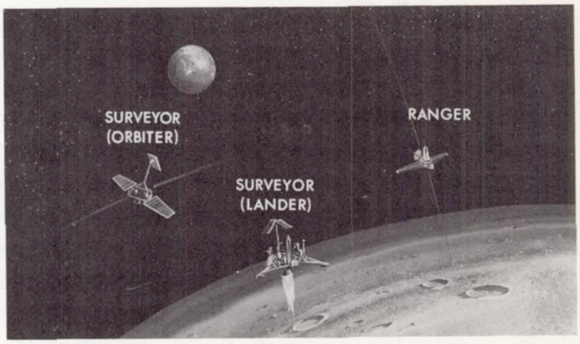

FIGURE 22–1.—Unmanned lunar spacecraft.

Why are we carrying out this program? The reason is that it has great scientific implications. The Moon has been traveling in space without an atmosphere for millions of years and has picked up samples from outer space; the analysis of these samples will be of great importance to the understanding of our solar system. A knowledge of the construction of the Moon will assist us in determining how our solar system came into being. This understanding will, in turn, give us a clue as to how our particular solar system relates to other solar systems in the universe.

These three spacecraft, Ranger and Surveyor Lander and Orbiter and the experiments they carry, were not selected casually. NASA has a working arrangement with the National Academy of Sciences. Their space science board reviews our overall scientific program from a policy standpoint and also provides membership on the particular panels that review each of the experiments proposed for space exploration. Thus, these three projects were approved following technical and scientific study of resources and manpower.

Figure 22–2 shows the NASA step-by-step program for man in space leading to manned lunar landing in this decade. How did we arrive at a decision to initiate this ambitious project or series of projects? Just 2 years ago only the Mercury project was being implemented. Projects Gemini and Apollo were not approved. We did not know at that time whether man could exist and operate a spacecraft outside the Earth's environment. However, 2 years ago Major Gagarin of the Soviet Union orbited the Earth and returned safely and our own Commander Shephard had a successful suborbital flight. A series of technical studies carried out within our own research centers and by industry on contract led to the belief that a manned lunar landing was feasible. The matter was studied by the Space Council headed by the Vice President, was reviewed with him by the Department of Defense, by NASA, by the State Department, and by the AEC, and a recommendation was made to the President that we accelerate the space program. The President, in turn, made this recommendation to the Congress on May 25, 1961, where it received unanimous endorsement. It should be made clear that this program specifies a *manned* landing. Man can contribute in many ways to the success of space exploration. He can make measurements that are difficult to make with unmanned devices. He can review and inspect and act when unexpected events occur in ways that can never be programed into automatic equipment. He can actually assist in the mission itself, in the flying of the spacecraft, in the landing, in the communications, and so forth. However, we would not send men to the Moon unless we had the unmanned program as well—for we must ascertain, from the Ranger and the Surveyor missions, conditions on the Moon in order to design the lunar excursion module itself. Unmanned spacecraft will also be used to measure radiation and magnetic fields around the Earth and to investigate solar flares. There are many scientific measurements that must be made by unmanned spacecraft before man can be sent into space to enhance our scientific exploration further.

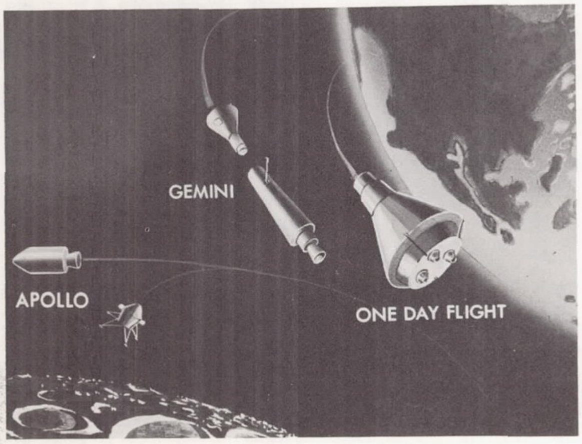

FIGURE 22–2.—Manned space flight.

Once we made the decision for the manned lunar exploration we were confronted with a wide variety of different courses that could be taken: Should the mission be accomplished by direct flight; rendezvous in Earth orbit; or rendezvous about the Moon? Again, drawing upon comprehensive data from NASA and contractor studies, it was decided that we would have a program that would provide the greatest safety, could be carried out at least cost, and could be carried out on an earlier time scale by selecting the lunar rendezvous rather than either of the other modes. However, again this was a subject that involved not only all levels within NASA but also the President's Scientific Advisory Committee, even the President himself. The decision was made to go ahead with all of the elements shown in figure 22–3—the

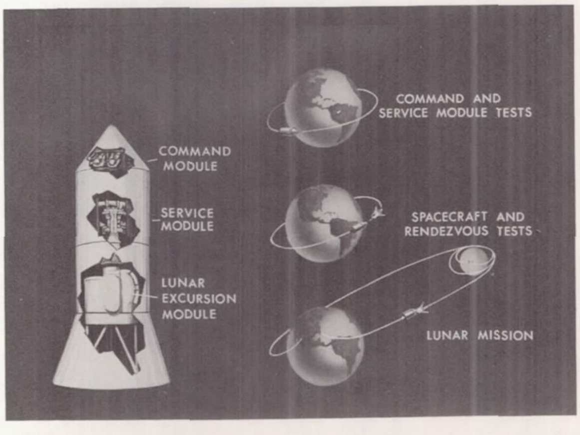

FIGURE 22–3.—Apollo spacecraft.

command module, the service module, and the lunar excursion module for the final descent to the lunar surface.

Figure 22–4 shows the launch vehicles required for the manned lunar, or Apollo mission. The Saturn I has been flown successfully four times with an active first stage. The flight test of a Saturn I with an active second stage is scheduled for late 1963. When the Saturn I becomes operational, we will be able to place some 22,000 pounds into Earth orbit in comparison with the present Soviet competence of 15,000 pounds. That capability, however, will not be sufficient for the lunar landing mission. For the lunar mission the Saturn V will be needed. It will have a weight-carrying capacity in Earth orbit of 240,000 pounds; this capacity is necessary in order to inject into lunar transfer the 90,000-pound payload required for the lunar landing. The Saturn V will represent a major step forward in our launch vehicle capability. This step, we believe, will give us the means to become truly preeminent in space. The decision to go ahead with this launch vehicle development, however, was not made without very thorough review with the Department of Defense. NASA has an agreement with the Department of Defense that neither agency will initiate development of a new launch vehicle without a thorough review and without the concurrence of the other. Thus, before initiating the Saturn V program, the concurrence of the Secretary of Defense was obtained.

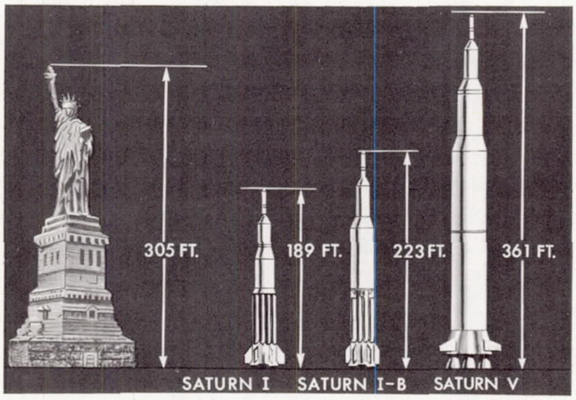

FIGURE 22–4.—Large launch vehicles.

As in the case of the vehicle developments, the decision to use Cape Canaveral (fig. 22–5) was made only after all alternatives were considered. At the request of both the Department of Defense and NASA, Dr. Kurt Debus, who is in charge of the NASA Launch Operations Center, and General Leighton Davis, Commander of the Atlantic Missile Range, reviewed, in addition to Cape Canaveral, a site off the Georgia coast; the Bahamas; Brownsville, Texas; White Sands, N.M.; Hawaii; and Christmas Island. They looked at these sites from the standpoint of logistic cost, cost of moving personnel to the particular location to perform their jobs, the problem of building up schools, and all the things needed to support a community of 30,000 to 40,000 people. In addition, they looked at the sites from the standpoint of national security. After careful evaluation, it seemed obvious that we would be better off to expand the competence already existing at Cape Canaveral rather than embark on a new large complex. We are now utilizing this launch site for all our Atlas, Titan Minuteman, and Polaris development launches. Cape Canaveral, comprising 15,000 acres of land, is to the east of the Banana River (on the right in fig. 22–5). NASA is acquiring the middle section of land, called Merritt Island, between the Indian and Banana Rivers. This section contains 85,000 acres of land—an amount required to carry out the lunar mission with opportunity for further expansion.

Figure 22–6 indicates the kind of launch complex planned for the future. At Complex 39 the total large launch vehicle with the Apollo spacecraft will be assembled, checked out, and finally taken on an Earth crawler some 2 to 3 miles to the launch pad (shown in figure) for fueling and for takeoff. It is believed that this plan will improve our scheduling and provide an ability to check out the equipment under controlled conditions before committing the vehicle to the launch pad. As a measure of the complexity of these operations, the total capital investment at Merritt Island will reach approximately $1¼ billion.

Another question which had to be answered in conjunction with this program was how we were going to build the large stages needed for

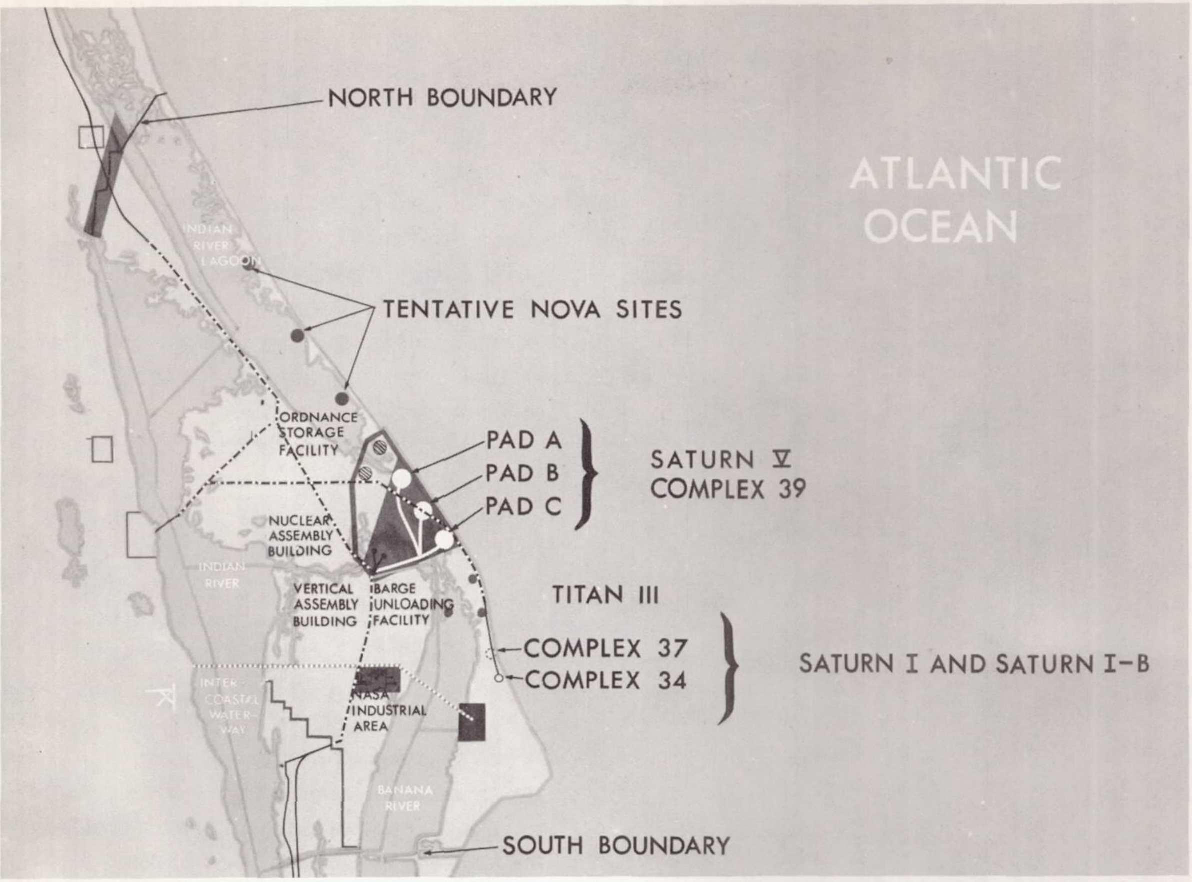

FIGURE 22-5.—Cape Canaveral.

the Saturn launch vehicles. An essential factor in deciding on the facilities to be used was that the only feasible method for transporting the stages from building site to launch site was by water. Figure 22-7 shows the site chosen—the Michoud Plant just outside New Orleans where under one roof there are over 40 acres of plant space, with 40-foot clearance throughout, all air conditioned, and accessible to ocean-going vessels. At this plant, NASA contractors will develop, fabricate, and assemble the large Saturn stages for NASA. The stages will then be taken by intercoastal waterway to the Mississippi Test Facility, shown in figure 22-8, some 50 miles away. At this facility the stages will be static fired and checked out before going to Cape Canaveral. Both Michoud and the Mississippi Test Facility are government owned facilities which will be used by contractors to carry out their development responsibilities.

For manned space flight, figure 22-9 gives an indication of the total activities involved in attaining U.S. preeminence in space. The Marshall Space Flight Center at Huntsville, Alabama, directed by Dr. Wernher Von Braun, is charged with managing the development of the Saturn launch vehicle. The Manned Spacecraft Center at Houston, Texas, is responsible for management of the development of the Apollo capsule, service module, and lunar excursion module (as well as the Mercury and Gemini projects), and for carrying out astronaut training and actual flight operations. A program office in Washington, the Office of Manned Space Flight, provides the focal point for all these activities. Attached to this office are two groups of support contractors: Bellcomm for systems studies, and General Electric for integration studies, reliability studies, and development of the automatic checkout system.

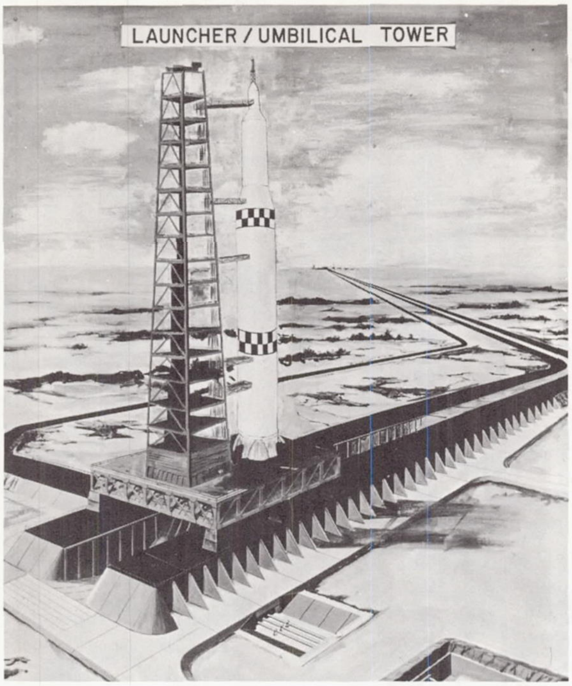

FIGURE 22-6.—Vertical Launch Complex 39.

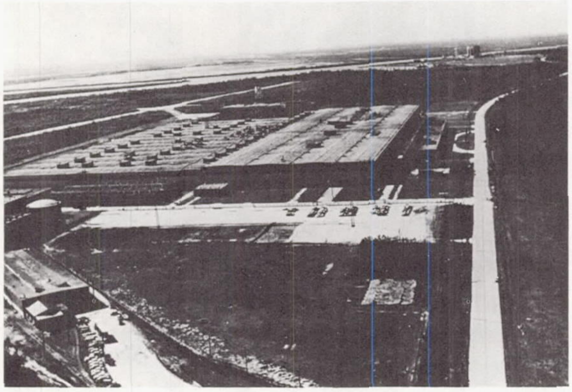

FIGURE 22-7.—Michoud plant.

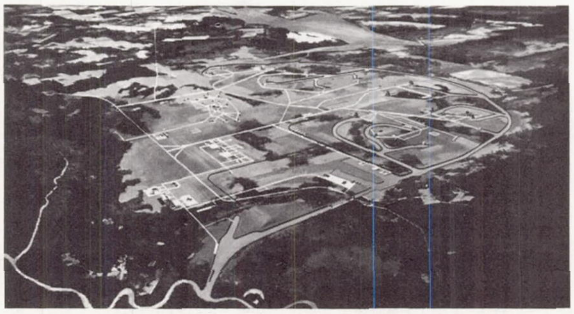

FIGURE 22-8.—Mississippi Test Site.

The dynamic nature of the space program is indicated in figure 22–10. Two approaches are used in the continuous process of reviewing future possibilities. "Paper" studies of a variety of alternatives are made. Some systems now being investigated are (fig. 22–10): larger launch vehicles in the Saturn V class; a manned orbiting laboratory that will continue in orbit for long periods of time with resupply capability; a lunar logistic vehicle that would permit astronauts to have a longer stay time on the Moon by taking supplies to the lunar surface prior to a manned landing; an advanced unmanned planetary spacecraft for placing payloads either in orbit around the planets or on the surface of the planets and for relaying information back by radio; a synchronous-orbit meteorological satellite which would appear to remain stationary as it turns around the Earth each 24 hours and which would have the video capability to scan a large portion of the Earth or to focus with sharper detail on a possible typhoon or hurricane; methods for improving our world tracking and data acquisition. These studies are being carried on at the same time that studies of the technical feasibility of new elements to use in these systems are being made (fig. 22–11). The two approaches must be made simultaneously. We must have the conceptual studies, and we also must conduct research in the laboratory. New kinds of propulsion for these missions and new kinds of space power must be investigated. We must, using wind tunnels and various other ground facilities, investigate new ways of reentering from Earth orbit, from the Moon, and from the planets. We must investigate a variety of electronic devices for stabilization and for instrumentation. We must investigate ways of integrating man with spacecraft. We also must investigate ways of improving our capability to fly in the atmosphere.

NASA is organized to attack the various problems as shown in figure 22–12. We have five program offices: the Office of Manned Space Flight whose responsibilities have been mentioned; the Office of Space Sciences that interfaces with the scientific community and also is responsible for all our unmanned missions; the Office of Applications, responsible for developing the technology for meteorological satellites, communications satellites, navigation satellites, and so forth; the Office of Advanced Research and Technology, concerned with research leading to future aerospace systems; the Office of Tracking and Data Acquisition, responsible for tracking stations around the world.

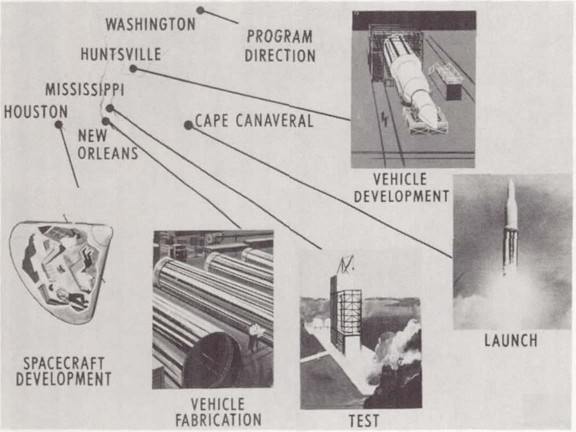

FIGURE 22-9.—Major activities, manned space flight.

FIGURE 22-10.—Future systems studies.

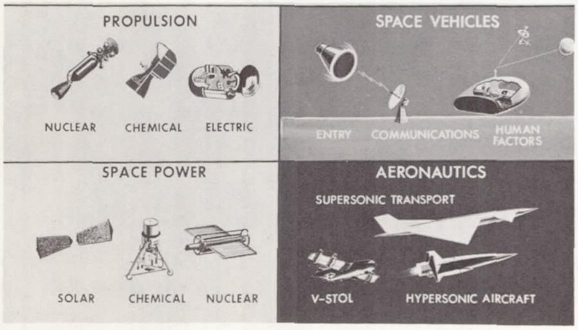

FIGURE 22-11.—Advanced research and technology.

Figure 22-13 shows the overall NASA operating organization. The five program offices report to the general management as do the various field centers. Under this concept the Headquarters program directors, are responsible for both staff and line functions. A program director has a dual role in which he both advises and operates. He is the principal advisor to NASA's general management in regard to his assigned program area. He is also the principal Headquarters operating official in regard to management of his assigned program. He manages this program by working directly with the center directors and their project managers. In addition to handling such matters as budget and programing of funds and establishing and issuing technical guidelines, each program director is also responsible for providing continuing leadership in external and interagency relationships related to an assigned program.

Under the management reorganization which NASA initiated in November 1961, the directors of NASA's research and development centers report directly to NASA general management rather than to a particular program director as was previously the case. This change was made in recognition of the fact that most of the NASA centers are, in effect, multipurpose in scope although each has a prime orientation; for example, the Marshall Center is responsible for the development of large launch vehicles. Most have broad capabilities, which is thought

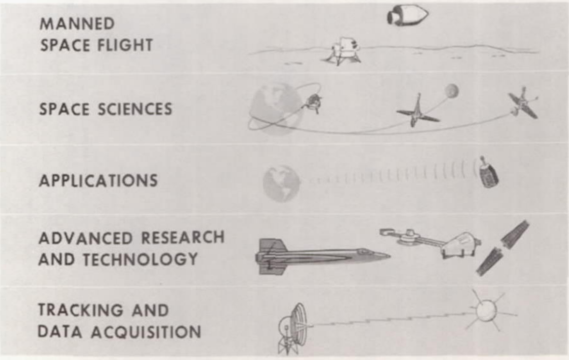

FIGURE 22-12.—NASA programs.

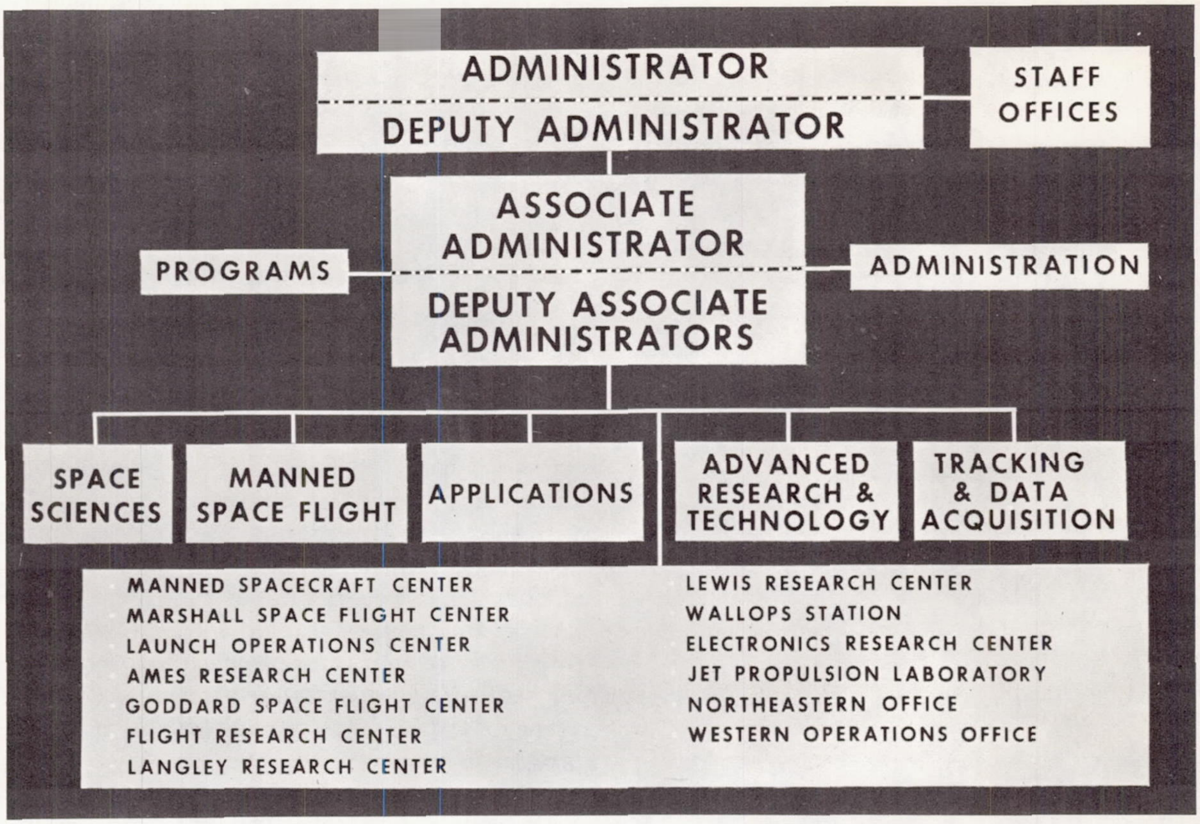

FIGURE 22-13.—NASA operating organization.

to be important in maintaining flexibility in our operations and obtaining better feedback from our flight missions into advanced research and technology, and vice versa.

Following the reorganization, we have taken steps to improve and strengthen the staff services available to general management. The primary purpose for this is to provide general management with more accurate, complete, and timely information on which to base program policies and decisions—particularly in terms of insuring that the interrelationships among the five basic programs are continually being properly adjusted. These staff services are provided by the Office of Programs and the Office of Administration. These offices hold the responsibility for providing staff services to all three members of general management and to the Headquarters program directors. This approach helps to minimize the size of Headquarters staff services and at the same time permits better integration of these services throughout NASA.

A few general remarks may be made in summary. In working with the Nation's industrial community, it is our responsibility to find more effective methods of selecting research and development contractors—better ways of evaluating their performance and providing economic incentives based upon performance. In carrying out this responsibility, we must have not only the managerial but the technical competence to coordinate wisely the efforts of our contractors. In order to obtain and achieve such technical competence, it is necessary that we produce in-house at least some portion of the basic research and design effort on our space projects. Responsibility for coordinating and directing the planning of each project lies in our program offices. A project plan, including procurement aspects, is prepared for each proposed project. Each project is approved by

NASA's general management and, following this approval, the cognizant center director is made responsible for the conduct of the proposal activity, for the negotiation of a contract with the contractor, for the technical and business administration of the contract, and for the signoff for the agency when the contract is completed. For every procurement of $1 million or more, a source evaluation board is appointed to evaluate all companies participating in the procurement competition. This board reports to the director of the cognizant center if a contract is for less than $5 million. In those cases calling for obligations of $5 million or more, the Administrator and his top staff must approve the contract. It might be well to emphasize that this a source evaluation board, not a source selection board. Depending on the size of the contract, the final responsibility for selection of the contractor must rest on either the director of the responsible center or the NASA Administrator, Mr. Webb. The NASA system of decentralized procurement sometimes presents a problem to our contractors, particularly the subcontractors who are anxious to get business and who sometimes experience difficulty in discovering the exact locus of the procurement decision in time to present their case properly. For those who have encountered this problem, the only reply is that we do our very best to avoid this situation. However, we feel it imperative to avoid becoming a large, overcentralized, and slow-moving agency.

It is our policy at NASA to give small business every possible chance to participate in the procurement opportunities of the space program. NASA's missions logically call at times for large prime contracts; however, even then we make certain that prime contractors and their subcontractors carry out contracts in a way that treats small business fairly. On January 1, 1963, under agreement with the Bureau of the Budget, NASA inaugurated a system under which 12 prime contractors and their first-tier subcontractors are asked to send NASA Headquarters information on each subcontractor.

One item on this information system indicates orders placed with small business. This will keep us more informed on how small business fares in the space program early enough so we may introduce management action if necessary. Also, and importantly, we are including a clause in each of our major contracts requiring the contractor and his subcontractors to report patentable innovations to us, and also to report nonpatentable innovations which flow from the expenditure of government funds. We believe that we have a responsibility to make certain that all industry, whether space oriented or not, has the opportunity to utilize these nonpatentable innovations when they arise from government financed work. The development of this type of innovation is an important by-product of the space program which we must see fanned out generally to industry for future use.

Much remains to be done in selection and management of NASA programs. More persistent attention and imaginative effort are called for than has been required thus far. President Kennedy has said that when the first American astronauts reach the Moon late in this decade it will not be just one or two Americans making the historic landing, but all Americans, for we must all work together to put them there and bring them safely home again. With continuation of the work which has been done so far and with as much determination in the future as has been evidenced to this point, we shall succeed in our efforts to become the world's leading space-faring nation.

23 The Prime Contractor's Role in the National Space Program

JOHN LELAND ATWOOD
Chairman of the Board and President,
North American Aviation, Inc.

North American Aviation, Inc., has participated in the national space program since it was awarded the contract for development of the X–15 aerospace vehicle in 1955. Since 1955 our rocket engines have launched nearly all of the satellites and space probes; we are developing and building the second-stage vehicle and the engines for all three stages of the advanced Saturn space system, which will send the Apollo spacecraft to the Moon, and we are developing and building this spacecraft as well. We are also exploring future space efforts through research in advanced modes of propulsion for deep space travel, and life-support requirements on long flights to one or more planets.

Although we are thus equipped by experience to offer some pertinent observations about space activity, I would be the first to acknowledge that an aerospace company's work in this field is significant only in terms of the United States space program. Our civilian space work is under contract with the National Aeronautics and Space Administration, which monitors the progress of our work through reports, briefings, and on-site representatives.

Despite this close surveillance on the part of NASA, the contractors are not simply manufacturers of products to customer specifications. NASA provides prospective bidders with a kind of multidimensional envelope of requirements, such as weight, payload, length of time for the mission, and so forth. Within this envelope the contractors competing for the program will design a system, present a plan for developing it over a period of time, and provide cost estimates. Once the contract is awarded there begins a continuing technical coordination between NASA, the contractor, and the subcontractors in creating the system. This coordination continues throughout the course of the program. The contractor proposes improvements to the design on the basis of knowledge gained during the development period. In short, through its technical capability and day-to-day familiarity with the program, the contractor must be a vital creative force.

It is obvious from the foregoing that the contractor maintains a close working relationship with NASA personnel and carries an obligation to them and to NASA as an institution for the efficient performance of its responsibilities. This includes, of course, not only achieving the technical goals set forth in the original NASA requirements, but doing so within the time schedule and the cost limitations agreed upon insofar as humanly possible.

It may be pertinent to discuss some of the requirements for participation in the national space program.

Although space standards are necessarily exacting, there is really nothing mysterious in space development efforts. Because this is an unfamiliar medium, there is a tendency to think that it must be reached by some arcane avenue known only to a relative few. The exact opposite is the case. Precisely because space represents a wholly new environment, it requires new knowledge in almost every scientific field. It is hardly an exaggeration to say that there are as many avenues to space work as there are scientific and technical disciplines.

To cite North American's own experience, up to the end of World War II most of our professional employees were mechanical engineers. Today they have degrees representing more than 175 different college majors. Some of these appear to be far removed from our normal lines of activity—such as, bacteriology, geophysics, medicine, microbiology, and psychology; but be assured that these fields are basic to the national space program. The fact is that space activity offers even more avenues of entry than defense contracting. It is not exclusive in nature but inclusive.

What, then, is the key requirement for successful participation in space work? It is the ability to contribute original solutions to new problems. Because the space environment is so foreign to our previous experience, not only the answers but the questions are new. Who would have thought, a few years ago, that vehicles could be propelled by motive power from electrical discharge? Yet in the medium of outer space, very small thrust engines operating on this principle will be able to guide vehicles traveling at interplanetary speed over extremely long distances. Several modes of electrical propulsion—ion engines, plasmajets, magnetohydrodynamics, to name but three—have been opened up for intensive study through this original approach to the problem of long-distance space power.

To provide these unheard-of questions with imaginative answers, private industry needs to adopt a rather unaccustomed frame of mind. In the world of commercial business there is at least some opportunity to influence the market by advertising and promoting a new product. But in space work the customer's needs are dictated by the mission. One must become a far more sensitive student of the customer's requirements, for these determine absolutely what sort of services one many provide.

For any community interested in space work, attention to the needs of the customer is not alone the responsibility of industry, but also of the educational and financial institutions and other elements of society. We are not considering here the kind of work begun by simply retooling and hiring large bodies of skilled labor. We are considering work that presupposes a high level of professional training among the personnel and the existence of advanced facilities and equipment. These are assets requiring an appreciation and understanding by the community not just by the companies that might be involved and this, in turn, requires some long-term preparation. If you do not have the caliber of personnel and facilities at your command when a specific opportunity shows itself, it is already too late to take advantage of it.

To press this point further, a company must recognize that it is not equipped for space work simply by virtue of manufacturing capacity. The ability to produce hardware is, of course, essential to a prime contractor and to a space supplier at any level. The company must not only do some manufacturing itself but must have experience in this work to give effective direction to subcontractors. However, space work does not involve large-scale production. Even more than modern-day defense contracting, it is custom manufacture. Each program generally requires a fresh engineering approach and often new scientific knowledge. Research and development therefore represent the biggest part of space work. This program in turn, requires a much higher level of employee training, more flexible and imaginative management, and more informed corporate planning in order to make the best use of the firm's resources.

Although this program presents a greater administrative challenge, it has a certain advantage to the new company or community entering the field. No one region has a monopoly on the raw materials required. The basic resource needed for space work is not metal or fuel but knowledge. This commodity is easily transportable and knows no geographic boundaries. It is not too much to say that any American community with an appreciation of the educational requirements involved can participate in space work.

Let us approach some of these points in more detail by considering space activity from the standpoint of the prime contractor. What does he need to compete successfully for a new program and then to carry it out to the satisfaction of the government and the Nation? The answer to this question will tell us a great deal not only about the prime contractor's business but also about the business of his subcontractors and suppliers and of a large part of the community.

First, the prime contractor needs highly trained and talented professional people. He acquires these in two ways—by hiring them, and by training his own. For a long time North American has hired a new crop of top-rated graduating engineers every year. Even in periods of dropping overall employment, this annual acquisition of young engineering talent does not drop substantially. We want to assure that regardless of short-term conditions we will always maintain the company's technical capability. In addition, we also take on many employees with graduate degrees, principally to perform research work at various levels of application in physics, chemistry, mathematics, metallurgy, the life sciences, and other fields. Among North American's 36,000 salaried and advanced technical people, there are more than 18,000 degrees, including 2,440 master's degrees and 427 doctorates.

To help provide this level of trained personnel, industry itself bears a clear responsibility. I am sure that North American's educational programs, including scholarships for students, direct financial support of specialized courses, and general grants to colleges and universities, are typical of the industry.

At the same time the community itself, since it is concerned with its own economic well-being, needs to have an appreciation of the problem and a willingness to act. This responsibility touches all elements of the community—the educational institutions, the state and local governments, and the taxpayers. In this category the Midwest, with some excellent universities, is second to no section of the country.

The other source of higher personnel skills is the contractor's own employees. North American, for one, has adopted several programs to improve the education or training of existing employees. The oldest and most comprehensive of these is the Educational Reimbursement Program, in which employees are compensated for two-thirds of the costs in taking courses designed to increase their skills. In 1962, more than 10,000 courses were completed by more than 7,000 applicants. We have recently instituted two additional education programs for graduate work, in which full tuition and, in a number of cases, living expenses are given to candidates for advanced degrees. Although these programs are just getting under way, they are already covering 350 persons working on master's degrees and nearly 90 on doctorates.

Nor is this upgrading of personnel confined to supervisory and technical people. Many of those in North American's Educational Reimbursement Program are hourly employees. In addition, we have conducted for a number of years a program to train blue-collar workers for higher positions. In 1961, nearly 24,000 employees were taking training under this program.

In short, companies engaged in space work need personnel of improved training, and it goes without saying that the same level of skills must be maintained at all subcontract levels. Achieving these educational levels is a problem for both the companies and the community.

A second requirement is executive talent experienced in managing research and development programs. Completion of a major space program is not only a question of scientific and engineering skill but also of managerial skill. An effort involving almost the whole range of technologies and thousands of suppliers at different levels of responsibility naturally calls for unusual coordination. Supervising the simultaneous design and development work being performed by many subcontractors, each responsible for a subsystem or component that must be integrated with those of other subcontractors, requires teamwork and communications of the highest order. To complicate the problem still further, all effort must be made within tight schedule and cost limits. These three factors—technical achievement, schedule, and cost—continually demand difficult decisions. Many times a gain in one area necessarily means a loss in another. Thus, a high degree of managerial judgment is constantly required in order to develop a product that keeps faith with all of the original requirements.

Managers capable of making these decisions and ordering these programs are essential to the successful space contractor. While such managers must be technically trained, the role is difficult for the professional man who has been schooled in engineering analysis. Hard facts are supposed to be the tools of his trade; but, as a program manager, he finds himself marshaling pieces of preliminary information, juggling several problems at once, compromising one requirement in favor of another, making decisions that are often based on a broad fund of experience and judgment rather than on specific knowledge.

The successful space contractor must devote conscious effort to seeking out and developing managers who can meet these many-sided requirements. Failure in this quest can result in serious cost overruns, drastic schedule slippages, and other mishaps that reflect on the contractor's reliability.

A third need of the prime contractor is for new facilities and equipment to match the technical scope of space programs. This, in turn, requires capital expenditure. Insofar as North American is concerned, such expenditures increased from less than $6 million in 1953 to an estimated $43 million in 1963. In fact, during the 4 years from 1959 to 1962 the company's capital expenditures were greater than in all its prior years.

For many companies, such funds must be borrowed. This fact often means that lending institutions must have confidence not only in the financial stability of the borrowing company but also in the economic purpose of the facilities to be built. This is no real problem when one is constructing a factory to turn out products for a sure market. But in the case of research laboratories whose main function is to sharpen the company's scientific skills for the future, an appreciation does not come so easily. The financial community, no less than the space contractor, needs to have a thorough understanding of the nature of space work, of the high engineering content of the products, and of the long-term requirement for research. Again, the active participation of bankers in this space age conference demonstrates that Chicago's financial leadership is determined to strengthen its ties with the space business.

A fourth and equally important need is for trustworthy subcontractors and suppliers. It may not be generally realized that in large programs such as the Apollo and the XB-70, a great part of the work is subcontracted. In the current XB-70 program, North American has 15 first-tier subcontractors, about 1,800 second-tier subcontratcors in 36 states, and approximately 12,000 suppliers at all levels. In North American's share of the Apollo program, there are 19 first-tier subcontractors, several thousand second-tier subcontractors in 40 states, and a total number of suppliers that is expected to exceed 20,000. Most of the companies in both programs are in the small business category, and have less than 500 employees.

These subcontractors and suppliers are not chosen simply on the strength of their own salesmanship. They are measured against the criteria for space contractors that have been discussed herein. The prime contractor endeavors to be every bit as conscientious in his selection of subcontractors as the government was in selecting the prime, and these same criteria are enforced in all levels of the program. Although the exact sequence may vary, the source selection process is roughly as follows:

(1) Deciding which items to make ourselves and which ones to procure from a subcontractor or supplier. In general, our policy is to procure as much as possible from other sources unless an item is one of our specialties or unless it could not be satisfactorily procured elsewhere at reasonable cost. On a very large program such as the XB-70 or Apollo, we will even subcontract some of the structural surfaces

(2) Making up a list of qualified bidders for each subsystem and major assembly, after exhaustive investigation of their technical, managerial, and financial strength, and their past record of program performance. This investi-

gation includes inspections of plant facilities throughout the country

(3) Holding bidders' conferences for each subsystem, in which the technical and schedule requirements are explained to enable bidders to make realistic proposals

(4) Considering the proposals made on each of the subsystems from the standpoint of cost, design, managerial plan, and technical grasp of the requirements

(5) Selecting the subcontractors, with the concurrence of NASA or the appropriate customer, and negotiating the contracts.

Of all these criteria, the most important one at any level of participation is the ability to offer original answers to difficult technical questions. Sometimes the very feasibility of a weapon system or space system springs from a key development by one subcontractor. At still other contracting levels there are sometimes requirements that only one supplier can fulfill.

In the fuel cell used for auxiliary power in the Apollo spacecraft, there is a need for metal foil 0.004-inch thick. This foil must be welded at the edges, and the ability to weld it is practically unique with one second-tier subcontractor. Because of such a specialized capability, this particular company participates not only in the Apollo program, but in some 14 missile and rocket programs and 24 satellite and spacecraft programs.

In the beacon antenna of the spacecraft, there is a requirement for very small electronic circuits printed on a surface in geometric shapes. There is only one firm capable of supplying the type of printing needed and, of course, this firm received the contract.

It is significant that such indispensability is not confined to large organizations. Both of the companies cited are in the category of small business; one has about 300 employees and the other about 50.

One of the most important factors in such technical superiority is reliability. In many space programs—certainly in the Apollo program—we are dealing with vehicles that must perform as planned the first time they are used and in an environment that may be largely outside our previous experience. They are carrying human beings whose value, in our society, is infinite. Every element in the system—from major assemblies to the smallest part—must be counted on to function absolutely as intended.

Such requirements have given an entirely new definition to reliability. We have, in effect, refined the measure of reliability from a question of judgment, which is subject to human error, to a question of mathematics. We have adopted reliability standards and procedures for ourselves and our suppliers that require a major administrative effort to enforce. Quality-control personnel work with the manufacturing personnel to assure that conditions and standards are met at each step of the way. After they are manufactured, some components are tested and retested so many times that it costs more to inspect them than to build them.

The task of achieving and maintaining such reliability standards throughout a subcontract structure involving thousands of companies is immense. We very naturally seek out those companies that can exhibit procedures and facilities for such reliability or those who have a record of achieving high reliability on other programs and a willingness to adopt the standards that we demand.

I wish to emphasize that participation in space work is not through some secret formula but through the same qualities of dedication and application that make for excellence in any endeavor. There is a tendency among many to believe that because space programs are so massive and are sponsored by the government, there is no place for the newcomer. On the contrary, new companies are continually entering the defense and space business. North American has in the past gone out of its way to encourage a reliable firm to go into some field that we believe needs a higher grade of competition. We have also made it a point to upgrade the products of suppliers by sponsoring quality control or reliability programs, technical conferences, and other services.

In brief, there is not only room but also a continual need for reliable and creative suppliers at every level—suppliers who can make something better than others and who can be counted on to do what they say they will do.

In fact, you will notice that all of the needs of the prime contractor that have been cited apply as well to the other tiers of activity in space programs. Most of them are within the control of the contractor himself. Some others can be enhanced with support from the community. Most important, both contractor and community should be aware that admission to space work is not won by some mysterious process or gimmick but by genuine ability. Whether at the prime or subcontractor level, the space participant must be concerned, not with appearances, but with substance. Scientific and technical proficiency, financial strength, organizational efficiency, business integrity—these are the qualifications for space work. To achieve these qualities, the contractor must approach the national space effort not so much in terms of a body of business open for competition but in terms of what the contractor can genuinely contribute to its success.

24 The Role of the Subcontractor

CHARLES L. DAVIS

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Minneapolis-Honeywell Regulator Company

The question is often asked in today's business world, "How do you get into the space business?" Businessmen who are not part of the national space effort wonder whether the space business is different from commercial and industrial activity. They wonder whether there is a place in space for their company. It is only natural for businesses throughout the country to want to share in the new, large market that space has opened up. Since only a few, very large companies fit the role of prime contractor, there is broad industry interest in the role of the subcontractor.

A contractor, by definition, is one who contracts to perform work or to supply articles at a certain price or rate. In this space age, however, there is no single contractor, no Government agency, that has all the capabilities necessary to handle alone a major space project such as Apollo. We are a nation of specialists who will overcome the problems and complexities of space travel by working together and pooling and applying our skills in concert to accomplish the space mission. Why is it, then, that some companies have found an important and continuing role as a space contractor while others with apparently similar skills fail to qualify as space-age contractors? There are certainly great needs. We need better sensors; better computers; better metal alloys; better sources of power; better knowledge of extreme heat, cold, vacuum, and pressure; better solutions and communications; better navigation, and so forth.

These problems, and thousands more, require solutions—and the key and common denominator in the space business is the capability to find new and better solutions to space problems and requirements through advanced technology and management of scientific resources.

The subcontractor's role is not simply the production of known parts and devices on schedule; it is, rather, having the capability to use specialized knowledge and inventiveness toward the solution of a problem, and then creating new designs of hardware to perform a special function in an extreme and unusual environment. This holds true whether a subcontractor supplies components, simple apparatus, complex subsystems, complete systems, or pure knowledge. To illustrate this point, two hypothetical companies will be described. Company A makes bolts; its catalogs list thousands of different kinds of bolts. The company thinks of itself as a bolt maker. As far as a role in space is concerned, the outlook of the company officers is that they wish some of their bolts could be used in space vehicles. They cannot answer how. Company B also makes bolts and in many respects is outwardly like Company A, but there is a big difference. Company B thinks of itself as an expert in the technology of fastening things together. It is continuing research in the use of clips, rivets, resins, and welding as a means of fastening. The attitude of Company B toward space is that it has the capability to understand a requirement and its mechanization so that the resulting peculiar fastening problems can be understood and be validly and flexibly solved. There is no doubt that a company like "B" will eventually become active in space work, while Company A will not and will probably wonder why.

Minneapolis-Honeywell is also a good illustration of this point. It is a world leader in automatic heating controls. The achievement of this position was not because of its first invention of a furnace control or the fact that it is the largest manufacturer of thermostats; its leadership is the result of the application of advanced technology to the design of controls that will give the human being the greatest comfort. Thus, research begins with the determination of what constitutes comfort for a normal human being and what are the problems of maintaining a comfortable, trouble-free environment.

The lesson we have learned is this: Successful fulfillment of a subcontractor's role requires an understanding of advanced technology and dedication to solving the problems and requirements of this technology, rather than simply manufacturing and selling hardware. Project Apollo is a prime example of how this philosophy works for Honeywell. We are developing a flight control and stabilization system for the Apollo command module under contract to North American Aviation. Since no one has ever traveled to the moon before, you can appreciate the unknowns and the problems that require solution within certain broad guidelines while working continually, side by side, with the technical people at North American. It is our responsibility to find the best solution for producing equipment to do the job within the allotted time. Producing the equipment is the final step and, in a sense, one of the easier ones. More difficult is determining what should be produced. There is, for instance, the fact that human astronauts are an integral part of the control system; therefore, we need to know a great deal about this human component.

We are already aware that he represents the most compact, high-powered, precision computer-actuator ever developed. But how do we get the most out of him? What displays are necessary on the control panel? What color should they be and how large? Shall we operate them with knobs, switches, or buttons?

We need to find out how far he can reach, how much endurance he has, and what jobs he can do better than machinery. We also need to know whether our control system components will affect the atmosphere he has to breathe or whether it's the other way around.

This opens still another avenue of research—the materials our system should be constructed from. Some adhesives and plastics give off noxious gases in the Apollo command module atmosphere, and these must be found and discarded.

It is not at all the way it used to be. In the past, an airplane was designed first and then flight controls were designed to accommodate its performance characteristics. There were many test flights to iron out bugs before production of flight controls ever began. But there will be no "test flights" to the moon and back. Critical systems are going to have to work right the first time.

To achieve this goal of perfection, extensive laboratory assurance testing and performance simulations of the various elements of Apollo are being carried out at all levels. Some ideas will be found to work; others will be found lacking and new approaches will be tried.

Remember, also, that the system being developed at Honeywell must be compatible with dozens of other systems. The fuel supply, electrical supply, computers, radar, navigation—all of these and more interact with the flight controls. Design changes from the laboratories of the National Aeronautics and Space Administration, North American, M.I.T., or elsewhere will in turn influence the design process taking place at Honeywell. Subcontractor flexibility is a basic premise to the success of our effort to get a man on the moon. Such flexibility usually comes from experience.

Our experience in developing flight controls for generations of advanced aircraft, followed by guidance systems for unmanned satellities, was evidence that we could solve the problem of attitude stabilization and control for the Mercury spacecraft.

Our Mercury experience was directly applicable to Gemini, for which we are now developing the attitude control and maneuver electronics and guidance system. At the same time, two other programs contributed to Honeywell's overall body of knowledge in spacecraft control: the X–15, for which we developed an advanced concept in flight control, and the X–20 Dyna-Soar space glider, for which we are developing both flight control and guidance systems.

All of these efforts helped prepare us for the challenge of Apollo. A few brief examples may help to illustrate some of the interrelationships of these programs.

Traditionally, directional control for flying vehicles has been accomplished through foot pedals operated by the pilot. Since foot pedals are heavy and cumbersome, we sought to eliminate them in Apollo. Our past experience in developing what is known as a "side-stick controller" for the X–15 led us to believe that side-stick control might also be perfected for Apollo. We subsequently were able to establish through studies with test pilots the feasibility of doing away with foot pedals. Our experience was transmitted to McDonnell, the Gemini prime contractor, and foot pedals were also eliminated on Gemini, with a great saving in weight.

The Apollo flight control system must be able to accept commands from either the pilots or the inertial guidance system. A knowledge of inertial guidance is therefore imperative in the development of flight controls. Since we are developing inertial guidance systems for both Gemini and X–20, as well as a number of unmanned missiles, a wealth of problem-solving capability is available to our Apollo people.

Of course, these pieces of information don't simply spring into being. But by advancing key personnel through a variety of related programs, the knowledge necessary to solve interrelated problems is spread through the company. Honeywell has been tailored, you might say, to take maximum advantage of "cross-pollenization of experience."

The savings in time and money achieved through elimination of duplication of effort and invention have been significant. This is especially important in a program as complex as Apollo, a program which depends for its success on maximum utilization of the nation's scientific resources.

There is, in our Apollo design group and among the designers and engineers of other subcontractors, a continual accordianlike flexing of technology. Concurrently, we are conducting applied research, preliminary development, design, prototype fabrication, testing, and production. If you visualize each of these phases as a pleat in an accordian, you can appreciate what happens as the phenomenon of change constantly occurs. A breakthrough in development at NASA or North American or Honeywell causes a compression of time in each of the succeeding phases.

It is a far cry indeed from the concept of a subcontractor as a manufacturer who works to narrow specifications provided by the prime contractor, as if a product or device could be furnished from a catalog. It is a concept in which a subcontractor is selected because he possesses areas of problem-solving capability, a pool of skill, and the demonstrated capability to use it.

The space business is not a place for a company not willing to take chances—to innovate and invent. It is not a business where you can count on long production runs on a perfected product. The subcontractors who succeeded on Project Mercury are not thus assured a place on Gemini or Apollo unless they have something better to offer. The programs grow ever more advanced and so must the products and services offered by potential subcontractors.

Honeywell, in its 77-year history, has gone through a continuing metamorphosis that has led to participation in space across a broad front. It has existed in three eras, the first when it invented and produced the first automatic heating control devices. During the second era, it broadened its research and production to cover the entire automatic control field with products ranging from tiny switches to giant computers. The third and present era includes all the elements of the previous two plus many areas that don't fit neatly into categories.

We think of the Honeywell of today as a broadly based, diversified company developing and producing solutions—in analysis, and then in hardware—based on advanced technology.

We believe that this philosophy must extend to all levels of subcontracting. While North

American has called on Honeywell to utilize its experience to develop a flight control system for Apollo, Honeywell in turn must call upon component and parts suppliers.

In choosing such suppliers, the yardstick applied is every bit as unyielding as it is at the highest levels of the program. Companies that become successful on subcontracts even at the component level will be companies active in research, skilled in the direction of research and development effort—able to work by plan and within cost limitations, and able to meet the challenge of long-term reliability.

The level of sophistication required of all subcontractors today is a direct reflection of the complex nature of this nation's goals in space. Just as science must reach new high levels of accomplishment in the space age, so must industrial management reach new levels in application of advanced technology.

25 Systems Engineering

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JULIAN M. WEST
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In an article on Project Apollo published in *Business Week* last fall, the magazine estimated that 20,000 companies and at least 150,000 people would become involved in this national undertaking. The welding together of the effort of so many to achieve a single goal in a limited span of time presents in itself many problems of organization and management. In addition, the project is characterized by the complexity and difficulty of the technology which must be employed if success is to be realized. The necessity to utilize complex technology imposes a requirement for sophisticated technical management. Systems engineering is a management tool created specifically to improve the technical management of large development programs. Its function is to provide the manager with organized technical information which results from, first, planning studies and, second, other studies which amount to a continuous review of the program. This kind of information is necessary for the manager adequately to control and direct the project.

In the remainder of this paper, the systems engineering organization within the Apollo project is described and, by selected examples, the nature of the systems engineering function is clarified. In the process of doing this, Bellcomm, Inc., a contractor of NASA, will be fitted into the framework.

ORGANIZATIONAL RELATIONSHIPS AND RESPONSIBILITIES

Systems engineering is in the Office of Manned Space Flight in NASA, which has a director and two deputy directors, one of whom is responsible for certain program matters directly related to the NASA Centers. The other, as Deputy for Systems, has the overall systems engineering responsibility. Bellcomm's role as a contractor is to support this systems organization. Hence we must, of course, work closely with NASA.

In discussing systems engineering, it seems quite natural to me, an individual from the Bell System, to follow the thoughts of Mervin J. Kelly, a former president and chairman of the board of Bell Telephone Laboratories. Dr. Kelly pioneered the establishment of systems engineering in this country when he clarified its function and set it up as an operating technical organization within Bell Laboratories. By the way, the name "systems engineering" first came into use at that institution around 1948 and has since become quite generally accepted. Many of the thoughts that follow originated with Dr. Kelly.

To place systems engineering in its proper context in any large project like Apollo, it is helpful to recognize in broad terms what such a project is. It can be described as an endeavor to convert some new technology along with some old, better understood technology into manufactured hardware. This hardware, with human control and operation, is intended to perform a desired function. In the present case the function, or mission, is landing men on the lunar surface and returning them safely. Now, the new technology originates from applied research and the hardware results from a manufacturing operation. Between the applied research, which uncovers new and potentially useful technology, and the terminal operation of manufacture of hardware embodying the new technology, there are some recognizable steps. These intermediate steps may be called development, design, and engineering for manufacture. These steps, plus that of manufacture, are currently being implemented in Project Apollo.

In an orderly foresighted program, systems engineering has the responsibility of recommending to management new system development programs that should be undertaken. This recommendation includes a description of the new system, a definition of its operational, technical, and economic objectives and an outline of the broad technical plan to be followed in the successive stages of development leading to manufacture and actual operation. Thus specific development and design of new systems, two of the intermediate steps, can be carefully programed in conformity with the plan established by systems engineering studies. These studies are concerned, for example, with the technological feasibility of a new system—is the technology available? The planning studies also enquire as to the compatibility of the system with its expected environment and, further, seek to optimize the system by considering the various conflicting requirements placed upon it. In short, one of the principal responsibilities and manifestations of systems engineering is thorough technical planning.

As the development step proceeds, systems engineering has a continuing function of objective appraisal and review. In this capacity it acts as a control on the program and also provides a check-and-balance effect. It carries out these functions in several ways. By maintaining close contact with development progress and plans, it can appraise development decisions and results and amend the system plans as required. In cases in which development decisions must, of necessity, be made on the basis of incomplete or inadequate data, system engineering can carry out studies in depth which test the validity of the decision in terms of systems performance. Such analysis ferrets out those decisions which won't stand up and verifies those that will. In this way, confidence in the outcome of the development is maintained.

This monitoring of the program is continued into the final stages by the participation of systems engineering in the preparation of the overall system test plans and the evaluation of the tests. From the test results it is possible to discern how adequately the new system will meet its established goals.

The functions and responsibilities of systems engineering for Apollo fall into the broad framework I have just described. This is indicated by the following responsibilities:

(1) Definition of the overall system requirements (including nominal mission capability)
(2) Definition of the nominal mission profile
(3) Development of the primary Apollo system specification
(4) Definition of the overall system test plan
(5) Definition of the overall reliability and quality control program

With this listing of some of the responsibilities of systems engineering in Apollo, one major function that it does not have should be emphasized. Systems engineering, as a staff function, does not have "line" responsibility for hardware development. This function resides in the Centers and their tiers of contractors.

THE ROLE OF BELLCOMM, INC.

Bellcomm was formed barely one year ago in response to a request from James E. Webb, the NASA Administrator, to the top officials of the American Telephone and Telegraph Co.

> to assist NASA . . . by providing an organization of experienced men capable of giving the responsible NASA officials the benefit of the most advanced analytical procedures and the factual basis they need to make the wide range of system engineering decisions required for the successful execution of the manned space flight mission. . . . such arrangement can in no

way impair NASA's direct responsibility for all decisions in the planning, engineering, and procurement areas. There will be no delegation of such responsibility to a nongovernment organization. What we are seeking is not a means of diluting the responsibility or authority of NASA's appropriate officials, but rather the most skilled and experienced assistance available to enable us to exercise that responsibility and authority in the most effective manner.

At present Bellcomm has a staff of about 100 technical people, about two-thirds of whom are from the Bell System, primarily from Bell Telephone Laboratories. Bellcomm is a separate Bell System Company with, at present, a single assignment—to assist NASA. The statement of work in the contract requires us "to perform studies, technical fact finding and evaluation, analytical investigations, consulting effort, and related professional activities in support of manned space flight and related programs of NASA."

Of the many studies currently being carried out in the systems engineering area, perhaps none illustrates the broad nature of the activity better than the overall or primary Apollo system specification. The nature of this document and its place in the program can, perhaps, be conveyed by a statement of its purpose. The purpose of this specification is (1) to define the objectives for the Apollo system and its major subsystems; (2) to define the technical approach to be used to accomplish these objectives; (3) to establish system and critical subsystem performance requirements necessary for the Apollo system to meet its objectives; and (4) to establish a uniform set of system design data. The specification, prepared by the Office of Manned Space Flight and Bellcomm, reflects the combined thinking and judgment of the appropriate NASA Centers, as well as the Office of Manned Space Flight.

In addition to studies directly concerned with the manned space program, our systems engineering team has looked at part of the NASA unmanned program, the Ranger and Surveyor programs, in cooperation with the NASA Office of Space Sciences. The objective here has been to ensure that, in the national interest, the unmanned program to the greatest degree possible supports and supplies useful information to the Apollo project. Thus we find systems engineering concerned with interrelationships between projects just as it more often is concerned with relationships within a project.

In conclusion, it is desirable to emphasize the necessity for an organized "systems engineering" approach to our modern, highly technical developments. The penalties for not fully utilizing this management tool can be extremely severe.

26 Management of the Space Program at a Field Center

WERNHER VON BRAUN

Director, George C. Marshall Space Flight Center, NASA

As a background for the discussion of the management and procurement practices of the Marshall Space Flight Center it may be helpful to give a thumbnail sketch of the Center itself, and its role in the development of the Saturn vehicles for Project Apollo.

The Marshall Space Flight Center (fig. 26–1) was formed in 1960 by the transfer from the U.S. Army to NASA of about 4,400 Civil Service employees and an integrated complex of engineering, laboratory, fabrication, and test facilities then valued at $100 million. Our employees now number about 7,000, and our facilities have been enlarged through additions and new construction.

Figure 26–1.—Redstone Arsenal, Huntsville Area.

Marshall's civil service personnel include many with experience in rocketry stretching back over the past two decades. Figure 26–2 shows the broad categories of employees.

The Marshall Center (aerial view shown in fig. 26–3) has the facilities and personnel for conducting a rocket program all the way from conception through design, development, fabrication, and testing—with the aid of major contributions from contractors. Our in-house technical competence is concentrated in nine major divisions, which are not project oriented, but are alined along the lines of professional disciplines such as mechanical engineering, electronics, flight mechanics, and the like. Division personnel participate in active projects, future project studies, and supporting research. They keep their knowledge up to date and judgment sharp by keeping their hands dirty at the work bench on in-house projects selected specifically for using and nurturing their competence.

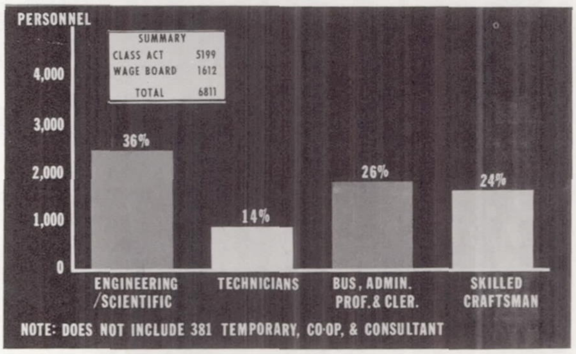


Figure 26–2.—MSFC manpower; Civil Service distribution.

FIGURE 26–3.—Aerial view of Marshall Space Flight Center.

Prototype stages of rockets are fabricated in our Manufacturing Engineering Division for research and development testing. Figure 26–4, which was made in January 1963, shows the fabrication of three first-stage boosters (S–I) of the Saturn I vehicle. The fourth booster, in the right background, was flight tested at Cape Canaveral March 28. This was the fourth straight success in the Saturn I flight testing program. It again demonstrated the soundness of the engineering design in clustering eight engines, and paid further tribute to the painstaking efforts of our people to obtain the maximum in quality assurance and reliability in manufacture, inspection, testing, and launching.

Two or three static firings are conducted on all stages fabricated at the Marshall Center before they are taken by barge to the Cape for flight tests. The test stand shown in figure 26–5 is part of a complex that includes a dynamic test stand for checking out an entire Saturn I vehicle, a highly instrumented blockhouse, and facilities for component and engine testing.

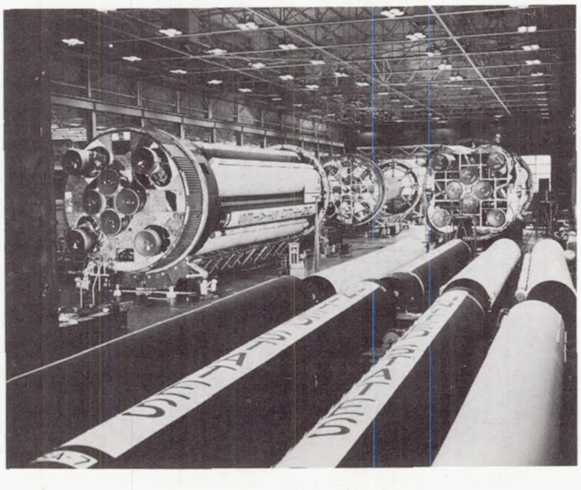


FIGURE 26–4.—Fabrication of S–I boosters of Saturn I.

An entirely new test complex is under construction for the larger Saturn V/Apollo launch vehicle.

The primary task of the Marshall Center for the next few years is to provide Saturn launch vehicles to support Project Apollo. (See fig. 26–6.) The Saturn I will test the Command and Service Modules of the Apollo Spacecraft in Earth orbit. The Block I vehicles include the first four Saturn I's which have already been launched, with only the first stage live. The next Saturn I launch, scheduled for later this year, will flight test the first of the Block II vehicles, with both stages live. The Saturn IB will test the entire Apollo spacecraft, including the Lunar Excursion Module, in Earth orbit. The Saturn V, which can place 120 tons into Earth orbit, or boost 45 tons to escape velocity, will lift the three-man Apollo spacecraft to the Moon.

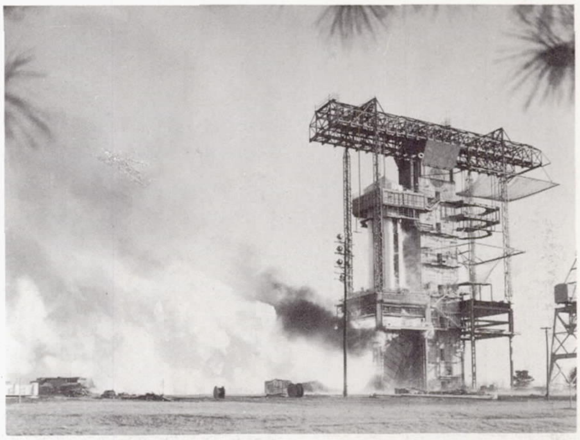


FIGURE 26–5.—Test stand for Saturn I boosters.

Our second category of assignments includes research related to launch vehicle development. In a third area we perform advanced system studies for space transportation concepts in the future. The Martian Electric Spaceship is an example of this type of study. Figure 26–7 shows an artist's concept of a 360-ton spaceship, powered by a 40-megawatt nuclear-electric power plant, which could be used for carrying a crew from an Earth orbit to a Mars orbit.

The future Projects Office at Marshall is the focal point for coordinating all contract studies and in-house efforts related to future space transportation systems. It charts the course for our future, analyzing and appraising the many ideas for better space transportation advanced by outside sources or members of our own Center. Many of its studies must view launch vehicle-spacecraft systems as units. (See fig. 26–8.) For only after the entire mission profile has been studied, can an intelligent demarcation line between Earth launch vehicle,

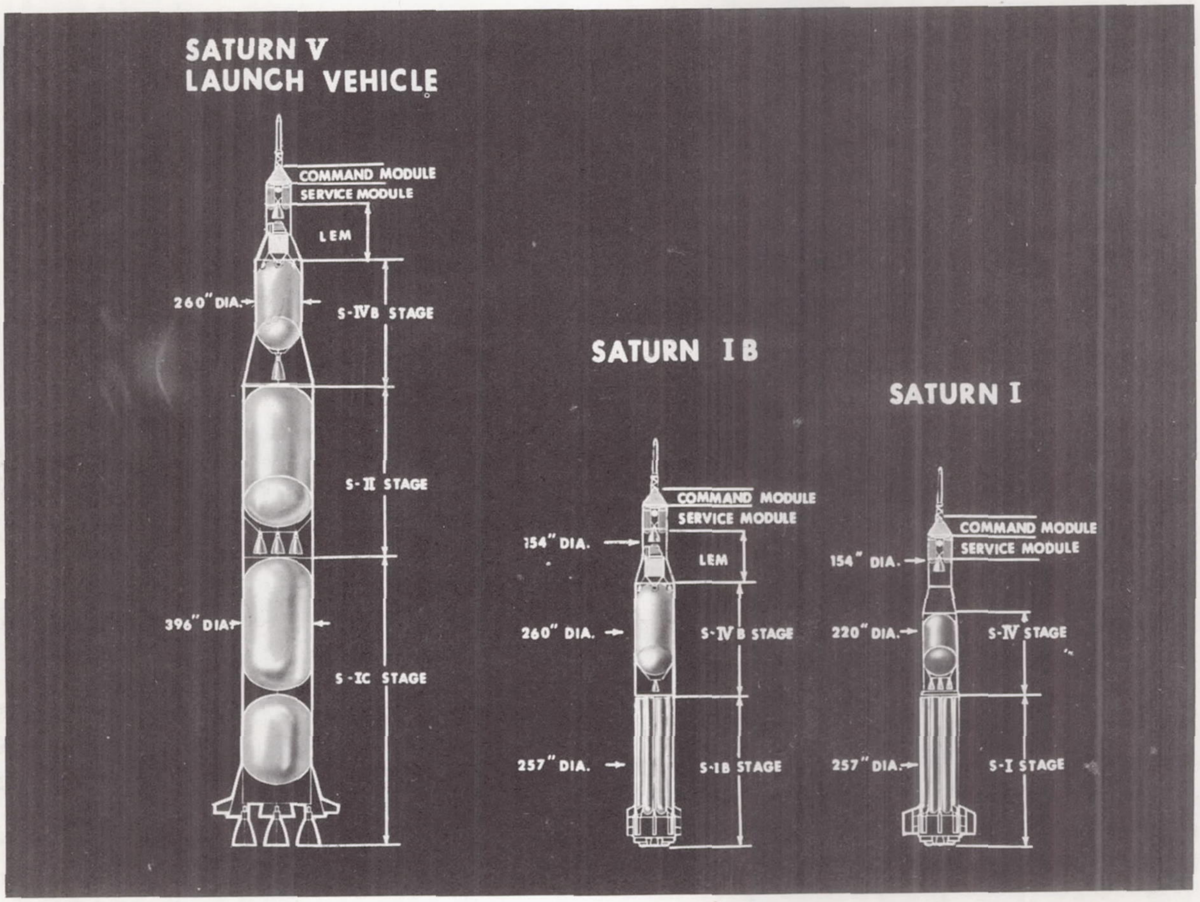


FIGURE 26–6.—Saturn vehicles.

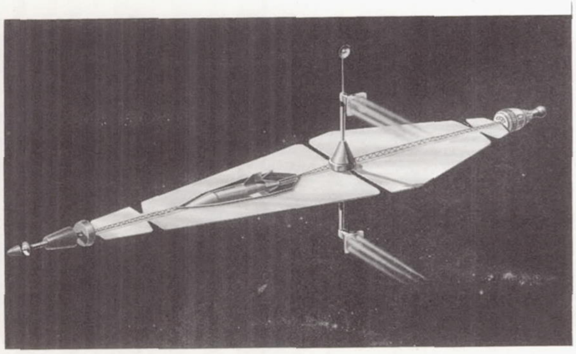


FIGURE 26–7.—Concept of Martian electric spaceship.

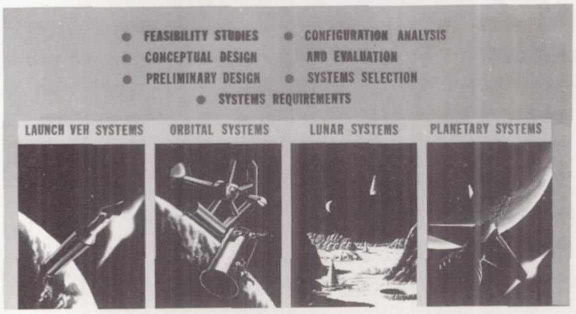


FIGURE 26–8.—MSFC future projects.

deep space propulsion system, and spacecraft proper be drawn. In our studies we seek to establish the relationship between the state-of-the-art, performance, schedule, cost, and probability of mission accomplishment and growth potential. Study results are fed into the NASA Long Range Plan, which is updated every year. Such an up-to-date appraisal of future possibilities will permit top NASA management to make sound program decisions.

The Marshall Center's civil service personnel have been distributed according to their direct or indirect support of programs shown in figure 26–9. More than 85 percent of our Marshall effort goes to support the Office of Manned Space Flight. This figure also shows that almost 80 percent of our employees are supporting the three Saturn launch vehicle programs. Although these people possess a wide variety of talents and have years of specialized experience in rocketry, we do not claim to be able to carry the ball alone.

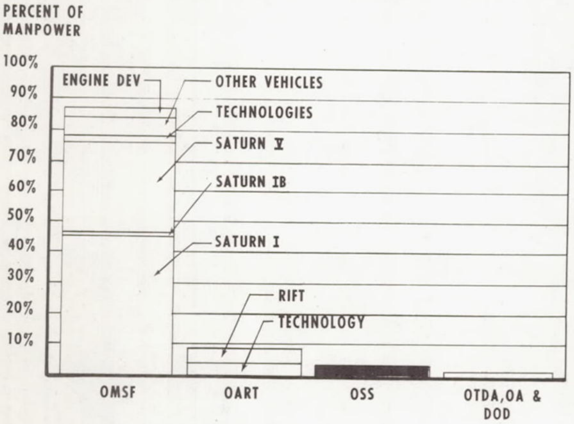


FIGURE 26–9.—MSFC manpower; Civil Service distribution by program, fiscal year 1963.

When our personnel were transferred to NASA to form the Marshall Center, we naturally left the Redstone, Jupiter, and Pershing weapon system projects with the Army. Since we were then working primarily on the Saturn I launch vehicle project, our in-house effort in fiscal year 1961 comprised 19 percent of our total budget. (See fig. 26–10.) Our own efforts have increased steadily since that time because of the additional tasks given us. But our total effort has taken such great jumps each fiscal year that our in-house operations represent a decreasing percentage of our total budget—only 8 percent in the proposed FY 1964 budget.

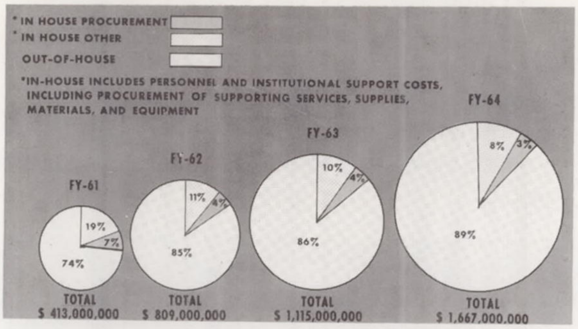


FIGURE 26–10.—MSFC contractors—distribution of MSFC funds.

In addition to expanding our facilities at Huntsville, we have acquired the 40-acre Michoud Plant in New Orleans (fig. 26–11) for the assembly of vehicle stages and have started construction on a nearby site in Mississippi for static testing units fabricated at Michoud and by contractors on the west coast. These government-owned facilities will be operated by contractors.

One of the reasons for selecting the present method of operation at Michoud and at the Mississippi test site was the deliberate intention of keeping competition open within industry for contracts to build future stages. We did not believe that the government should construct major, unique, and expensive fabrication or testing facilities at a contractor location if doing so might later present a disadvantage to other sources in the competitive selection process.

Each stage of a launch vehicle is a complex system of its own, with propulsion, structure,

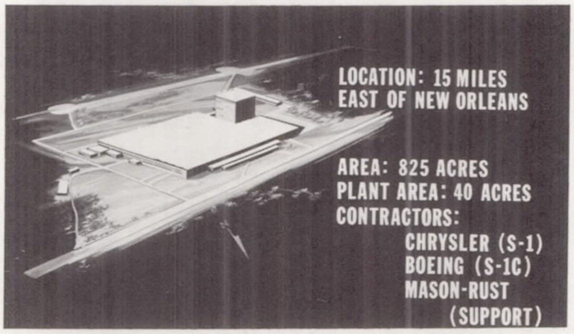


FIGURE 26–11.—MSFC Michoud plant.

electrical network, and controls. Figure 26–12 shows the prime contractors and the major subcontractors for the Saturn I.

We will build eight S–I stages for the Saturn I at Marshall. The Chrysler Corp. as prime contractor is under contract to produce twenty-one S–I stages at Michoud and may ultimately produce many more. The second stage is being developed by Douglas at Santa Monica, California. Mason-Rust, Inc., is our operating services contractor at Michoud.

The first-stage booster (S–IC) for Saturn V is being designed jointly by the Marshall Center and The Boeing Company. (See fig. 26–13.) Marshall will build three S–IC stages for ground tests, as well as the first flight booster. Boeing is presently under contract to produce ten S–IC flight stages at Michoud. The second stage (S–II) is being developed by North American Aviation, Inc., at Downey and Seal Beach, California. S–II stages will be brought by ship through the Panama Canal to Mississippi for static firing. The third stage (S–IVB) comes from Douglas Aircraft Corp. It will be designed, developed, and manufactured at Santa Monica, California, and static fired at Sacramento.

A survey made at the Marshall Center in February 1963 among the stage and engine contractors in the Saturn vehicle programs showed that small business firms received more than 50 percent of the dollars subcontracted by our prime contractors. (See table 26-I.) We are vitally interested in the selection of subcontractors, for the sake of our reliability program. We try to encourage our prime contractors to use only those subcontractors and vendors who have demonstrated their competence through the production of equipment that has been certified and man-rated. In this area there must be a delicate balance between sole-source restrictions that seek to extend competition, and

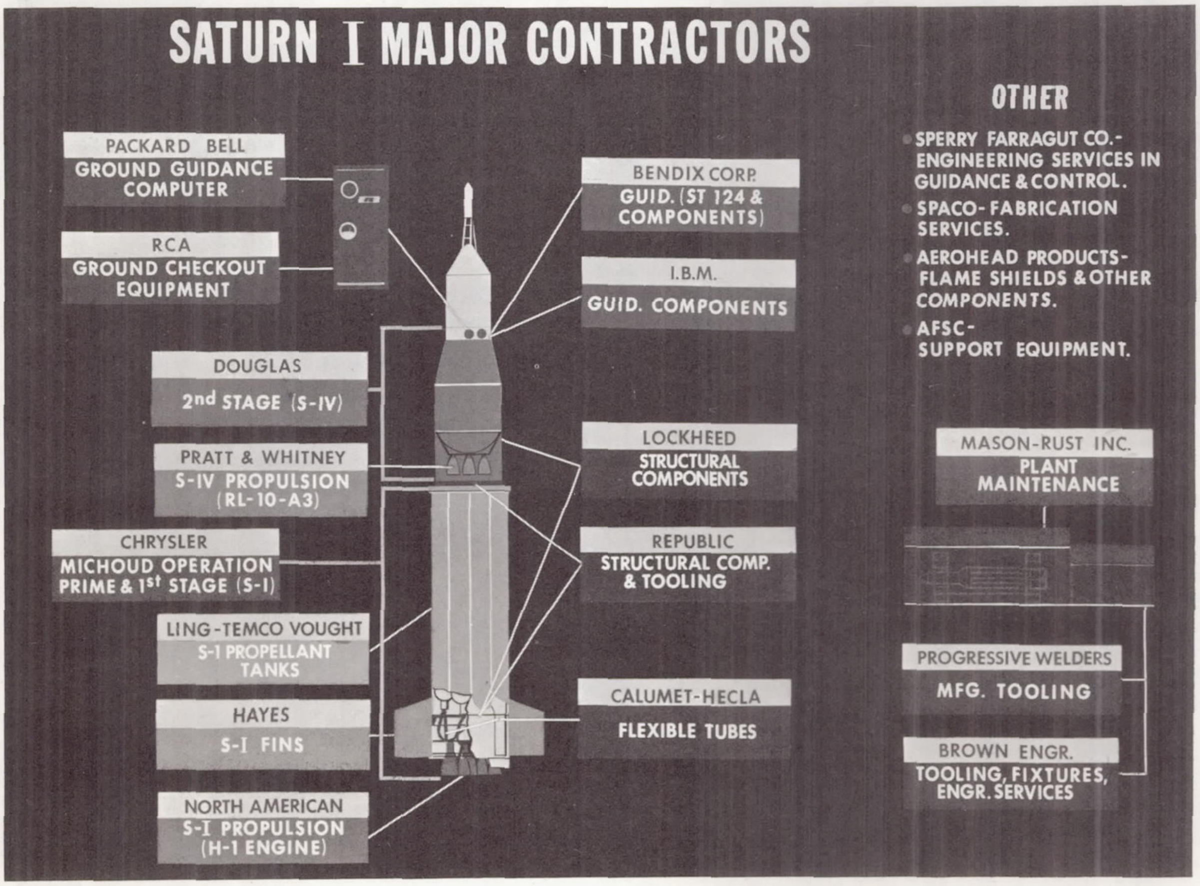


FIGURE 26–12.—Saturn I contractors.

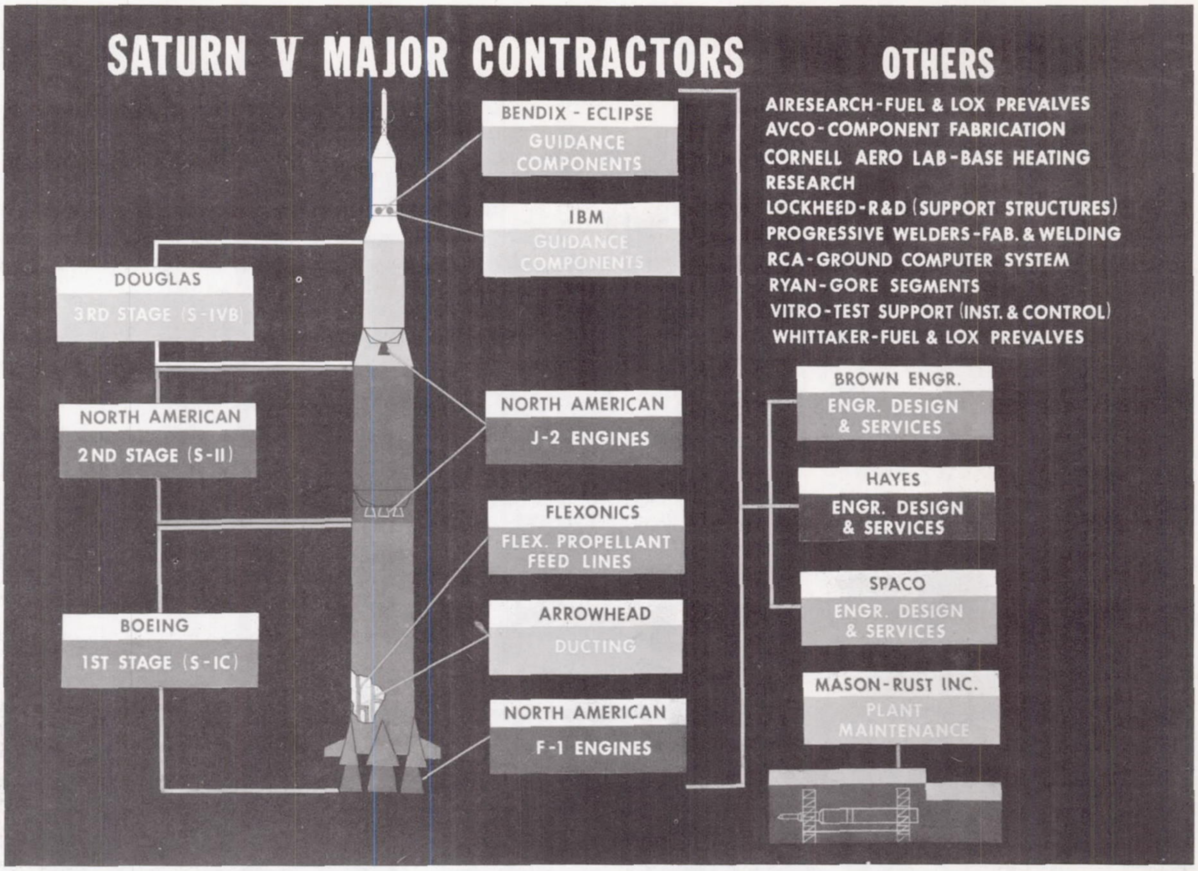


FIGURE 26-13.—Saturn V contractors.

the reliability attainable through procurement from a contractor who has clearly outstanding abilities in a specialized area. Some companies have acquired unique technical experience, facilities, and equipment that would cost hundreds of millions of dollars to duplicate.

The Saturn Systems Office (fig. 26-14) exercises project management at the Marshall Center for the Saturn vehicles. Project management could be defined as the direction of the efforts of many diverse and highly specialized organizations into a single coordinated pro-

TABLE 26-I.—*Small Business Firms in Saturn Program*

Contractor	Stage or Engine	Period	Subcontracts, total dollars, millions	Percent to small business
Chrysler	S-I	June 1962 to February 1963	12. 0	60. 2
Boeing	S-IC	August to December 1962	6. 8	25. 5
NAA/S & ID	S-II	January 1962 to January 1963	8. 2	32. 0
Douglas	S-IV	January 1961 to January 1963	14. 8	55. 0
Douglas	S-IVB	January 1961 to January 1963	7. 2	0
Pratt & Whitney	RL-10	January to December 1962	20. 4	61. 7
NAA/Rocketdyne	H-1, J-2, F-1	January to December 1962	77. 6	61. 8

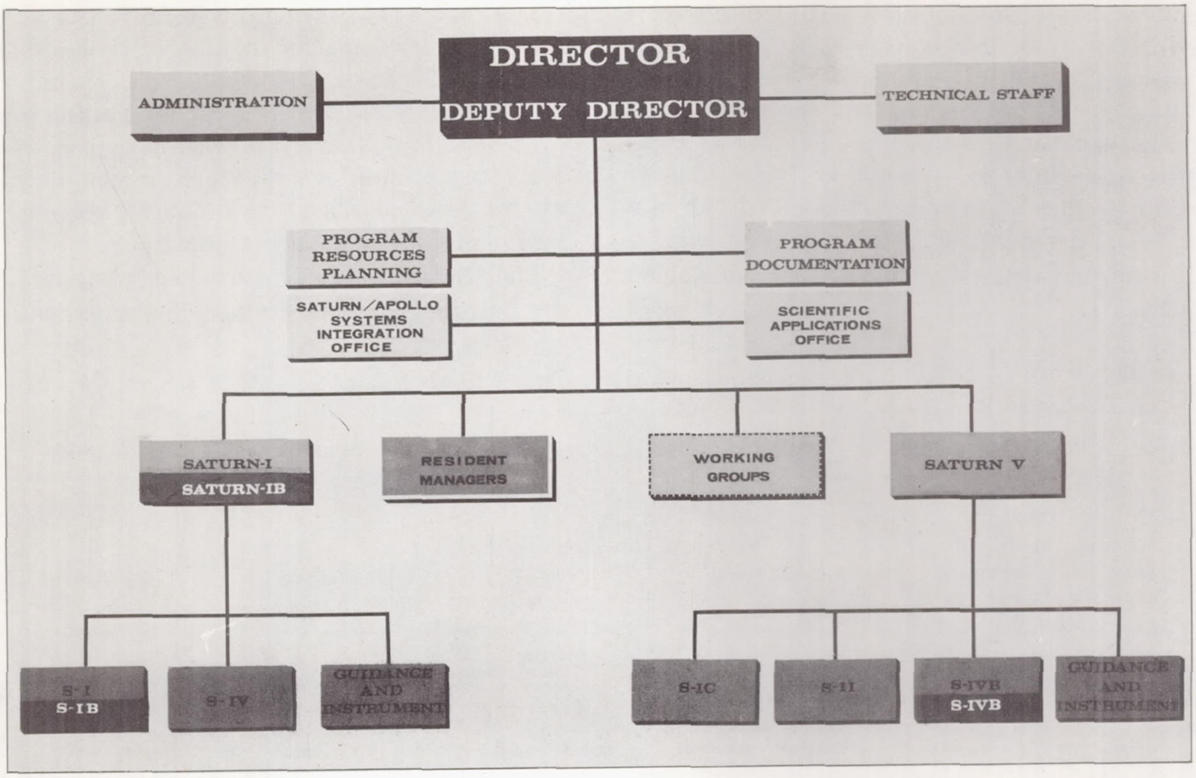


FIGURE 26-14.—Saturn Systems Office.

gram to produce a single end objective. The project manager must work by a carefully planned schedule that ties each step of his program together in time and space. He directs, coordinates, programs, and budgets his available resources to achieve a single aim. His project, an entity within itself, must merge with the projects of other managers to complete the overall program, Project Apollo.

Since the Saturn Systems Office is basically a technical project management operation, it is staffed largely with technical personnel. They are supported as necessary by administrative, budgetary, and programing personnel from other staff offices, and receive technical assistance from the personnel in Marshall's nine operating divisions.

The Marshall Center retains technical direction for all of its research and development contracts (fig. 26–15), including those placed and administered by other government agencies. To insure daily personal contacts and to provide a sure, clear line of communication, the Saturn Office locates resident managers in the plants of each prime contractor.

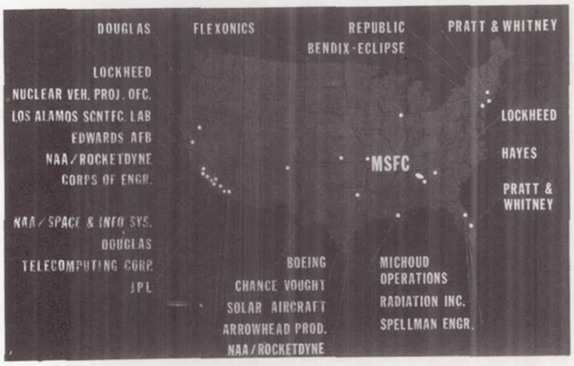


FIGURE 26–15.—Project management—MSFC offices in contractor-operated plants.

Resident managers are supported by on-site staffs of technical, administrative, and contractual personnel. The size of the staff varies from a handful of specialists in some offices, to about 175 curently assigned to Michoud Operations in New Orleans. Through daily personal contacts at the contractor's plant, the resident manager can provide rapid direction to resolve problems, and may even spot and resolve potential problems before they become stumbling blocks. If the resident manager finds a problem beyond the scope of his staff, he returns it to the Saturn Systems Office. This office can draw on the technical knowledge of our nine in-house divisions. The solution is returned to the contractor through the resident manager's office.

The Saturn Office brings project direction and hardware development together. (See table 26–II.) It is the only office shown in the table with responsibility for both. The offices on the two levels above the Saturn Office have responsibility for project direction and review only; whereas, the levels below this office are responsible for producing the actual hardware.

TABLE 26–II.—*Saturn Project Management*

Level	Program	System	Stages	Missions
Director, OMSF	Policy & Review			
Director, MSFC	Review & Direction			
Director, SSO	Planning & Execution	Integration	Management	Integration
Working Groups		Technical support		
Line Activities		Planning, Design, Fabrication, & Assembly, Test, Launch		
Contractors			Design, Fabrication, & Assembly, Test, Launch	

The nationwide primary field operations of the Saturn Office are divided into three categories; stage development and production, testing, and launch. (See fig. 26–16.) For example, S–II stages for the Saturn V will be developed and produced by North American Aviation, Inc., at Downey and Seal Beach, California. North American will accomplish research and development testing in its own facilities at Santa Susana, California, and acceptance testing at NASA's Mississippi Test Operations. The joint effort of both NASA and contractor personnel will be required when the stage is launched as part of a composite vehicle at Cape Canaveral.

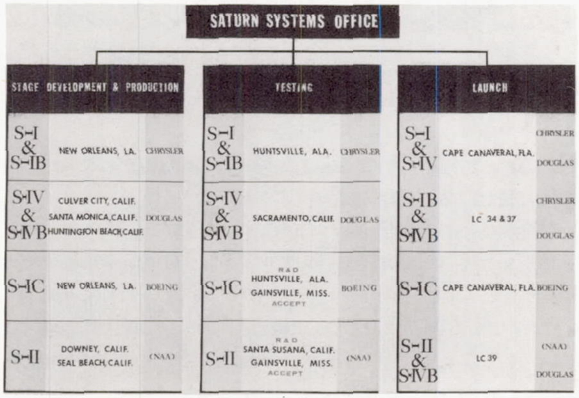


FIGURE 26–16.—Saturn primary field operations.

Contact with contractors is maintained through two major channels—one for technical information, the other for contractual changes. (See fig. 26–17.) both channels originate and end at common points, however: the Saturn Office and the Resident Manager's Office at the contractor's plant.

If the solution to a technical problem requires contractual changes, the necessary negotiations are handled through the contracting officer in

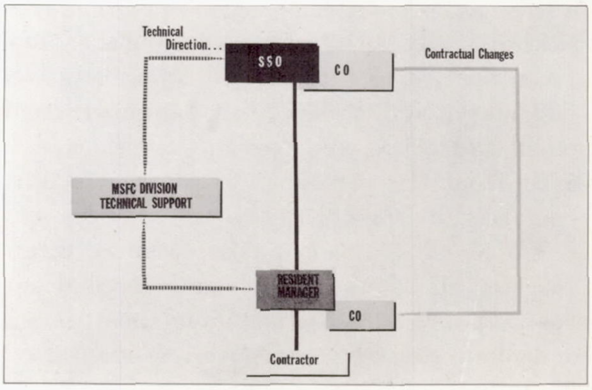
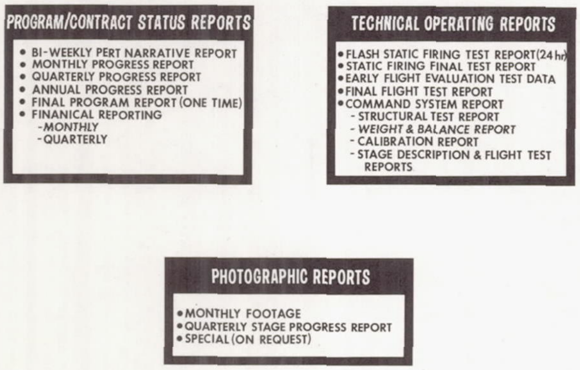


FIGURE 26–17.—Contractor management plan.

the Saturn Office and the contracting officer on the resident manager's staff. The resident contracting officer continuously monitors contractual performance and naturally reports directly to the resident manager. (See fig. 26–18.)



PROGRAM/CONTRACT STATUS REPORTS

- BI-WEEKLY PERT NARRATIVE REPORT
- MONTHLY PROGRESS REPORT
- QUARTERLY PROGRESS REPORT
- ANNUAL PROGRESS REPORT
- FINAL PROGRAM REPORT (ONE TIME)
- FINANICAL REPORTING
  - *MONTHLY*
  - QUARTERLY

TECHNICAL OPERATING REPORTS

- FLASH STATIC FIRING TEST REPORT(24 hr)
- STATIC FIRING FINAL TEST REPORT
- EARLY FLIGHT EVALUATION TEST DATA
- FINAL FLIGHT TEST REPORT
- COMMAND SYSTEM REPORT
  - STRUCTURAL TEST REPORT
  - *WEIGHT & BALANCE REPORT*
  - CALIBRATION REPORT
  - STAGE DESCRIPTION & FLIGHT TEST REPORTS

PHOTOGRAPHIC REPORTS

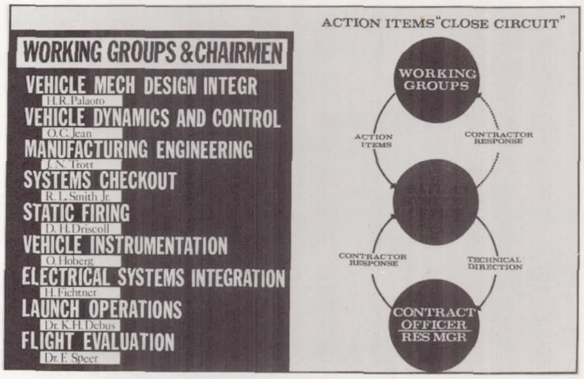
- MONTHLY FOOTAGE
- QUARTERLY STAGE PROGRESS REPORT
- SPECIAL (ON REQUEST)

FIGURE 26–18.—Typical contractor reporting requirements.

The keystone of Marshall's contractor management is daily personal contact with the contractor by our resident manager. This personal-contact management is supported, however, by formal contractor reporting requirements. These reports are used as management tools to review progress against previously defined program milestones. These reports vary from teletypes on static firing tests to a quarterly motion-picture report. Two of the most important are a Contract Status Report and a Monthly Financial Report. Together they contain enough information for measuring all contractor efforts from budgeting to testing.

There are two types of Saturn technical groups—working groups and coordination panels. Our nine Saturn working groups (fig. 26–19) focus the best technical talents of Marshall employees and our contractors on vehicle system problems. The chairman of each group is appointed by the Saturn Office, and is responsible for all group actions, including the naming of members to his group.

The communications pipelines illustrated at the right of the figure have proven simple and workable. The analyses and recommendations of the Marshall-Industry working groups are channeled to the Saturn Office project managers in the form of action items. The project manager forwards the necessary resulting instructions to the contractor, through the resident manager. If the contractor questions the technical direction, he can respond through the resident manager to the Saturn Office. From here the response may be returned to the responsible working group for further consideration, completing the chain of communications.



WORKING GROUPS & CHAIRMEN

VEHICLE MECH DESIGN INTEGR
H.R. Palaoro
VEHICLE DYNAMICS AND CONTROL
O.C. Jean
MANUFACTURING ENGINEERING
J.N. Trott
SYSTEMS CHECKOUT
R.L. Smith Jr.
STATIC FIRING
D.H. Driscoll
VEHICLE INSTRUMENTATION
O. Hoberg
ELECTRICAL SYSTEMS INTEGRATION
H. Fichtner
LAUNCH OPERATIONS
Dr. K.H. Debus
FLIGHT EVALUATION
Dr. E. Speer

FIGURE 26–19.—Saturn working groups.

The Saturn vehicle must be compatible with the spacecraft and launch facilities. This is accomplished through intercenter coordination panels (fig. 26–20) which are very similar to the working groups in organization and methods of operation. The panels are composed of scientific and technical personnel from the Marshall Center, from the Manned Spacecraft Center in Houston, and the Launch Operation Center at Cape Canaveral. In resolving technical problems, the panels have the full support of each field center's technical capabilities and those of their associated contractors. The coordination panels refer unresolved matters, when necessary, to a Space Vehicle Review Board made up by the center directors. Major program decisions of this board are again reviewed by the Office of Manned Space Flight.

Working level contacts are daily and routine among Marshall, Manned Spacecraft Center, and Launch Operations Center personnel, both in-house and contractor.

There have been as many as 1,900 Chrysler and 1,200 Boeing employees working closely with our Marshall Center employees at Huntsville on booster stages for the Saturn I and Saturn V.

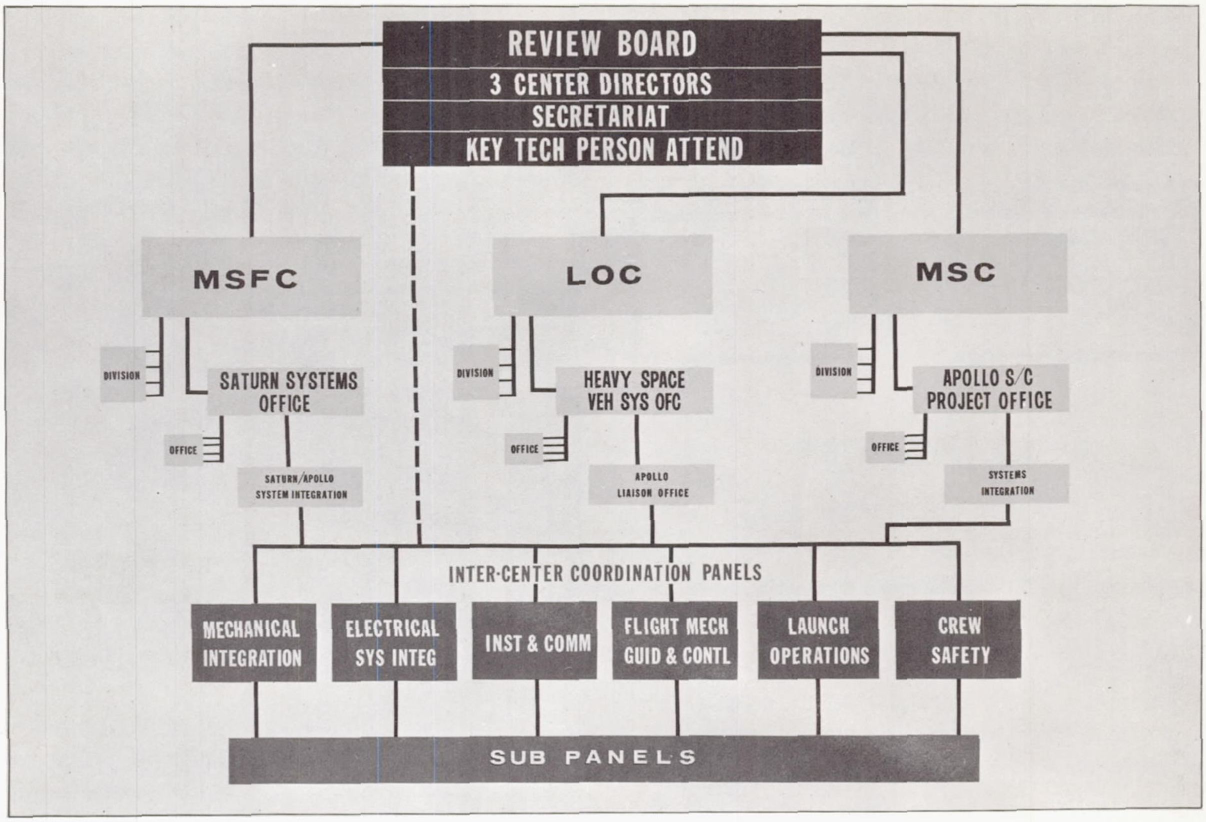


FIGURE 26–20.—Saturn-Apollo interface organization.

Now, how does the Marshall Center go about selecting launch vehicle, stage, or engine contractors?

First, a procurement plan is drawn up for all research and development projects of more than $100,000. If the cost is expected to exceed $5 million, the plan is submitted to the NASA Associate Administrator for approval. If the amount is expected to be less than $5 million, the center director approves the plan.

The procurement plan includes a description of the proposed hardware, a list of all known sources, the method of procurement to be used, steps to be followed, a realistic time schedule for completing each major phase of the procurement action, the recommended type of contract to be used, and any special features, such as reliability requirements, which are planned for inclusion in the contract.

If the ultimate cost of the work to be contracted is expected to exceed $1 million, a Source Evaluation Board is appointed to evaluate the proposals submitted. Senior Technical business management, and procurement personnel are appointed to the board by the center director, or are recommended to the NASA Associate Administrator for appointment if the contract is expected to exceed $5 million.

The board determines the qualification criteria to be used in the evaluation of proposals from potential contractors. In addition to the many technical factors relating to design, development, and test programs, the board develops a list of factors relating to business management. These may include project organization, manpower and facilities availability, direct and related experience, past performance, project scheduling, estimates of cost, subcontracting structure, labor relations record, quality assurance programs, and others.

After the board drafts the minimum qualification criteria, it gives the statement to the procurement office for preparing a final source list. The board reviews the list, making recomendations for additions or deletions, in an effort to achieve a balance between permitting maximum competition and avoiding the solicitation of companies which will not have a reasonable chance of being competitive. The early elimination or withdrawal of those firms which clearly do not have the experience or capabilities to perform the work is beneficial to the company, and also reduces the effort required in the selection process.

A preproposal conference is usually held next. Here the technical and business details of the procurement will be presented, and the company representatives may ask questions. Any company may send representatives to this conference, whether the company is on the source list or not.

Companies considered qualified will then be asked to submit proposals. Again, any company that wishes may submit a proposal. The engineering time and expense for submitting a proposal is substantial, however; we think it only fair and reasonable to advise any interested company when its qualifications appear marginal for a particular job.

Requests for proposals issued by the Purchasing and Contracting Office should ask for enough information to satisfy the needs of the Source Evaluation Board for information, and no more. The ground rules to be followed in selecting a contractor should be stated clearly. The major factors to be evaluated are stated, and their relative importance explained.

After proposals are received, they are given a thorough evaluation by the board. The technical and management aspects of proposals and of companies are considered together, for they are closely related. The proposal alone is never the sole basis for evaluation. Information is obtained by board members from other government departments as to their past experience with the companies which have submitted proposals.

After the proposal and the company's record of past performance are studied, actual plant visits are made. Advisory committees or consultants may be used for obtaining additional information.

Upon completion of the evaluation, the board prepares its findings and submits them to the center director or the Administrator of NASA, depending upon which official has authority to make the final selection. The board normally arranges for an oral presentation to the selecting authority, during which the members may also answer any questions he may have.

The board does not make a recommendation to the selecting official. That is his decision alone. The board's findings should provide him with the kind of analysis of the qualifications of the competing companies, based on their proposals, on past performance, and on current capability that will facilitate the selection. The goal of this entire procedure is to make it possible for the responsible official to select the contractor which appears to be best qualified to perform the work successfully within the required schedule at a reasonable cost.

The board tries to give him enough information so that he will not have to make a decision on faith and intuition, without sufficient thought and study. The board's findings are as accurate, complete, and thorough as it is possible to make them before they are submitted to the decision-making authority.

Our personnel at the Marshall Center have always believed that it is better to build a rocket in the factory than on the launch pad. It is true that the final test of a rocket system is a successful launch. But this is a poor and expensive method of checking the soundness of design, the quality of workmanship, or reliability of a rocket system. Our Quality Assurance Division has the heavy responsibility for seeing that each launch vehicle is ready for flight testing when it is delivered to the launch site. This task is accomplished through a Quality Assurance program that penetrates the plants of our prime contractors and subcontractors in depth. A variety of comprehensive tests on components and systems and on the composite vehicle are made on the ground to assure that each mechanical and electrical system will operate properly in the air.

Representatives of our Quality Assurance Division have important roles in contract negotiation in an effort to assure reliability. We found long ago that you cannot assure quality by inserting in the contract a well-intentioned but meaningless statement that says, in essence, "Please do a good job." We try to tell the contractor in detail what we want, and how he can obtain it. We go into his plants to help him establish a sound inspection and testing program.

The NASA NPC–200 series of documents which outline specific quality assurance requirements are included as a part of all major NASA contracts. NASA's quality control procedures are the stiffest ever faced by American industry. These documents must be supplemented, however, with development of new and better materials, better design, better techniques in manufacture, and improved means of evaluating the end items produced.

To create a product which we can commit to the rigors of space, we must do more than that which we can describe in specifications and procedures. We must have the dedicated support and concern of all elements of industry and government for obtaining the ultimate in perfection. This is the type of quality program which we cannot define legally, for it involves an attitude more than a procedure. It is, however, a program which we can afford, because it requires far more dedication than dollars.

The extreme cost per vehicle now precludes extensive "testing to failure" as a means of verifying the flight worthiness of vehicles, or even major vehicle subsystems. This means that more emphasis will have to be given to quality and reliability in all upstream activities, such as design, selection of materials and components, manufacturing and assembly, and so forth.

We consider the money spent on reliability, quality assurance, and testing programs one of our soundest investments in Project Apollo.

The payoff to our efforts will come when three astronauts blast off for the Moon in the not too distant future, and about 1 week later return safely to Earth.

Panel Discussion

Leader: KENNETH H. MYERS
School of Business, Northwestern University

ROBERT C. SEAMANS, JR.
JOHN LELAND ATWOOD
CHARLES L. DAVIS
JULIAN M. WEST
WERNHER VON BRAUN

MYERS: The following discussion by Dr. Seamans, Mr. Atwood, Mr. Davis, Mr. West, and Dr. Von Braun concerns items of interest to midwest firms, firms which may be desirous of entering space or military work for the first time or of expanding their activities in these areas. Pertinent questions are: At what level might a company consider entering or expanding its activities—the prime level, the first tier of subcontractors, the second tier, or other areas? In what areas, in terms of technical activity, might we select as our targets, or should we aim at, activities which are evolutionary, that is which build substantially upon previous contractual activities—or should we aim at new areas? Finally, where might a company obtain the necessary information?

Dr. Seamans has spoken of a firm which had submitted six or seven bids for available NASA contracts; the firm in question was unsuccessful in each of these attempts. In such a case it might be asked what level of entry was being sought? What might these attempts have cost? In what principal respects was this firm less attractive than the other bidders? How might this bidder have corrected his approach perhaps at an earlier date?

SEAMANS: The firm in question had made proposals for a prime contract. This firm had invested in the facilities necessary for a major role in the space program. However, they had not built up their technical staff sufficiently either to prepare a good proposal or, more importantly, to give us confidence they they could manage this technical activity if NASA awarded them the contract.

ATWOOD: North American has, I think, tried seven times, more than once, without winning a contract. I doubt the batting average is much better than one in seven for the contracts on which we bid.

MYERS: In other words, a firm which has considerable experience in space work and a record of achievement and success might also expect to be unsuccessful a considerable portion of the time. Would that be true also, Mr. Davis, at the subcontracting level, first tier?

DAVIS: Well, I think it holds true whether bidding is done by an experienced firm or a firm that is attempting to enter the space business. One of the most difficult decisions is deciding what your firm can do best; if your firm is not the best performer in the area selected you have little chance of winning the competition.

MYERS: Have either Mr. Atwood or Mr. Davis found the debriefing sessions with NASA helpful? In other words, have you been apprised of the reasons why your firm did not win a competition?

ATWOOD: Yes. The review of an unsuccessful bid and a critique are of great value to conscientious technical and managerial people.

MYERS: Is that kind of activity or facility available to subcontractors?

DAVIS: I think that the NASA services in this regard are naturally geared to the prime contractor because the point of decision is between NASA and the prime contractor. Certainly, subcontractors, particularly major subs, prepared to perform a complete functional part of the system do benefit from the overall briefing. I think that it is a little harder for the subcontractor to get a definition of requirements in his own terms.

MYERS: The suggestion has been made that, as the age of space progresses, more and more of the opportunities will be of an evolutionary character. This theory was supported or perhaps amplified by Mr. Davis in his paper in describing the experience of Minneapolis-Honeywell in developing control systems for conventional aircraft; then for experimental aircraft, then for Mercury, Gemini, and Apollo. Do you feel that as time goes on, less and less opportunity will be available to firms without prior experience because of the evolutionary character of this industry?

VON BRAUN: That depends greatly on the particular field being discussed. Rocket engine development, as an example, is undoubtedly a field in which a newcomer would find it very difficult to compete with well-established and entrenched organizations that have been working in this field for a long time. On the other hand, this is a very fast moving field. Rate of obsolescence is high and there is always a possibility that a newcomer could achieve a breakthrough; this accomplishment would suddenly put him ahead of the rest of the fold who have followed more conventional channels. So, I think the belief that the space business, in general, may become limited, in time, to certain established companies is not very well founded.

SEAMANS: An executive of one successful firm pointed out to me that they never enter a field where there are already strong contractors. They first look at their own capability to see where they can leapfrog and come in with something that would be revolutionary sometime in the future and, hence, place them in a position to get a large percentage of the market. I think that industry has to be looking ahead and not trying to get into this business by making small changes in already existing components.

MYERS: Would opportunities to conduct feasibility studies be an attractive point of entry—into a new technique?

WEST: I think that the feasibility study is an excellent way to get started and, although the batting average on getting a contract on competitive bids may be low, the batting average on getting a follow-through contract from a feasibility study is much higher because there is a continuity and a carry through that is very noted.

MYERS: In other words, the firm which does obtain a feasibility study and carries this off successfully has a leg up, so to speak, on any further development along these lines.

WEST: It is almost inevitable that this should be so. We attempt always to make feasibility studies in such a way that there is still a good competition after completion. It is inevitable, however, that the firm making this study should have the inside track.

SEAMANS: Mr. West put in a word of caution because, in the case of the Apollo contract, for example, there were three feasibility studies following which we had an industry conference to review with all of industry the results of this Government financed effort; the final contractor, North American, was not one of those companies which had originally participated formally in the feasibility work.

DAVIS: From a purely business standpoint, it is far better to perform a feasibility study under Government contract than to do it on your own. It is better from two points of view: the obvious one, and the fact that you get a more direct pipeline to the requirements and the technical guidance of NASA.

MYERS: In a speech before the NASA-Industry Program Plans Conference, February 11, 1963, James Webb, Administrator of NASA, stated

> As a policy in making prime contract awards we are steadily moving in the direction of insisting that prime contractors obtain components from those sources which have already developed reliable hardware. Our object here is not only to insure that NASA obtains the best available performance, but to encourage prime contractors to seek out superior subcontract skills among companies of proven performance . . .

This policy seems to indicate that firms which already have proven performance in specialized areas such as control systems or cryogenic facilities will continue to receive very favorable consideration in future contracts. Is this substantially the current policy of NASA?

SEAMANS: Yes. This, I believe, is the correct approach. I think those industries that demonstrate that they can do a job which meets all the performance requirement, that stay substantially within costs and schedule, are the companies that ought to stay in this business.

MYERS: Thus, prior performance is given a high rating in terms of the criteria by which contractors are selected.

SEAMANS: It most certainly is. However, this does not prevent companies that have not had an interest in this kind of business from entering the field. But they must understand that they are not going to receive contracts by submitting brochures. Contracts will be awarded on the basis of technical and administrative competence.

Opportunities and Challenges in Space Procurement

Auspices: *Chicago Area Research and Development Council*

Presiding: **MURRAY JOSLIN,** *Chairman, Chicago Area Research and Development Council*

Introduction

MURRAY JOSLIN

Chairman, Chicago Area Research and Development Council

The objectives of the Chicago Area Research and Development Council are to expand existing research and development and bring into being new research and development capability in this part of the Midwest. We consider these objectives, in the broadest possible sense, to be in the national interest. This Conference on Space-Age Planning has identical objectives.

This session is perhaps analogous to commencement exercises. The period that has gone before has been one of learning. The period that follows is to be one of accomplishment. At the close of this session we, like graduates, are expected to put into action what we have learned at the Space-Age Planning Conference. The graduate's diploma carries with it a great responsibility, the obligation to repay the collective community that made its achievement possible. Our mythical diploma carries an even greater responsibility; for the contributions we may be capable of making, if not made, might mean everything to our country's position in this the Space Age.

27 NASA Procurement Policies

ERNEST W. BRACKETT
Director, Office of Procurement, NASA

When NASA became an operating agency, one of the first questions considered was who would design and develop engines, satellites, space vehicles, and the other items which would be used in its program. NASA inherited from the National Advisory Committee for Aeronautics (NACA) three large research centers. Should these be expanded and other installations built to do this work, which is sometimes termed the "arsenal system," or should contractors be engaged to develop hardware items?

The decision was that the research centers would be used to do certain research work in order that NASA would be knowledgeable and capable of designing the program, but when it came to producing space hardware NASA would contract with commercial companies for its requirements. This has been its consistent policy. In fiscal year 1960 it spent 64 percent of the total amount appropriated by the Congress in contracts, and in 1962 this percentage increased to 90 percent. The total of NASA's authorized appropriation in the present fiscal year is $3.7 billion, and of this amount 90 percent or more will go to contractors. The amount requested by the President for next year is approximately $5.7 billion, and of whatever amount is appropriated, more than 90 percent will go to contractors.

An example of NASA's dependence on industry is the method by which we obtain liquid hydrogen. Hydrogen is a fuel that will be used to a large extent in space vehicles, and while it is theoretically a commercial product, there are small commercial requirements for it. The question earlier confronting NASA was: Should it erect its own plant with government money and operate them, or have a contractor operate them, or should it try to buy hydrogen from commercial contractors who built their own plants? Again the decision was to look to contractors rather than to engage in this commercial field. Today we have four large contracts for liquid hydrogen and are about to make a fifth, and the plants and production of this fuel are privately owned and financed by the commercial contractors.

These facts illustrate the part contractors are playing in NASA's program, and also the market available for companies which are or may wish to engage in this field. Our program is a national program, and any company, wherever it is located or whatever its size, is welcome to compete for what it is capable of contributing. As the program grows more and more, companies will be needed to perform NASA contracts and subcontracts.

The space field, just as did the automobile field, later the aircraft field, and then the missile field, seems certain to expand. While satellites and space vehicles are different from automobiles and airplanes, much of the basic mechanical technique is not so different, and many of the components which go into them are only an adaptation of things that are already being made. There will be changes such as miniaturization, lighter and stronger materials, longer life and greater reliability—but these are only refinements of things quite like items which have already been produced. There may also be new items developed as a result of research which is taking place. Companies that do get into this field may find that there will be adaptations of many of these things in the commercial field.

Some of you may be asking what NASA buys, how it buys, and what you should do to get into this field as prime contractors or subcontractors. Our system of procurement is a competitive system. We do not select a contractor because it has a plant or a capability and then give it a contract. We make known our requirements and ask companies to compete for contracts. It is therefore necessary for companies to go aggressively after contracts, both prime and sub. Our part is to make known what we need, where to find this out, and what will be expected of contractors.

NASA has eight research centers, and each of these contracts for the projects which are assigned to it. For instance, the Marshall Space Flight Center at Huntsville, Alabama, has the Saturn space-vehicle project and the Goddard Space Flight Center at Greenbelt, Maryland, contracts for weather and communications satellites. Each research center, in addition to contracting for research and the development of hardware, buys a substantial amount of supplies such as tools, wire, steel, and components for use in its in-house research work. The Marshall center stocks approximately 35,000 line items. We have a booklet entitled "Selling to NASA" which tells you the name and address of each center, some description of what it buys, the name and phone number of the top procurement man and small-business specialist at each center, and information about our procurement system.

If a company is interested in contracting with NASA, it should file with each procurement office with which it wishes to do business a Standard Form 129. This will place the company on the research center's source list for the field of contracting in which it specializes.

Whenever our specifications for requirements are detailed to such an extent that all companies will be bidding on exactly the same thing, we purchase by formal advertising; that is, we solicit sealed bids and award the contract to the lowest responsible bidder. However, most of our procurements, at least dollarwise, are for research and development—for things like the Apollo spacecraft where there are no specifications. For this type of item we ask companies to submit proposals which are evaluated, and the company which is considered best able to produce the item at a reasonable cost is selected. This type of contract is made by negotiation.

In procurements for research and development of over $1,000,000, NASA appoints a source board to evaluate the proposals submitted by competing companies. If the estimated cost of the contract is under $5 million, the board reports its findings to the director of the research center, who selects the company with which a contract will be negotiated if satisfactory terms can be agreed upon. If the estimated cost is over $5 million, the selection is made by NASA's Administrator with the concurrence of the Deputy and Associate Administrators at Headquarters.

The cost and time required to prepare proposals for the larger research and development contracts is substantial, and only those companies are invited to submit proposals which are considered to have the capability and experience to perform the work. However, any company may submit a proposal and it will be evaluated on the same basis as the invited proposals. NASA secures competition both in formally advertised and in negotiated procurements whenever possible. In a few instances one company is considered to be in a unique position because of its past experience or there is some other substantial reason why it should be selected as the contractor without competition, and it would be a disservice to other companies to ask them to compete when clearly the one company should be chosen.

Whenever a fair price can be established we use a fixed-price form of contract. However, in research and development work there are uncertainties such as unforeseen technical difficulties which may arise, and it is frequently impossible to arrive at a fixed price. In those instances the cost-plus-fixed-fee type of contract is necessary. This provides that the Government will pay the contractor all its reasonable costs for the work it performs, but the fee, which is its profit, is fixed at the inception of the contract. The average fee for this type of contract is approximately 6.5 percent of the cost estimated at the time the contract is made.

This type of contract does not give contractors a real incentive to hold down costs. Therefore, we are trying to write provisions into our contracts which will give companies incentives to save costs and to deliver items which will perform in a superior manner. If contractors can produce at costs less than the estimates and more than meet the targets for performance which are set up in the contracts, we will pay a higher fee, but if the costs exceed the target or the item does not meet the standards set, the fee will go down. One of the problems NASA is experiencing with incentive contracts is the difficulty of fixing fair cost and performance targets because so many of the things we are buying have never been made before and there is no past cost and performance experience which can be used as a basis for arriving at fair targets.

NASA is placing a great deal of emphasis on the reliability of the items it buys. Satellites and space vehicles are expensive and technically complex, and a defective part cannot be replaced after a satellite is in orbit. Therefore, detailed inspection must take place to a greater extent than is usual in assembly-line production runs and a contractor's reliability program is closely watched.

NASA is largely in the research and development field. We contract for things which have never been designed or built before. We foresee no quantity production contracts, which often follow the development of military items. The companies which are producing engines, space vehicles, and similar items required in the space program are largely those which have produced airplanes, missiles, and complex electronic items. Many of these companies have engineering staffs experienced in these fields and the extensive test facilities which are necessary for this work.

There are opportunities in other types of prime contracting, for many more companies which do not have these facilities, but perhaps the largest opportunity for companies in the Illinois area is in the subcontract field. Some time ago we asked nine of NASA's larger contractors to give us information on their subcontracts. They reported that approximately 50 percent of the dollars they received in their prime contracts was spent in subcontracting, and they had more than 10,000 first-tier subcontractors and suppliers located in 46 States. Many companies which cannot handle a large prime contract can produce subcontract items. A part of NASA's procurement program is to see that prime contractors do subcontract as much of the work as is practical and that they obtain competition before placing their subcontracts.

One of the difficulties experienced by companies who want subcontract work is not knowing where to go or how to obtain subcontracts. It is suggested that these companies make known to the major airframe, missile, and electronic producers their capabilities. The larger prime contractors maintain source lists of companies interested in subcontracting. NASA does not direct prime contractors to select any subcontractors—otherwise it would take away to some extent the responsibility of the prime—but it does review and approve the prime's subcontracting system or individual subcontracts of more than $25,000 under a cost-type prime contract.

In order that companies may know where to go for subcontract work, a synopsis of each research and development procurement estimated to cost over $100,000 is placed in the Department of Commerce *Business Daily*, which is published each working day and is available by subscription, at the time the procurement is started. The synopsis also lists the names and addresses of the companies to which "Requests for Proposals" are being sent. This affords companies seeking subcontracts an opportunity to sell their products or services to prospective prime contractors before those companies prepare their proposals and line up their principal subcontractors. It also releases to the press a list of all major contracts which are awarded monthly and this list is carried in many trade journals. We also itemize in the Commerce *Business Daily* supplies for which NASA is formally advertising if the cost is estimated to be $10,000 or more.

NASA recognizes the importance of small business concerns in our Nation's economy and their potential contribution to the space program, and is actively seeing that they receive a fair proportion of our dollars at both the prime and subcontract level. Small business companies cannot be expected to produce large engines or space vehicles where huge facilities and large engineering staffs are required, but they can successfully perform many contracts and supply many of the components used in the large systems.

During the last fiscal year, of the 100 companies which received the largest dollar amount of NASA contracts, 24 were small business concerns. Forty percent of the dollars which NASA spent last year on contracts was with contractors located in surplus labor areas. Where small business companies competed for contracts, they were successful in receiving those contracts to the extent of 57 percent of the dollar amount. Of the 118,000 separate contractual transactions NASA had last year, large and small, small business companies received 66 percent. However, the majority of our dollars went into contracts for engines, space vehicles, and similar items which must be placed with larger companies. Last year 744 procurements were set aside for the sole participation of small business.

At NASA Headquarters and at each of our offices which do contracting, a small-business specialist is available to counsel and assist any company that wishes advice. We work closely with the Small Business Administration, and its field representatives furnish our contracting offices the names of small business companies that may be available to perform our contracts as procurement requirements arise.

Each prime contractor which receives a contract of $500,000 or more must have a small-business program and a small-business specialist whose function in part is to see that when subcontracts are placed small-business sources get an opportunity to compete. We receive periodic reports from prime contractors on the amount of subcontracts they place with small business companies and follow these up to be sure smaller companies are receiving their fair share of business.

At the time our major prime contracts are negotiated, we require the contractor to advise what items or parts of the work it intends to make in its own plant and what it will buy from others. This becomes a subject of negotiation, and after the contract is awarded the prime contractor may not change this pattern without the approval of the contracting officer. This assures a level of subcontracting. There are many items that subcontractors, particularly small business concerns which specialize in certain fields of work, can produce economically and with high quality.

Our statutory procurement authority is the same as that of the military departments, the Armed Service Procurement Act of 1947, and our procurement procedures follow quite closely those of the Armed Service Procurement Regulations—for instance, in the items of costs which are allowed or considered unallowable. Those of you who have had contracts with the Army, Navy, or Air Force will find our contract provisions very much like those in the military contracts.

After NASA places its major contracts, one of the military departments usually administers it for us. This includes such things as audit of vouchers for payment, approval of overtime, inspection, and so forth. We also ask one of the military departments to buy certain things for NASA if they are contracting for the same items. For instance, the Air Force bought the Atlas boosters used in the Mercury project because it was buying Atlas missiles. Where another agency buys an item for us, the contract is that agency's contract. It selects the contractor and uses its contract provisions, except for the patent provisions which must be in accordance with the NASA statutory provisions While NASA makes many of its contracts for construction, the Corps of Engineers is contracting for much of our requirements at Cape Canaveral and the Manned Spacecraft Center at Houston, Texas, and for some of the work at the Marshall Space Flight Center in Huntsville, Alabama.

One feature of NASA's contracts which is different from other Government agency contracts and of particular concern to some contractors is its patent provisions. These carry out the patent provisions laid down in the Space Act. If your company has any special questions in regard to our patent policy or clauses in the contract, your legal counsel should contact Gerald O'Brien, the Assistant General Counsel for Patent Matters, at NASA Headquarters.

The patent waiver policy is of particular interest to many. While the provisions of the Space Act form the basis for the waiver to contractors of title to commercial rights in inventions, they do not do so in any specific detail. The patent provisions of the Act are unique in this respect, for under the Act the Congress has imposed upon the Administrator of NASA broad discretionary power and responsibility to prescribe the circumstances which would govern the disposition of rights in inventions made under NASA contracts in a manner that will best serve the public interest. The National Aeronautics and Space Act provides that the government is to own inventions made in the performance of work required under NASA contracts unless the Administrator chooses to waive the right of ownership, which he may do when he feels that such action would serve the interests of the United States.

Each waiver granted by the Administrator must be subject to a royalty-free license to the government for the practice of the invention by or on behalf of the United States or any foreign government pursuant to any agreement or treaty with the United States. Accordingly, NASA waiver policy becomes, in effect, NASA patent policy vis-a-vis contractors' inventions.

The Act also provides for advice and assistance in these matters in that it requires that recommendations concerning proposals for waiver of rights of the United States to these inventions should be obtained from an Inventions and Contributions Board established within the Administration. In order to provide guidelines for this Board to follow in advising the Administrator in waiver cases, it was necessary to promulgate waiver regulations outlining NASA patent policy. This policy, and these regulations, should, it seems, be designed with the primary objective in mind of aiding NASA in the attainment of its mission established by the Congress for the space program. This is no simple matter and appears logically to require the attainment of two intermediate goals. First, our industrial community must be maintained as a sound and growing element of our economy, and second, a significant segment of that community must be encouraged to participate without reservation in this nation's aeronautics and space program.

As an increasing portion of the technological and scientific manpower of this nation is being devoted to space and defense-oriented technology, it is essential to a prospering economy that opportunity be given to industry to transfer the benefits of advances in these technologies into commercial channels. To the extent that the waiver of rights in inventions made under NASA contracts will achieve this objective, such waiver of rights would appear to be in the interest of the United States. After consultation with other agencies, after public hearings, and after considerable deliberation, NASA in October of 1959 issued its present Patent Waiver Regulations.

As our experience under these existing waiver regulations has grown, the conditions existing in 1959 have considerably changed. New programs have been established by Congress in a manner officially interpreted as requiring the taking of title by the government to contractor inventions made in these programs. Moreover, in recent months there has been increasing evidence of an agreement within the Executive Branch to at least the fundamental policies which are desirable in this area. Accordingly, we at NASA believe revision of our present regulations to be desirable. We believe that with the benefit of many congressional and industrial studies of this subject it is now possible for NASA to adopt new criteria which would more favorably serve in the attainment of the basic objective of this agency, while at the same time giving adequate recognition to the patent policies and programs of other government agencies.

We feel that revision of our present regulations is also desirable for the following reasons. First, one goal of NASA, if not the entire Government, has become to seek early commercial realization of the benefits of government-sponsored research and development. It is the opinion here that this goal could be more clearly emphasized than it is by our present regulations. Second, while the regulations currently in effect deny waiver of inventions of a particular space-oriented nature, it has become evident that emphasis should be placed not on a technological basis but rather upon considerations that include the ultimate uses of inventions as they affect the consuming public, competition, or essential government programs. Accordingly, NASA published on October 26, 1962, a proposed general revision of our present waiver regulations. Public hearings on this proposed revision were initially held on December 10, 1962, and were completed on January 28, 1963.

The general policy of these regulations is that waiver will best serve the interest of the United States when it will stimulate the application of new technology to peaceful activities and aid in the more effective utilization of the scientific and engineering resources of the nation. While waiver should not be granted where the private retention of exclusive rights would be inequitable to competitors, unfair to the consuming or using public, or contrary to the interests of the public health, safety, or security, we favor the waiving of exclusive rights to industrial contractors in other cases whenever such action will foster the prompt working of the inventions or is otherwise equitable.

At times, educational institutions and nonprofit or commercial companies may have ideas for basic or applied research which they believe will advance the space program and which they wish to pursue at NASA's expense. Such ideas may be submitted as an unsolicited proposal for a contract and they will be considered by NASA. Ten copies of such proposals should be submitted. They should include information about what the contractor wants to do, how he will try to do it, what results might be expected, and what it will cost. You will find information about unsolicited proposals in the booklet "Selling to NASA."

Unsolicited proposals may be submitted to the Office of Grants and Research Contracts, Headquarters, NASA, which will see that they reach the proper program and technical offices for review and consideration. If the idea will be supported by NASA, procurement will be initiated and the proposer will be informed. If it will not be supported, a letter so stating will be sent to the proposer. The average processing time of review is about 6 months although we are trying to speed this up.

Unsolicited proposals are not the way to sell items of existing hardware. If a requirement exists for such items our regular procurement processes are used and, if possible, competition is obtained. An example of the type of project which lends itself to unsolicited proposals by commercial companies is a feasibility study for some new ideas which may eventually result in a hardware item.

As stated at the beginning, NASA is heavily dependent on its contractors for the success of the space program which means so much to our country and the free world. There will be commercial applications from things which contractors will learn in the performance of space contracts and subcontract work. If you are interested in this field of business you need to compete for contracts and we hope you do. It will take team work between contractors and the government to make this country number one in space exploration.

28 Impact of the Lewis Research Center on Midwest Industry

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The purpose of this paper is to describe the Lewis Research Center of NASA and what it may mean for those who are interested in, or concerned with, space programs in the Midwest. There are a number of ways in which the Lewis Research Center may be said to have an impact on Midwest industry.

First, and foremost, is the existence of the Lewis Center in the Midwest at Cleveland, Ohio. One of 11 major centers of NASA, the Lewis Center is currently the second largest with a staff of approximately 4,500 people, 1,500 of whom are professional engineers and scientists.

The major tasks of the Lewis Center are research and advanced technology in propulsion and power for space flight. (See fig. 28–1.) Physically, the Center occupies 350 acres at the Cleveland Airport with an auxiliary location of 6,000 acres near Sandusky, Ohio. Lewis comprises extensive laboratories in many buildings for virtually every kind of physical (fig. 28–2), chemical, electrical, and metallurgical research. (See fig. 28–3.) In addition, unusual tools for propulsion and power technology include such items as altitude facilities for engine operation (fig. 28–4), research size rocket test stands (fig. 28–5), including the one fitted with a water spray tower for silencing and scrubbing exhaust products (fig. 28–6), high-speed wind tunnels of various sizes, such as the one with a Saturn vehicle in it (fig. 28–7) and one (fig. 28–8) which has a 10- by 10-foot test section with speeds three times the speed of sound. These tools also include turbopump test stands for liquid metals (fig. 28–9), space simulation chambers (fig. 28–10), computing and data processing equipment (fig. 28–11), radiation sources such as the cyclotron (fig. 28–12), and a 60-megawatt reactor (fig. 28–13) which is beneath the shielding shown and which is contained in the building shown in figure 28–14.

FIGURE 28–1.—The Lewis Research Center.

The Lewis Center came into being in 1941 as an outgrowth of the power plants group at the Langley Research Center of the National Advisory Committee for Aeronautics, established in 1917 as the nation's first research laboratory for studying flight. During World War II, the Lewis Center made major contributions to reciprocating engine cooling and high octane fuels. The period immediately following saw the development to a high degree of the air-breathing turbojet and ramjet engines. Development of these engines relied heavily on basic results from compressor, fuels, combustion, and turbine research at Lewis. Every major U.S. engine flying today's jet aircraft has been put through its paces at the Lewis Center to have some item or other of Lewis research incorporated into it. Early work on liquid-fueled rockets, mostly high-energy propellant rockets, paralleled the air-breathing program and expanded rapidly in 1957. The current program of the Center is aimed at advancing the technology of chemical, nuclear, and electric rockets, and of space electric power for a wide spectrum of power levels. It includes the background research and technology in metallurgy, basic chemistry, fuels, fluid flow, heat transfer, electronics, control dynamics, nucleonics, and other topics pertinent to these engines and to new and unusual propulsion and power generation systems. New activities added at Lewis within the year include responsibilities for development as operation articles the Centaur launch vehicle, the improved Agena launch vehicle, and the 1,500,000-pound-thrust M–1 engine. Centaur and M–1 are based on the hydrogen-oxygen technology which Lewis pioneered for NACA within the last decade; the technology of flying liquid hydrogen is vital to many of our future missions, notably Apollo. Centaur itself is a vehicle that is planned to soft-land robot instruments on the Moon.

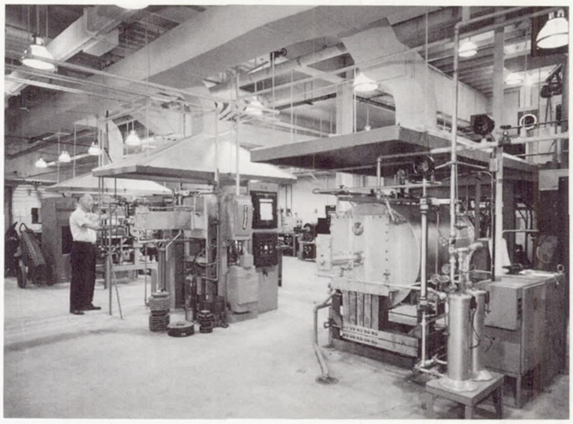

FIGURE 28–3.—High temperature materials laboratory.

FIGURE 28–4.—Altitude test facilities.

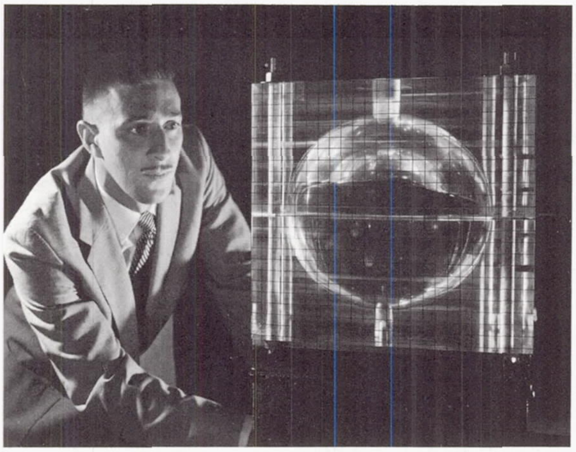

FIGURE 28–2.—Study of the behavior of liquids in various environments.

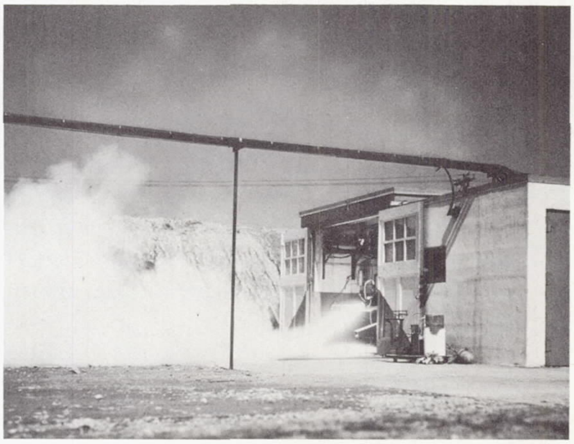

FIGURE 28–5.—Static rocket tests.

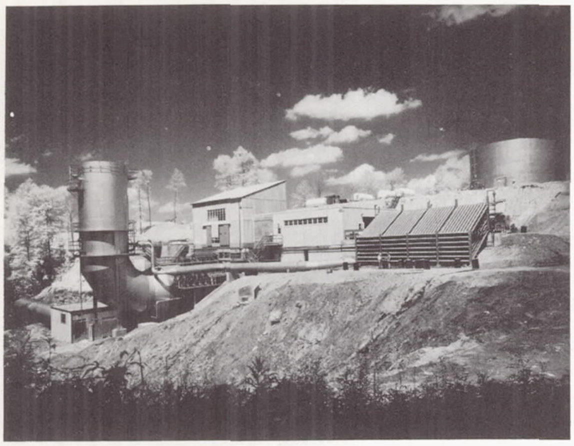

FIGURE 28-6.—Large rocket test stand.

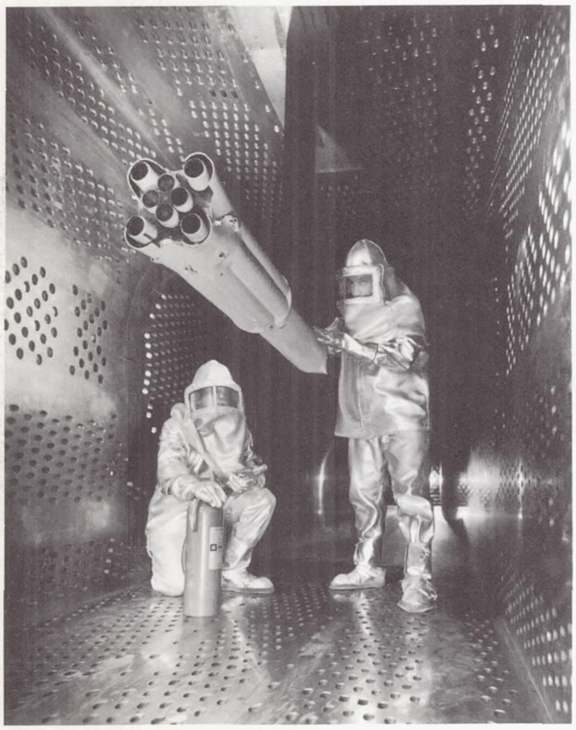

FIGURE 28-7.—Saturn I model in 8- ×6-foot supersonic wind tunnel.

Another way in which the impact of the Lewis Center may be examined is in terms of the money that is expended. In fiscal year 1963, for example, approximately $389 million of NASA's $3.7 billion budget will have been spent from Lewis, as follows: $37 million for salaries in Cleveland; $74 million for supporting the Center and for construction of facilities, two-thirds of it in Northeastern Ohio; $201 million for major projects, mostly in California; and $77 million for smaller research and development projects, both in-house and out-of-house, and widely contracted throughout the country. Although the name Sciaky is seen on the huge electronic beam welder, the name Chicago Bridge and Iron on the 30-foot-diameter space-vacuum facility for electric rockets, the name Flexonics on equipment in the rocket laboratory, and although studies on space research are being made at the University of Chicago, Armour Research, Northwestern, and Illinois Institute of Technology, the Midwest is not receiving a share of the space research and development dollar in proportion to its economy and population compared with that received by the coast areas and certain southern parts of the country.

FIGURE 28-8.—The 10- ×10-foot supersonic wind tunnel.

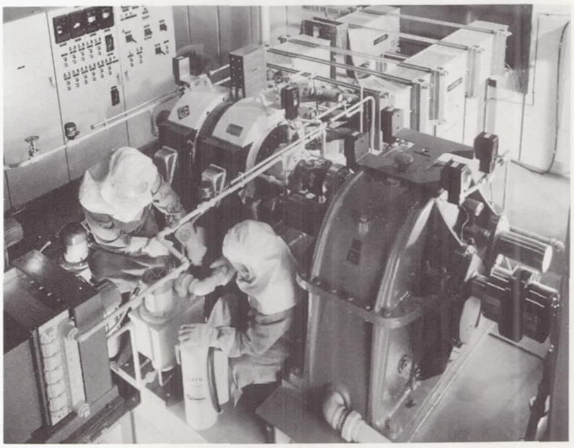

FIGURE 28-9.—Liquid metal pump studies.

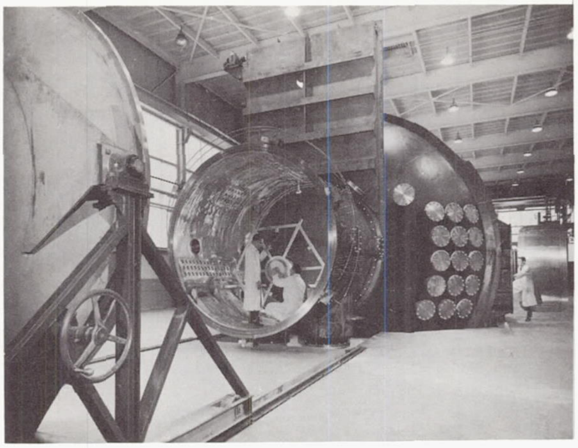

FIGURE 28–10.—The 25×80-foot space environment chamber for testing electric thrustors.

FIGURE 28–11.—Data acquisition and reduction.

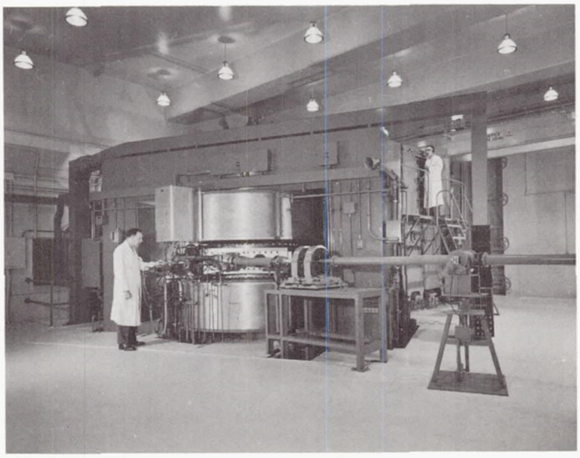

FIGURE 28–12.—The 60-inch cyclotron.

FIGURE 28–13.—The 60-megawatt research reactor, Plum Brook Facility, Sandusky, Ohio.

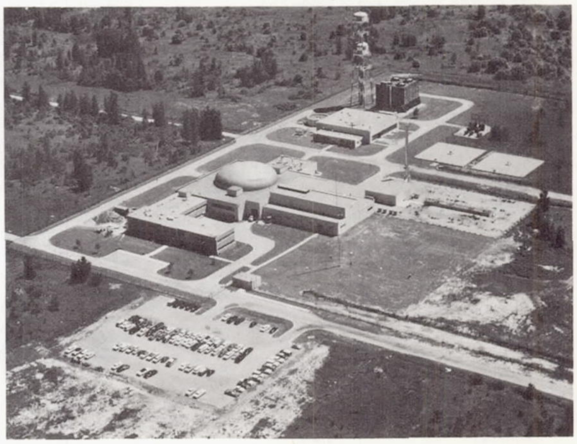

FIGURE 28–14.—Containment vessel of the Plum Brook 60-megawatt research reactor.

This introduces the third way in which the Lewis Research Center can impact Midwest industry. The key word is participation. On the one hand, the space program needs the very best talent that it can muster simply because of the enormous difficulty of the technical tasks ahead. Some of these tasks have been described previously.

On the other hand, the very activities that make the space program succeed are creating the new techniques of manufacture, the new approaches to organization and management, and the new products, services, and ideas that spell progress and prosperity. The Midwest should be able to participate in the technologically oriented work of the space program. Research and development and the new areas of industrial activity that stem from them derive from intellectual activity of scientists and engineers. Consequently, these activities tend to concentrate where the intellectual environment is "right," where a high rate of fundamental inquiry is being pursued, and where there exists a nucleus of recognized experts in the fundamental sciences. This intellectual environment is usually associated with universities or with university-related research institutes. The Midwest is well endowed with great universities and great research institutes. Admittedly, the Midwest does not have the aircraft industry that has evolved into the launch vehicle and spacecraft business, nor the unique topography and climate of the deserts that have helped spawn the big rocket business. Nevertheless, it may be possible to catalyze greater participation in the Midwest in the technological work of the space program via the Lewis Center.

However, in most cases contracts for work must be awarded on a competitive basis—that is the law as enacted by Congress. That is, contracts to the Midwest cannot be awarded on the basis of friendship or sentiment, or a desire to give someone a fair share. Be warned—the many firms already in the aerospace field offer keen competition and the problems are tough. I do pledge our help at Lewis in familiarizing Midwest industry with the needs of the space program, particularly our part of it at Lewis, and with the status of the technology.

Still another impact of the Lewis Center is in the area of potential industrial applications of the results of the space program.

Research and development is a creative component of our nation's economy and so should exert a large leverage on its growth. Expenditures for research and development have increased more than 10 times in each of the last 2 decades, and they have now passed $16 billion; more than $12 billion is Federal money, mostly for defense and space. The sheer volume alone of the results that are pouring out from this research and development effort raises the question of how to hasten and increase the use of these results in the economy of the Nation. The space effort has been likened in its effect on the American economy to World War II.

NASA is experimenting with various methods of speeding and maximizing the entry into the economic stream of the country space-derived inventions, inovations, ideas, techniques, processes, and so forth. These methods involve better communication between space program participants and other industries. Descriptions of these programs by Louis Fong and Howard Gadberry have been presented in previous papers; they also have described new methods of forming metal, expanded uses of newer materials, and other current applications of space-related technology. The Lewis Center participates in this activity by screening both its in-house and its contracted programs for potentially useful innovations. These are then described in various appropriate methods, usually by suitable publication. Follow-up consultation may result.

The following examples from among more than 100 innovations with possible usefulness that have been identified at Lewis in the last few months indicate the kinds of item that are being pinpointed:

(1) Advanced nickel-based alloys with the following features: high stress characteristics at approximately 1,800° F, high impact strength, oxidation resistance, the ability to be cast into forms without high vacuum requirements

(2) An amplifier that can detect signals as small as microamperes at 30,000 volts d.c. level and give 1 percent accurate readings at ground voltage

(3) Inexpensive vacuum-jacketed connectors with very low heat leak for pipe and tubing for liquefied gases

(4) A portable electron-beam welder for field service; the unit is about 21 inches by 21 inches, weighs less than 100 pounds, and can weld tubing up to ½-inch outside diameter

(5) An optical torque meter capable of high precision for wide ranges of torques on machinery that may be rotating at extremely high speeds.

Recently, the Center has solved by consultation the problem of breakage in cores for small electrical resistors for one manufacturer and the problem of a difficult brazing job between two unusual materials for another concern. As the program grows, conferences, seminars, tours, movies, and displays are among the possible ways of disseminating information about potentially useful accomplishments from the space program at Lewis.

If history conveys a lesson, however, the biggest rewards from the exploration of space are completely unforeseen and unpredictable at this time. New discoveries, including those from the laboratory of space itself, create new knowledge; and knowledge is the basis of all of our economic gain.

Next, consider what might happen in fiscal year 1964. The NASA budget, which is currently up for debate in Congress, totals $5.7 billion, and the Lewis Center is represented in this budget at about $605 million. Of this money at Lewis $49 million will go to salaries, $17 million to operations, and $19 million to support of in-house research and development. These latter two amounts will probably be largely local procurement. Major projects on contracts are slated at $427 million; the programs Centaur, Agena, and the M–1 engine will take the lion's share of this project money. Some $26 million will represent the Lewis share of an $800 million construction of facilities program in the NASA budget, with $67 million for research and development contracts; about $22 million of this is already planned; $45 million remains to be allocated.

It is not known yet if Lewis will receive all of this budget. But examine for a moment what is entailed in the construction of facilities and in the research and development contracts. The construction of facilities part of the 1964 budget at Lewis consists mostly of alterations or additions to create more test capability with simulated space environment. Types of equipment include vacuum chambers of various sizes (from a few cubic feet to many feet in dimensions), vacuum pumps including both roughing pumps and oil diffusion equipment, cryogenic refrigeration equipment, and the associated pumping, piping, plumbing, controls, and instruments. The facilities budget also includes buildings and radiation-resistant shielding for assembly and disassembly of nuclear-fueled space-power apparatus. One item comprises a facility featuring an evacuated vertical shaft, 510 feet long and 28½ feet in diameter, for providing approximately 10 seconds of zero gravity for experiments that first are fired up the shaft and then are allowed to fall freely back down.

In the area of contracted research and development, there are a number of problem areas where ideas and hard work are needed. The broad projects and programs of the Lewis Center have already been described; here are some more specific needs. They have been selected with a view to identifying the kinds of things in which Midwest industry might be able to render assistance.

In the area of management of either liquid propellants for chemical rockets or liquid hydrogen for nuclear rockets, methods of controlling or damping the slosh of liquids in vehicle tanks are needed. Methods of determining the position and quantity of liquids in tanks during zero gravity are needed, and it is also desired to be able to estimate heat transfer and thus the amount of pressurizing gas necessary for cryogenic fluids in zero gravity flight more accurately than is now possible. Also, lighter weight high-strength tanks to contain liquid hydrogen are constantly being sought, perhaps tanks made of glass or combinations of glass with insulating materials and bladders for interliners.

For chemical rockets, new materials for ablation-cooled combustion chambers are desired to permit engine operation as long as 500 seconds with high-energy liquid propellants and without the complication of cooling the chamber. Visualize a simple rocket chamber that can be started, stopped, and throttled at will during space flight maneuvers. Hand in hand with ablation materials would be inserts for nozzle throats where composite structures, including pyrolytic materials or high-temperature metals, might be involved in order to retain throat dimensions during operation.

With regard to nuclear rockets, one need is for sensors for controls. For example, temperature-measuring devices that can be immersed in hydrogen at 4,000° R to 5,000° R and respond rapidly are needed; more accurate measurements of neutron flux in nonuniform flux fields are desired—for performance, the hotter the better! Thus, materials for fuel elements and methods of using them are very much needed, for in the nuclear rocket the technology of high temperature is being stretched to the very limit. A better statement of the dynamic properties of liquid hydrogen flowing through evaporator tubes is needed in order that the nozzle on nuclear rockets can be more accurately designed, and in order that the start-up problem on the nuclear rocket can be more accurately estimated. Research on the feasibility of gaseous reactors reaches an impasse at our lack of understanding of the hydrodynamic problem of fuel residence time, of radiant heat transfer to gaseous fuel, and of the criticality of gaseous cores.

With regard to electric propulsion, research on thrustors is in fairly good shape. It would take an exceptionally good idea to break in. The main problems lie in the power field.

Space electric power is needed over a wide spectrum of power requirements, at numerous voltages, both a.c. and d.c., for a wide variety of uses. The power levels range from hundreds of watts for communication, guidance, and experiments through many thousands of kilowatts to drive electric rockets on manned spacecraft at some distant date, at least a decade away, and maybe longer. These electric power systems must be lightweight and highly reliable as they may have to operate for at least a year for reasons of economy and, in many cases, in order to accomplish the mission.

To move from a bench demonstration of a feasible space electric power system to a flyable article may involve tens to hundreds of millions of dollars. Thus, it is exceedingly important to complete a sound research and development program before picking a particular item to develop into a flyable state.

Some areas where ideas could pay off include work on both primary and secondary batteries. Increased capacity under rapid discharge rates and better discharge-charge cycling characteristics for secondary batteries are needed. Besides these features, we would like to have low-temperature operation a possibility so that experiments can be turned on after long soaring periods in outer space.

Convenient solar cells will need to be extended to permit higher temperature operation and to be radiation resistant. Radiation resistance is particularly necessary for experiments that may fly in the region of trapped energetic electrons, since their concentration is now about 10 times that of the former Van Allen belt as a result of high-altitude nuclear explosions; this new source of radiation will probably last for many years, possibly about 100. Thin-film solar cells appear to be more radiation resistant than conventional cells and, if they can be put on flexible substrates, offer exceptionally great promise in convenience of packaging for launching into space flight. Furthermore, these thin-film solar cells may produce greater power per unit weight launched. They apparently can be made from such materials as selenium, silicon, cadmium sulfide, cadmium telluride, or gallium arsenide.

A very compact and rugged, although heavy, form of power source can be made from alpha-emitter radioisotopes combined with thermoelectric converters. Such isotope-fueled generators are providing electric power for several purposes in various nooks and crannies of the world: under the ocean, under bays, at the South Pole, and even in orbit. Possibilities for advance in this kind of power source are very much desired so that it can be useful for more than small power.

For intermediate power levels, that is, a few kilowatts or more, possibilities include small turbogenerators with closed-cycle operation with a gaseous working fluid—the Brayton cycle. Such systems would necessitate very efficient turbine compressor units that might operate at 2,500° R and 60 pounds per square inch into the turbine; these will need to be very efficient as three-quarters of the power generated in this kind of system is given over to compressing the circulating gas.

For electric propulsion the power requirements jump to orders of a few hundred to a few thousand kilowatts for unmanned space flight and from 10,000 to 30,000 kilowatts for manned space flight. Durations for the missions contemplated with electric propulsion are on the order of 10,000 to 30,000 hours, depending on which part of the solar system is being explored. Not only must these power-generating stations in the sky operate reliably for these long periods of time, but they must be designed to be extremely lightweight (less than 20 pounds per kilowatt) if the electric propulsion system is to be superior to other systems now in development. There are tremendously difficult technological needs associated with such a future space power program, and much of this work remains to be assigned. Much research is needed before any development can prudently be started. For example, cycles envisioned are either based on a turbogenerator driven by metal vapor heated by nuclear fuel, or a thermionic cycle with nuclear fuel. In the case of the turbine engine, fuel elements for high-temperature service in the presence of liquid metals are a need for the nuclear reactor. Virtually all aspects of the design of such reactors are a severe problem. Components for alkali metal vapors and liquids, that is, turbines to run on sodium vapor at 1,600° F or on potassium vapor at 1,700° F, are needed as well as the condensors, radiators, pumps, valves, lines, and so on. We are only beginning to understand the nature of the corrosion problems encountered with these liquid metals. The space radiator itself is a necessary adjunct of any power system, and for these big power systems it is apparently going to be by far the heaviest part of the system. A big unknown in its design is the extent to which it must be protected against meteoroid damage. The design of clever, reliable radiators that may be segmented, that may be folded and unfolded, or stowed and unstowed in some way during launch is a key problem.

Finally, the necessity for power conditioning equipment that is lightweight and reliable, commensurate with the rest of the electric power system, should be mentioned. Equipment, such as generators or alternators, inverters, transformers, and switch gear, that can go with these space stations, and that in order to be lightweight will probably entail high current densities necessitating considerable cooling, is a requirement; there is virtually no background of technology for this type of equipment in the United States at this point.

These remarks serve to introduce the Lewis Research Center, its goals and tasks, the magnitude of the effort that it will put forth during the coming year, the ways in which Midwest industry can expect to be affected by the presence of the Lewis Center, and some of the technical challenges that the work of this Center poses to industry.

29 Nuclear Propulsion—an Emerging Technology

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Although the events that took place beneath the west stands at Stagg Field in Chicago on December 2, 1942, have been referred to on at least several occasions during the Midwest Space Month, I believe that the subject of this paper gives me a particularly proprietary right to refer to that first controlled self-sustaining nuclear chain reaction. That first self-sustained nuclear reaction and the nuclear physics and chemistry work that preceded and followed it are examples of the unforeseen uses that scientific discoveries may eventually have. Although the general potential of a new source of energy could be postulated at that time, the impact on medicine, in industrial uses, in agriculture, in ship propulsion, and in large power generation systems could be only generally considered but not specifically anticipated at that time. Although we do not anticipate so fundamental a discovery in our space science and exploration program, we still anticipate major effects that will be felt in all fields as a result of the scientific and technological discoveries and procedures and manpower that are developed.

This paper presents a discussion of how nuclear energy, to a major extent, made possible by the scientific discoveries of those pioneers at Stagg Field in 1942, is being applied for use in the space program. Certainly, those scientists and engineers could not have anticipated these areas of current interest. Although this is still a comparatively new area of development in our space program, equipment has been tested and technology development programs are directed toward developing this whole new area of rocketry and power. It does now and will in the future offer many opportunities for industrial and research participation.

The early and practical utilization of nuclear energy in space is a major goal of this country's advanced propulsion and power generation program. To this end, we have adopted the program philosophy as follows:

(1) Early development
  (a) Use closest available technology
  (b) Determine feasibility
  (c) Evaluate flight problems
  (d) Provide early application of concepts
(2) Advanced research and technology
  (a) Provide technology for advanced systems
  (b) Evaluate feasibility of new concepts
  (c) Solve development problems.

Essentially, we utilize the closest available technology in order to provide early hardware developments which are aimed at determining the feasibility of systems and at evaluating the flight problems that we will encounter when we start operating systems in the flight environment. These early developments are so designed that they will provide a growth capability for early application in operational missions. While we proceed with this early development program, we consider that a major and essential part of the program is a parallel and continuing advanced research and technology effort. This effort will provide the technology in support of the early development program and of advanced high power systems, and it will also evaluate the feasibility of new ideas that are proposed.

Our program is composed of two major parts, nuclear rocket systems and nuclear electric power and propulsion systems. As might be expected, a large portion of these programs is a combined effort between AEC and NASA. Responsibility for providing the required reactor research and development rests with the Atomic Energy Commission. NASA assumes responsibility for the nonnuclear component research and development programs as well as for the integration of the reactor into operational systems and application of these systems in flight missions.

NUCLEAR ROCKETS

The nuclear rocket program is composed of several major hardware elements. The relationship of three of these elements, Kiwi, Nerva, and Rift, is illustrated in the figure 29–1. The reactor technology obtained from the Kiwi project will be used in the development of a flight propulsion system in the Nerva project. The Nerva propulsion system will be flight tested in the Rift stage. The Rift stage will be designed to fit the Saturn V launch vehicle in such a way that with continued development an early operational capability will be realized.

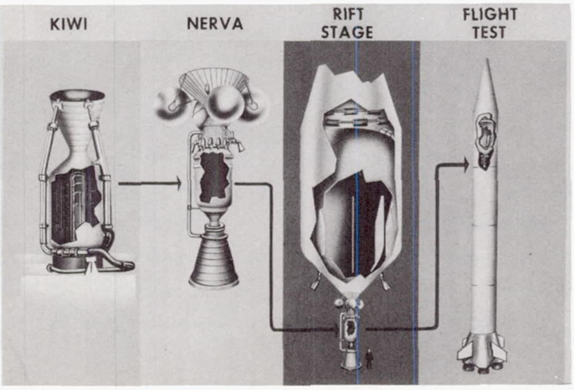

FIGURE 29–1.—Major steps in nuclear rocket programs.

Kiwi Project

Progress made in the Kiwi and Nerva reactor portion of the project sets the pace for the Nerva engine and Rift vehicle projects. Three Kiwi-A research reactor tests were run in 1959 and 1960 and were followed by three Kiwi-B experiments in 1961 and 1962. In the Kiwi-B series of reactors, the Los Alamos Scientific Laboratory established several designs which represented different approaches to the solution of problems associated with the use of the brittle graphite materials in the environment of a nuclear rocket reactor. In the conduct of this phase of the program, Los Alamos has worked with ACF Industries, Inc.; Air Products and Chemicals, Inc.; Egerton, Germeshausen, and Grier, Inc.; Bendix; Rocketdyne; and other groups. Armour Research Institute in Chicago has performed certain materials evaluation work for us and the Argonne National Laboratory has performed safety testing for us.

The first of the Kiwi-B designs, the Kiwi-B-1A reactor, was tested with gaseous hydrogen coolant flow in December 1961. A similar reactor, Kiwi-B-1B, was then tested with liquid hydrogen flow, as is required in a flight rocket engine, in September 1962. A photograph of that reactor at the test cell is shown in figure 29–2. This is the general configuration of the test setup of all reactors run to date. They have been fired with the exhaust jet pointing upward to simplify the facility installation. The nozzle in this test was regeneratively cooled with liquid hydrogen. The results of this test indicated

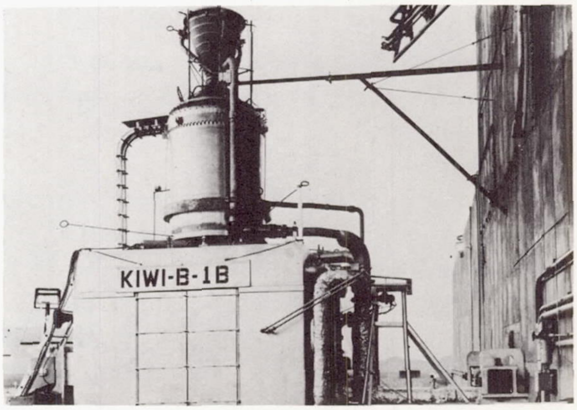

FIGURE 29–2.—Kiwi–B–1B reactor.

that the reactor could be started stably with liquid hydrogen. However, in this Kiwi-B-1B design, damage occurred in the reactor core similar to damage that had occurred in certain of the Kiwi-A tests. The fact that this damage has not been explained through extensive laboratory tests and analyses has made us discard the Kiwi-B1 design, for the present, as a candidate for the Nerva engine.

The most recent reactor test, the Kiwi-B4-A, was conducted by Los Alamos in November 1962. A photograph of that reactor is shown in figure 29–3. Although this reactor is, externally, very similar to the Kiwi-B1 reactor, the core design is substantially different. Almost as soon as the test of the Kiwi-B4-A reactor was started, flashes of light were noted in the exhaust jet. The test was continued until the flashes of light occurred so frequently that it was determined more could be learned by shutting down than by continuing. After disassembly of the reactor, it was found that there was extensive damage, probably due to vibrations that originated in the reactor. Work is now actively under way by Los Alamos and Westinghouse to modify the mechanical design so as to reduce the possibility of a recurrence of such vibrations to a minimum. Before the next reactor full power tests are run, component, subassembly, and full-scale mechanical and cold-flow testing will be conducted to evaluate the failure-mode hypothesis and to check the suitability of redesigns.

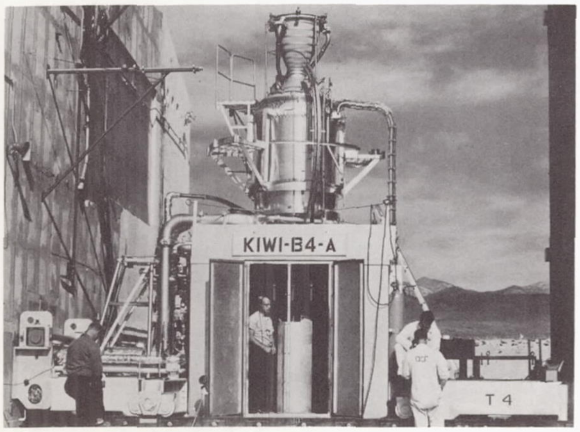

FIGURE 29–3.—Kiwi–B4–A reactor.

Nerva Project

The next element of our program is the Nerva development. This development is being conducted by Aerojet General Corporation with Westinghouse Electric Company as the principal subcontractor for reactor development. In addition, Bendix and American Machine and Foundry are subcontractors to Aerojet. A full-scale mockup of the Nerva engine is shown in figure 29–4. The engine stands 22 feet high. Shown in the figure are the reactor, the regeneratively cooled nozzle, the control drum actuators, and the thrust structure at the top of the engine. The turbopump, the tank shut-off valve, and gimbal bearing about which the entire engine may be swiveled for thrust-vector adjustment are mounted within the upper thrust structure section. The large spheres at the top of the engine are pressurized gas bottles used as a drive source for the pneumatic actuators in the system.

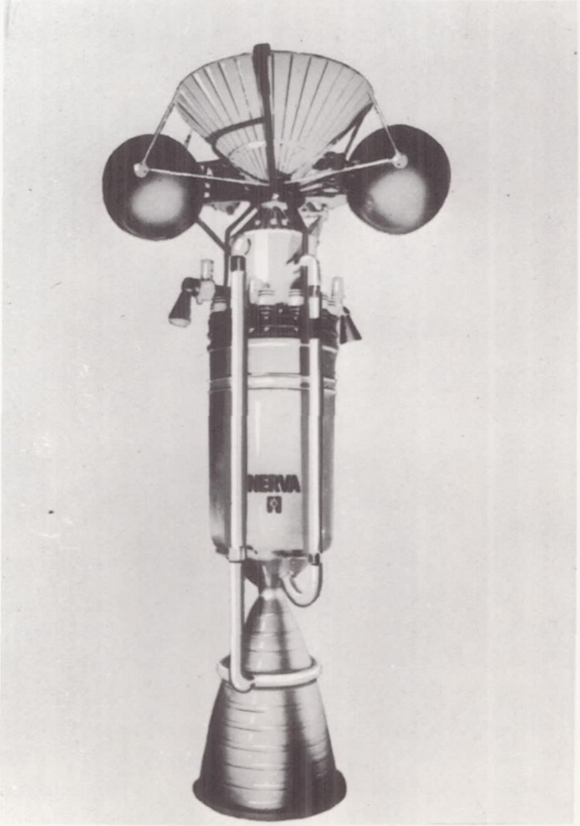

FIGURE 29–4.—Nerva mockup.

In the near future, our major emphasis will continue to be on the reactor of this engine. We are, however, proceeding with nonnuclear component work in both the engine and the flight-test stage programs aimed at evaluating the critical long lead time design and operating problems. While we will be pursuing work in these critical nonnuclear areas, the procurement of large numbers of flight components aimed at developing those components to high reliability will not be conducted until successful reactor operation is achieved.

Rift Project

As mentioned previously, the primary purpose of the Rift project is to flight test the Nerva propulsion system. However, its design will consider its eventual development to operational status as a third stage on the Saturn V vehicle. This stage is being developed by the Lockheed Missiles and Space Company.

Figure 29–5 shows a drawing of the Rift stage. It will be 33 feet in diameter, the same diameter as the Saturn V vehicle. From the exit of the Nerva jet nozzle to the top of the stage, it will stand approximately 126 feet.

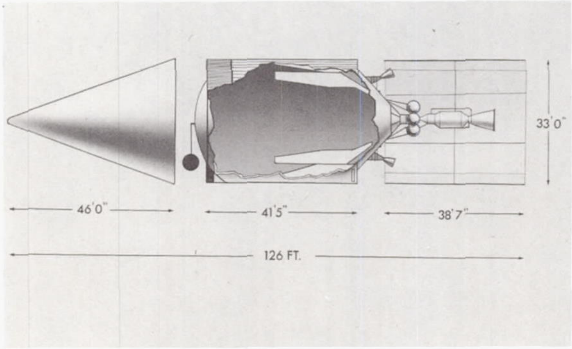

FIGURE 29–5.—Inboard profile of Rift.

Several unique problem areas are associated with the development of this Rift stage. It will require the largest flight tank ever constructed for liquid hydrogen. The combined effects of low temperatures, resulting from the use of liquid hydrogen, and the nuclear radiation generated by the reactor in the Nerva engine on the materials, structures, insulations, propellants, and so forth represent problem areas where research is now beginning. The nuclear flight safety requirements will require the development of new techniques for check-out, launch operations, and destruct systems in addition to those that are already provided for range and flight safety in nonnuclear applications. The combination of the comparatively heavy gimbaled nuclear engine and the large, but relatively lightweight, tank of liquid hydrogen presents unique aerodynamic and structural loadings and thrust-vector requirements. Finally, the requirements for engine restart and reactor cooldown after power cycles will impose additional factors that must be considered in the design of the tank pressurization, venting, and, particularly, the guidance and control. Four flight tests are planned on a trajectory, as indicated in figure 29–6, utilizing the Saturn V launch complex at the Atlantic Missile Range. These flights will be conducted with the Rift stage mounted on top of the Saturn V first stage using water ballast in a dummy second stage to obtain the proper stage acceleration conditions.

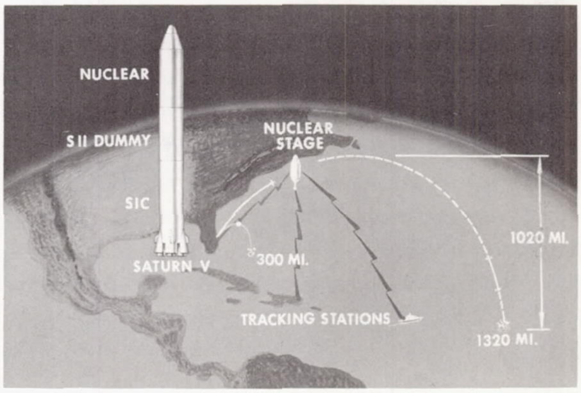

FIGURE 29–6.—Reactor in flight test (Rift).

Nuclear Rocket Development Station

The Nuclear Rocket Development Station (NRDS) is an area located approximately 90 miles northwest of Las Vegas, Nevada, in which facilities are being provided for all power testing of reactors, engines, and stages required in the nuclear rocket program. The large distance between NRDS and Las Vegas has made it necessary for the AEC, with NASA participation, to study comprehensively the means by which a community could be established near the test facilities so that recruitment and retention of the large number of high-caliber people required in the program can be encouraged.

The general layout of the test facilities that are being established at the NRDS is shown in figure 29–7. These facilities can be divided into reactor facilities, Nerva engine facilities, and Rift stage facilities. Some of the reactor facilities have, of course, been in operation for several years. An additional reactor test cell, Test Cell C, is now nearing completion, some of the Nerva facilities are under construction, and others are under design. In addition, support facilities will be designed and built during this year and next year. None of the Rift facilities have been funded for construction as yet, although design work will proceed in a limited way on certain of these facilities. It is important to emphasize that the facilities being built at the Nuclear Rocket Development Station in Nevada provide a national development capability for nuclear rockets that will not be duplicated anywhere else. This site could, therefore, be considered as the National Nuclear Rocket Development Station.

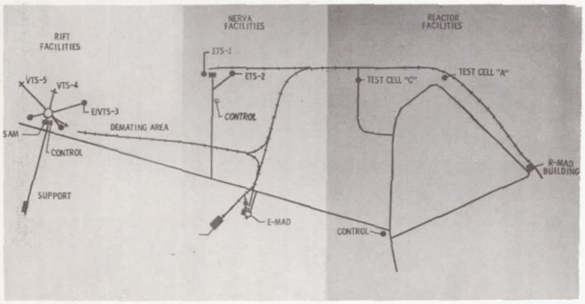

FIGURE 29–7.—Nuclear Rocket Development Station.

Nuclear Rocket Advanced Research and Technology

The last major element of the nuclear rocket program is the Advanced Research and Technology program which is aimed at providing technical support for our hardware development projects and also for providing the capability to build reactors and propulsion systems having performance characteristics well beyond those now under development. The principal work areas include reactors, nozzles, controls and instrumentation, turbopump and flow systems, system studies and mission analysis, and advanced concepts. Under the reactor area, the AEC and NASA are looking at concepts other than the graphite systems being used in Kiwi-Nerva. The Argonne National Laboratory is one of several groups participating in this effort. We are evaluating materials properties for such systems. We are working toward high specific impulse and long life systems over a wide range of power. This reactor area is the key to future advanced systems. However, much remains to be done in nozzle, pump, and control technology before we can develop reliable, high-performance systems.

NUCLEAR ELECTRIC PROPULSION AND POWER GENERATION

In addition to nuclear energy for nuclear rocket propulsion, nuclear energy for electric power and electric propulsion will be required. In the range of hundreds of kilowatts to many megawatts, the only practical source of long-life electrical power is nuclear energy. Applications representative of such power levels include orbiting manned space platforms, manned interplanetary spacecraft, communications satellites, and unmanned planetary probes. These applications can generally be divided into the needs for on-board power for communications, life support, data acquisition and so forth, and the power required for electric propulsion. A propulsion application, in the more distant future, is the manned interplanetary spacecraft. Such a vehicle would weigh a million pounds or more, might require orbital assembly, and would utilize a large electric rocket propulsion system requiring tens of megawatts of electrical power.

Table 29–I lists the program goals and major program elements of our nuclear electric power and electric propulsion programs. Several of the goals of both the power and propulsion subprograms are similar. Maintenance-free life of years will be required. Low weight is essential to achieve the full potential of electric propulsion systems—hence, the power program goal of 10 pounds per kilowatt of electricity produced. It is important to note that for on-board power systems, such low weight is desirable but not essential because of the large vehicles now being developed. With regard to the electric propulsion program, high thruster or engine efficiency is of major importance rather than engine

TABLE 29–I.—*Nuclear Electric Systems Program Goals and Elements*

Program	Goals	Elements
Power	10 pounds per kilowatt Watts to megawatts Long life	Snap-8 development Snap-8 flight evaluation Advanced research and technology Meca (zero-g flight tests)
Engine	High efficiency Long life 0.01 to 10 pounds thrust	Engine development Advanced research and technology Sert (Space Electric Rocket Tests)

weight, since the weight of the electric rocket engine itself is small (10 percent or less) in comparison with the electric-power-generation system needed to drive the rocket engine. The major electric-propulsion and power-generation program elements are listed in the right-hand portion of the table. Let us turn our attention to the first four elements, the Snap-8 development, the Snap-8 flight evaluation, the advanced research and technology, and the Meca project.

Electric Power Generation

Snap-8 development project.—The Snap-8 is a 30 kilowatt, reactor-powered, electric power generation system suitable for space flight applications. As shown in the figure 29–8, it is composed of two major components, the nuclear subsystem and the power conversion subsystem. The nuclear subsystem is composed of a nuclear reactor, shielding, and the associated pumps, tubing, and working fluid necessary to transfer

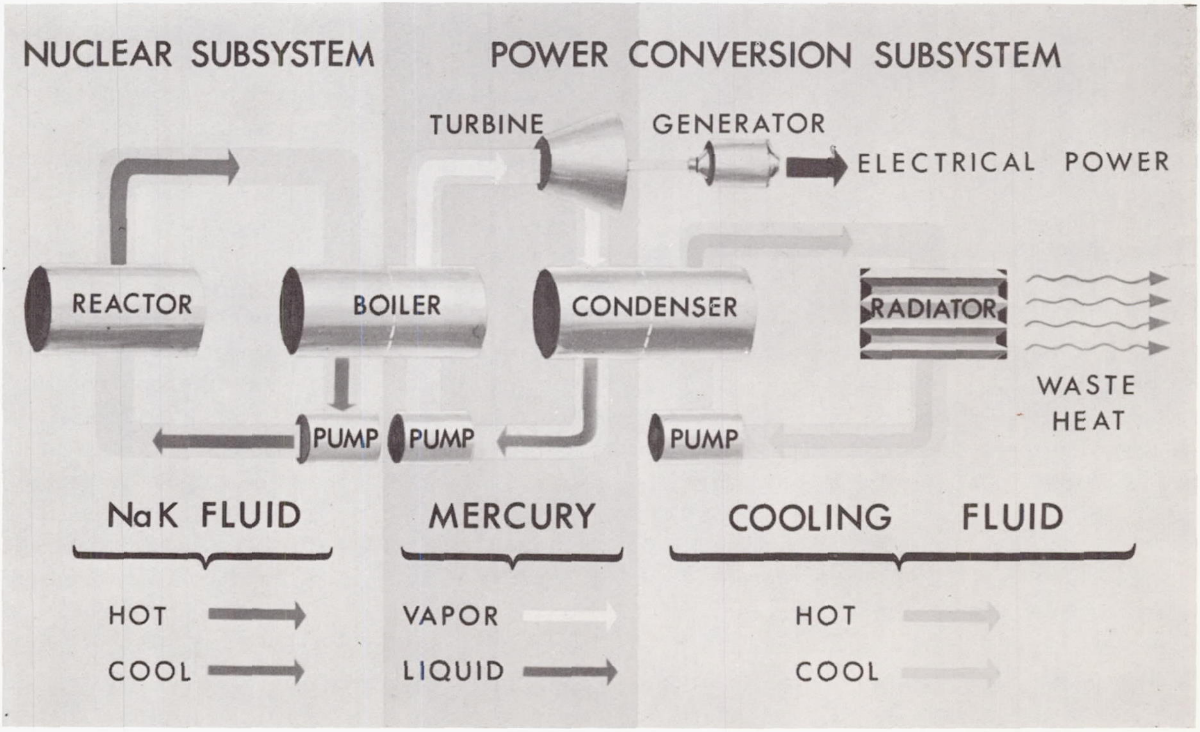

FIGURE 29–8.—Schematic drawing of the Snap–8 electrical generation system.

the heat generated in the reactor to the boiler. The working fluid, a mixture of sodium and potassium, is heated in the reactor and pumped to the boiler where its heat energy is transferred to the mercury in the boiler. It is then pumped back to the reactor and is reheated.

The heat energy transferred to the boiler causes liquid mercury in the second loop to boil. The resulting mercury vapor passes through a turbine which extracts enough energy to drive the generator. The mercury vapor is then cooled in the condenser and the resulting liquid pumped back to the boiler for reheating. The heat energy released by the mercury in the condenser is removed by a single-phase cooling fluid which is pumped to the radiator. The excess heat energy is then radiated to space and the cooled fluid is returned to the condenser. Not shown in the figure is a small fourth loop needed to provide cooling for the bearing lubrication system and various electrical components. In simpler terms, heat energy produced in the reactor is transferred to the turbine section where approximately 10 percent is extracted in the form of electricity. The unused heat energy is then rejected to space by the radiator.

Cycle temperatures range from 1,300° F in the reactor to 180° F in the generator. These temperatures coupled with the 10,000-hour maintenance-free lifetime requirement are presenting difficult problems in materials selection and bearing and seal design and particularly in the achievement of high reliability.

Snap–8 flight-evaluation project.—The objective of the Snap–8 Flight Evaluation Project is to evaluate the problems of starting and operating a Snap–8 Electrical Generating System in the space environment and to demonstrate such operation. The spacecraft is estimated to weigh as much as 10 tons including an electric propulsion system and will be launched by a Saturn IB launch vehicle. It is important to note that no major hardware commitments will be undertaken until Snap–8 Development Project progress warrants such action. Preliminary studies of spacecraft, design, operational safety problems, and so forth, are planned for initiation during this fiscal year.

Advanced research and technology.—The Advanced Research and Technology Project is aimed at acquiring the technology on which to base the development of future systems and is shown in figure 29–9. The 2,100° F, Rankine cycle, turboelectric system utilizes lithium and potassium as working fluids and a segmented radiator to minimize radiator weight. Figure 29–10 shows a thermionic direct conversion system which appears to be a simpler system than the turbogenerator system in that it has fewer moving parts; however, it required a maximum temperature of approximately 3,000° F. Both systems have design weights on the order of 10 to 20 pounds per kilowatt and are technologically far beyond current ground-based power-generating devices. The uncertain micrometeoroid environment and the lack of basic and engineering knowledge on materials, heat transfer, flow processes, and so forth, pose serious obstacles to be overcome before hardware development of such advanced systems can be undertaken. We, therefore, attach much importance to this area and, under the direction of the Lewis Research Center, are conducting a vigor-

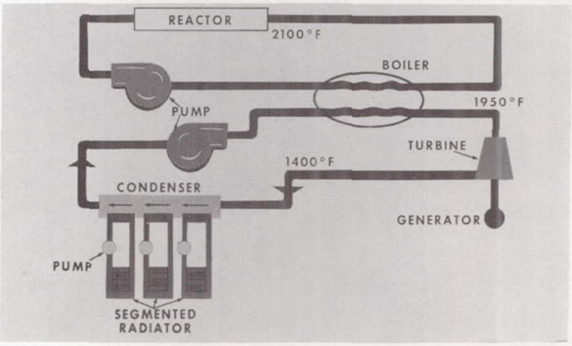

FIGURE 29–9.—Advanced turboelectric system.

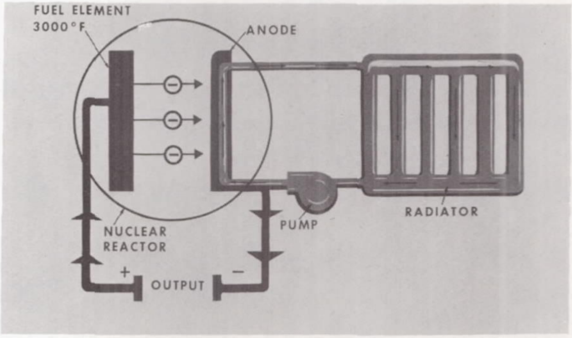

FIGURE 29–10.—Advanced thermionic direct conversion system.

ous program with approximately 25 industrial, research, and university contractors, as well as within NASA, to provide the necessary data. This program includes such items as the experimental evaluation of viscosity, specific heats, thermal conductivity, and so forth, of liquid metals and metal vapors of interest; the emissivity of radiator materials over a wide range of temperatures for space use; the boiling heat-transfer coefficients of the metal working fluids at the high temperatures required; and, the compatability of the metal working fluids with the containment materials and the components used in the system. This area of work also includes analysis and experiments on such system components as bearings, turbines, generators, pumps, thermionic emitters, and so forth.

Meca Project.—The Meca Project is aimed at determining the effects of relatively long-time zero-gravity exposure on liquid metal boiling and condensing heat transfer. The 8 or 10 minutes of zero gravity exposure needed to establish equilibrium conditions will be obtained in freely falling vehicles at high altitudes. Experiments weighing up to 1,000 pounds will be launched by small (110,000 pounds of thrust) solid rocket-powered vehicles shown in figure 29–11. Composed of available motors, vehicles will be launched from Wallops Island at a rate of 2 to 3 per year. The first experiments are in direct support of Snap-8 and will utilize mercury fluid and Snap-8 boiler and condenser component configurations. Data will be telemetered to the ground and also recorded on film. The camera package will be recovered by using techniques already developed.

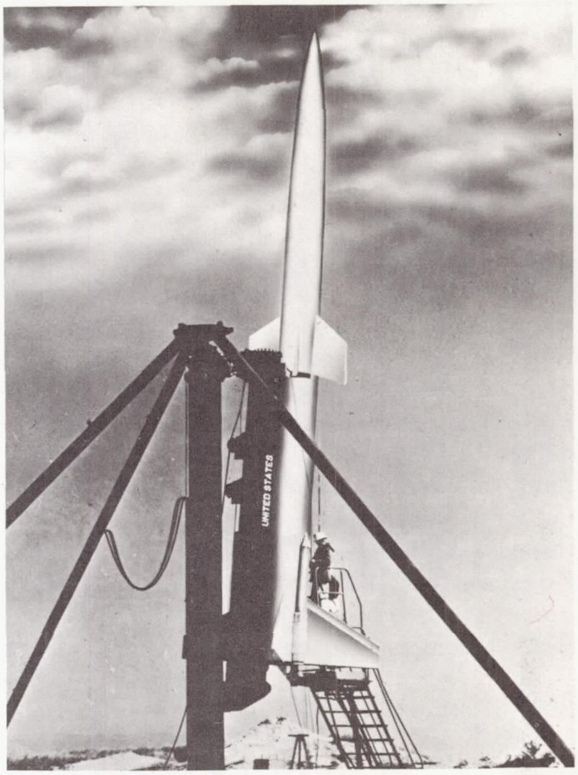

Figure 29–11.—Meca vehicle on launcher.

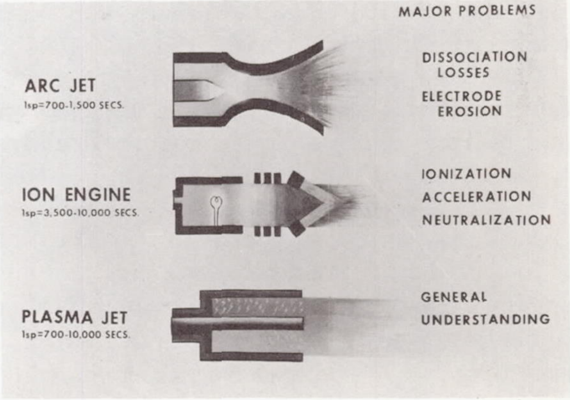

Figure 29–12.—Electric thrust chamber program.

Electric Propulsion

The propulsion subprogram is composed of an Advanced Research and Technology Project, an Engine Development Project, and a Flight Evaluation Project called Sert. (See table 29–I.)

Advanced research and technology project.—With regard to the Advanced Research and Technology Project, our efforts are directed toward providing the basic information necessary for the development of systems. Figure 29–12 lists the three main types of electric rocket engine that are being investigated: the arc jet, the ion engine, and the plasma jet. The arc jet develops thrust by heating a working fluid such as hydrogen or ammonia and expanding it through a nozzle. The ion engine depends upon electrostatic forces and reactions to accelerate a working fluid such as cesium or mercury and thereby develop thrust. The plasma engine utilizes electromagnetic forces to accelerate plasmas and thereby develop thrust. As can be seen in the left-hand column of figure 29–12, the arc jet has a specific impulse range of 700 to 1,500 pounds of thrust per pound per second of propellant flow. The ion engine develops impulses in the 3,500- to 10,000-second range. The plasmajet offers the potential of covering the whole range of the other two.

Another Advanced Research and Technology area that has been somewhat neglected in favor of work on thrusters is the power conditioning and control system. A program in these areas has been initiated this year and will be increased in 1964.

Approximately 26 industrial and university contractors are involved in the various portions of this overall program.

Engine development project.—The Engine Development Project consists of a number of development contracts for arc jet and ion engines aimed at providing hardware for ground and flight-test purposes. Hopefully, the engines developed as part of this project will be suitable for early applications. An example of this philosophy is the 3-kilowatt ion engine module, under development by the Hughes Aircraft Company, and the concept of clustering the basic 3-kilowatt unit into megawatt-size systems.

Figure 29–13 shows the basic engine module. It is a strip or rectangular engine rather than the circular or ring engine discussed in prior years. Its dimensions are approximately 3 inches by 6 inches. Figure 29–14 illustrates the clustering concept. The power levels have been selected so that each development would be suitable for the potential applications listed in the figure.

Sert project (*Space Electric Rocket Test*).—The Sert Project is composed of a series of electric rocket engine tests that, in general, cannot be performed meaningfully in ground facilities alone. By comparing flight-test results with data obtained in ground facilities, the limitations and accuracy of the ground tests can be determined. Because we can never expect to simulate the space environment completely, flight tests such as these are also necessary to prove or qualify specific engine developments for future mission applications.

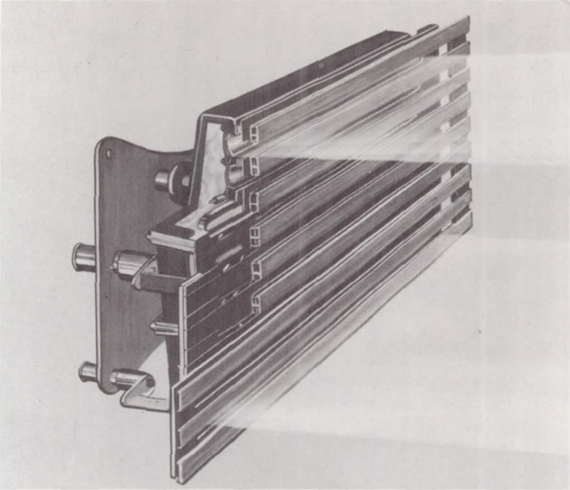

FIGURE 29–13.—Three-kilowatt ion engine module.

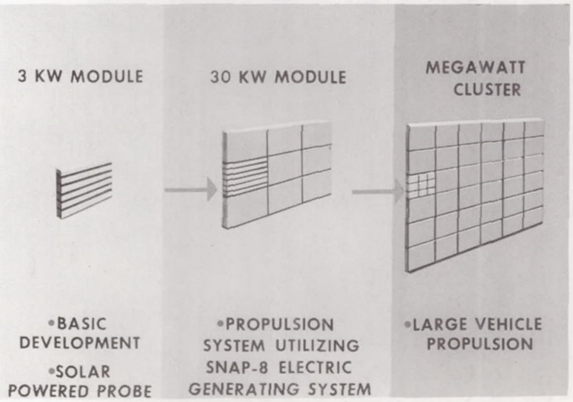

FIGURE 29–14.—Electric engine development.

The first Sert flight to be run later this year will consist of an ion-beam neutralization experiment. A 350-pound spin-stabilized capsule, built by RCA, will be launched from Wallops Island, Virginia, by a Scout launch vehicle on the trajectory shown in figure 29–15. This trajectory will give up to 55 minutes of free fall above the Earth's atmosphere. During this time, two ion engines will be operated in such a manner as to change the capsule spin rate. The amount of change in spin rate will be a measure of the thrust developed which, in turn, is a measure of the degree of neutralization achieved. Succeeding Sert flights will involve orbital trajectories as well as the ballistic type shown here.

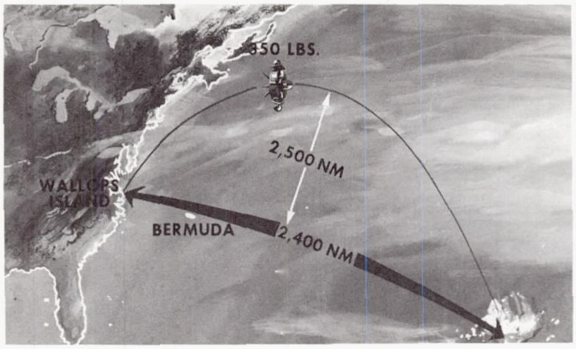

FIGURE 29–15.—Space electric rocket test (Sert).

CONCLUDING REMARKS

The door that was opened in Chicago in December 1942 has in less than 20 years led us to concepts and hardware for the utilization of that new energy source in space missions that could not be generally anticipated at that time. As a result of that dramatic scientific effort, we have established major goals aimed at the early and practical utilization of nuclear energy in space. We are convinced that a substantial effort is justified by the potential performance advantages and the many applications of these systems for difficult space missions. This work will lead us not only to the development of particular hardware items but will open new fields of rocket propulsion and power to permit us to travel freely in space.

Panel Discussion: The Job Ahead for the Midwest

Leader: EDWARD C. LOGELIN
President, Chicago Association of Commerce and Industry
and Space Month Steering Committee

ALBERT H. RUBENSTEIN
Professor of Industrial Engineering,
Northwestern University

ROBERT F. HALLIGAN
President, Hallicrafters Company

OTTO KERNER
Governor of Illinois

LOGELIN: The purpose of this panel discussion is to analyze the meaning of the Space Age Planning Conference—its meaning to the people of the Midwest, to industry, to education, and to the public. The panelists represent various phases of that public and will discuss their thoughts on the job ahead for the Midwest. Our topic is: "What do we, as businessmen, as educators, as citizens of Chicago, of Illinois, and of the Midwest, do about the challenges that have been infolded in this Conference on Space-Age Planning?"

RUBENSTEIN: I would like to make a few observations on what I believe to be some of the things that Midwest industry might do in order to prepare itself for the increasingly competitive research and development activity in the Space Age. These observations arise from intensive study over the past dozen years of the process of research and development in industry.

This activity, which we call research-on-research, involves about 15 graduate students and staff members in the Department of Industrial Engineering and Management Sciences at Northwestern University. Our research has covered many different industries and regions of this and other countries. We have studied and are in the process of studying research and development budgeting, project selection, the generation of ideas for research, the evaluation of research results for individual firms and industry groups, the organization of research and development in large and small companies, research and development capabilities, and many related topics.

Some of our observations thus far have relevance for the situation that this region faces in increasing its participation in the newer more sophisticated areas that are characteristic of Space Age research and development.

(1) The fact, well known to people who have played the research and development game, is that the results of research and development are highly uncertain and that there is no guarantee that specific projects or, indeed, the whole programs will pay off.

(2) There are severe time lags in the research and development process between input of resources and output of benefits in terms of increased profits or growth. We have examined many cases of successful, as well as unsuccessful research and development projects, and find that the times to payoff for a large proportion of the projects with high economic yields are typically of the order of 5 to 10 years.

(3) We have observed that a large percentage of the companies which are recognized for the development of major new products, materials, and processes have certain characteristics in common. Among them are: (a) they support a fairly large research and development activity; (b) they provide research and development with a voice in top management; and (c) they maintain a project portfolio that includes a significant percentage of high-level uncommitted work in areas related to their general fields of interest but not necessarily focused on specific end results. Much of this unfocused work is on a longer and more leisurely time schedule than that portion of the research and development program aimed at providing technical services or making minor improvements in products and processes.

(4) In many fields there appears to be a greater chance for a high payoff from more sophisticated, more scientific-based programs than there is from a straightforward brute-force attack, using conventional experimental methods. In other words, a deep study of the phenomena may yield solutions to many related problems when sufficient knowledge is achieved.

(5) Many of the companies, large and small, which have participated successfully in government-supported research and development work were able to compete in this field as a result of previously developed skills and research and development capabilities. There is sometimes a tendency to put the cart before the horse in seeking research and development contracts before the capacity to conduct them effectively is in existence.

(6) There appears to be a greater chance of payoff from both civilian and military research and development work when the scale of support for it is adequate and sustained over a long enough period to payoff. In this connection, I would like to mention some preliminary results of one of the half dozen studies of the research and development process currently under way at Northwestern.

This is a study of the expenditures and time required to develop new technical skills in an existing research and development laboratory. The preliminary data are from organizations in the aerospace industry, some very large and some medium-size organizations. The responding organizations provided information on a number of steps in the process of building the new technical skills. I would like to report on two pieces of these data.

The first is in answer to the question: How long did it take from the time work was initiated in this area to the attainment of the "first effective output," such as a paper published in a professional journal, a new product conceived, a government contract awarded, a difficult production or product development problem solved, and so forth?

The answer to this question is in terms of months and I will merely name certain fields and give the data for each company reporting on that field:

Infrared	24, 24
Data processing, computer	36, 18, 36
Reliability	28, 8, 12
Human Factors	6, 36
Ion Propulsion	6
Plasma Physics	15
Inertial Guidance	24

To these times must be added, in many cases, the time from recognition of the need for this skill to the initiation of work. This additional lag may be caused by the recruitment of people for this area from inside or outside the organization; designing, procuring, and installing equipment; and training or orienting new people both to the specific field and to the goals and methods of operation in the organization.

The other piece of data is on the number of professional man-months required as input to achieve the first effective output:

Infrared	300, 600
Data processing, computer	2,400, 60, 2,000
Reliability	100, 30, 48
Human factors	6, 48
Ion propulsion	60
Plasma physics	100
Inertial guidance	240

The cost of entering some of these new fields can be estimated by applying, as a rough approximation, a figure such as $30,000 per professional man-year including technical support and overhead.

Some policies which I believe might be followed by companies interested in significantly improving the scientific level of their research and development in order to compete more effectively in both civilian and government research and development are:

(1) Invest company money in research and development on a long-term calculated-risk basis and provide sufficient time stability to the program so that it is not jeopardized by short-term swings in economic conditions or company sales and profits. In other words, sustain it long enough for it to pay off, if it is going to do so.

(2) Concentrate a portion of this investment on a level of research fundamental enough to generate ideas for radically new products, processes, and materials.

(3) Establish and maintain a group of professional researchers on long-range more fundamental work of sufficient size to provide the potential for payoff.

(4) Seek out top-notch industrial scientists for this group. In other words, get a "fair share" of the very good people who do go into industrial research and development.

(5) Pay the going rate for these top notch people.

(6) Provide the environment and the scientific leadership that will encourage the development of significant ideas and skills from which products and proposals will flow.

HALLIGAN: In the past it has been said that the Midwest industry is capable of producing highly technical products of high quality and in high quantity. This statement is true, but it does not apply only to the past. It is equally true of the present, and will continue to be true of the future. It will be true whether we participate in the production of consumer goods, military products, or space-age systems. The statement is true because collectively we have the ingenuity, vision, and unity to make it true.

Midwestern industry has been especially noted for its ingenuity in manufacturing all kinds of equipment. By ingenuity we mean the ability to develop, to design, and to produce a product rapidly and efficiently and to have this product meet or exceed the needs of our customers. Contrary to recent statements, industry in the Midwest has led the country in the particular capability of ingenuity of product. One would have to travel far to find management and labor that would outshine that found in the great industrial complex of the Midwest. We should, therefore, be proud of our past contributions and our present contributions, and we should look forward to our future contributions to the defense and space programs with the same faith, vigor, and ingenuity that gave us our past accomplishments.

Succeeding in advanced programs for either military or space efforts will require the industry of the Midwest to have vision—or the ability to look toward the future requirements of both space programs and the everyday consumer.

In defense of the industrialist who manages a large complex business, I must say that the task of determining the direction in which he should lead his company relative to new designs and new products is a very difficult one. As in government, and as in universities, the industrialist must budget his expenses and must determine to the best of his ability in what areas he should invest his stockholders' monies in order to make his company grow. Unlike the government, the industrialist must balance his budget and must show a profit or else he, as an individual, is replaced.

We cannot afford, any one of us in industry, government or university, to compete in all of the programs that are being let by the government. But if we can develop the necessary insight to meet the needs of future programs, we can band together and at least give some of the other sectors of the country strong competition in future government business. If we have missed the boat in the past, as has been said, why must we continue to miss the missiles in the future?

Our job will not be an easy one, since the race has been started and we are admittedly late. But we of the Midwest are well known for our fortitude and our drive, and we will do everything we can to make up for lost time.

We need help in determining how we can best apply our research and development funds so that we will not go into great deficits trying to accomplish everything at once in an effort to compete directly with those who already have a head start.

We in industry are open to suggestions; we are eagerly searching for those areas that do hold promise for anyone who wants to try. The industry of the Midwest does try, and wants to keep trying with everything they have.

All of us have heard the oft-used phrase "in unity there is strength." In the events of the Midwest Space Month, April 9 to May 9, 1963, a gratifying unity prevailed between our local government, our local universities, and our local industries. These bonds should be strengthened, since each of us can help the other, and in turn we jointly can help the Midwest. The technical people in Midwest industry should be encouraged to participate individually and collectively with the Midwestern universities in their particular programs and to provide assistance in any way they can.

Let me give an example of how we at Hallicrafters feel about participating with universities on programs and how we are getting to know better what their programs are. Our Director of Research and Development has been assigned, practically full time, the job of establishing liaison with all of the Midwestern universities—

(1) To get to know the university people and their ideas
(2) To solicit their help in opening up new vistas of programs and products so that we in industry can better plan for the future
(3) To acquaint the universities with the capabilities of our industry and to let them know we stand ready to help in any way that we can in accomplishing their objectives.

In addition, we have made every effort to acquaint our local government with our capabilities and to keep them informed of future military and space programs with which we are familiar. Local government, on the other hand, has provided help through the proper channels to acquaint us with any additional information that they may acquire. We also have solicited help from other industrialists in the Midwest and, on many occasions, have joined up to make proposals, submit bids, and work together to acquire more business for the Midwest.

From the industrial standpoint we know that the military and space business of the future will be radically different from that of the past. No one industry, no one company, no one isolated group or organization is going to be successful in really increasing the Midwest's military or defense business without working together with others. We are making progress toward this end, but we still have a good measure to go. The universities, the local government, and the industries of the Midwest must join together their great knowledge and abilities so that they may capture their fair share of the military and space programs of the future.

We have the ingenuity to perform and we are gaining the vision. Now we must unite, and then we will be successful.

LOGELIN: Dr. Rubenstein, how can universities become more active in their cooperation with industry and, in the reverse, how should industries take action to enhance their cooperation with universities?

RUBENSTEIN: That is a difficult question. I will base my answer on the fairly fundamental premise that an industrial company and a university are two distinctly different types of institutions. This may appear obvious, but I think the implications of it are fairly deep. The goals of these two institutions are quite different and their methods of operations are quite different. I do believe that there is an area of cooperation but I think the best chance for this cooperation lies in an area of mutual interest, one which has already been identified and which is historic. This is in the area that includes education, science, and technology. Specifically, I think that there are two possible channels in this area. The first is the question of the training of scientists and engineers and the second is the generation and application of scientific and technical knowledge. I feel that this mutual interest is best served when each unit—the company and the university—is doing what it can do best; that is, the university is training people in advanced science and technology and is generating basic scientific knowledge at the highest possible level, and the company is using the skills of these people in an effective manner and is attempting to apply the fundamental knowledge which is generated by the university. I see no advantage, in the long run, of either party trying to carry out the other party's role, that is, industry attempting to do scientific training or the university attempting to do applied work or development work.

Therefore, in my opinion there are several possibilities of increased cooperation. One, for example, is that industry should provide a continuing and enthusiastic support for advanced level scientific and engineering graduate work at universities. This requires certain sacrifices by industry in terms of time and the loss of the talents of personnel for an extended period. It also requires meeting certain fairly stringent standards and requirements that the university has felt go with proper educational ventures. The university, on the other hand, should intensify its efforts to attract and maintain a relationship with industry in seminars and symposia, in technical programs that are of mutual interest. This does not mean that the technical or scientific level should be decreased and that these seminars should be given on a very low level. It means that more planning and thought should be given to the scheduling and the content of such seminars so that the competent people from industry can participate and learn something. Such programs have had a disappointingly low participation by industry people despite the fact that there has been a phenomental increase in seminars, at Northwestern, at any rate. A third possibility is that the talents of university faculties should be better utilized by industry on an individual basis, on a consulting basis; and I believe that this should be essentially at a high technical level so that a university person is always at the edge of his knowledge rather than merely passing on old information that he has had for a long time.

HALLIGAN: I don't want to start a controversy. However, I do know how Hallicrafters cooperates with the universities. Our director of research and development spends almost full time visiting universities in the Midwest, going into their laboratories, and attending joint seminars in which he finds out what studies the university people are making or planning, what their programs are, and tries to become acquainted with them. This is step one. Step two, he tries to acquaint the universities with what we are trying to do in industry—the two can go in different directions. Step three, after acquainting them with our program and becoming acquainted with theirs, he asks, in effect, how we can help the university meet its objectives. The university approach to a problem is a theoretical one—in which a concept is developed to a certain point. Beyond this point, where further development and testing are required, industry can meet this requirement. I think more industries could send representatives to universities. More of the university people could take a little interest in industry. In Hallicrafters, we have five consultants from universities on our staff who come in 1 day a week. They circulate through all our engineering departments, talk with our personnel, and also hold small seminars to try to bring them up to date on programs that are going on in the universities. More exchange of this nature would solve many problems and would produce university-industry cooperation.

RUBENSTEIN: I think the pattern you have described is a very admirable one.

LOGELIN: I think it behooves us in industry to get closer to the colleges and universities but sometimes I feel that there is great misunderstanding on the part of colleges and universities concerning what we may be doing in industry. We happen to have in our corporation a research laboratory employing about a thousand people with over a hundred doctors. A university man remarked to me "I imagine you have a laboratory and you call it that because you have one doctor."

Dr. Rubenstein, in your opinion, how can industry attract more top quality scientific and technical personnel; in other words, recruit them from education? What do you think is the most effective way to attract these individuals?

RUBENSTEIN: This problem has received a lot of attention in newspapers and on television recently. Perhaps a vital factor in attracting a top-quality scientist is the ability to supply him with colleagues. One might think that a new Ph. D., after spending a good many years in study, would be ready to go to work and start producing something useful. This may not be the case. It may require several years, particularly in a new field, for him to learn how to use his theoretical knowledge to produce hardware, and in this learning process he needs colleagues who are interested in the same things and with whom he can discuss problems. It is very difficult to place a new Ph. D. in a position in which he is the expert; for many years he has been used to turning to people who are experts and the abrupt change may be a traumatic one.

Providing scientific leadership in the laboratory and having it represented at the top levels in a company are very important factors that are charecteristic of our most successful large research-based companies. Another factor, a complex one, is providing the atmosphere conducive to scientific work, conducive to the generation of ideas, trying new things, risk taking, and so on.

In attracting scientists to or keeping scientists in the Midwest, there is also the factor of money. There is evidence—we have case studies involving our own graduate students—that many of those receiving Ph. D.'s in engineering and science are being offered several thousand dollars more for the same type of work by companies outside the Midwest region than by companies in the Midwest.

I think, given adequate pay and living facilities—these, incidentally, have, I think, been overplayed—the important things to a scientist are challenging work with colleagues whom they respect and with whom they can communicate and a chance to see his ideas develop into something at the other end, a new product or something that has some effect.

LOGELIN: Governor Kerner, you have gone to Washington on numerous occasions to help sell Illinois capabilities to the Federal Government and to the various agencies. Do you have any ideas or plans for the future for making this a regular activity?

KERNER: I have requested the legislature to provide me with funds to open up an Illinois office in Washington—not just for this purpose, but for keeping up-to-date on all of the things that are going on in Washington. I think one of the major purposes of our continuous contact with Washington is to find out what conditions the Defense Department or the NASA consider as precedent to securing contracts in the State of Illinois. One of the things for which we have been criticized is the fact that, although we do have the scientists and we do have the industrial and production know-how, unfortunately, they have not been brought close enough together. In order to deal with this problem, Dr. Lanier, Vice President of the University of Illinois, has contacted a number of Illinois industrialists to urge them to join together in a project to establish a research laboratory in the vicinity of the University of Illinois campus so that the scientists employed by the companies can work in the research laboratory with scientists from the university. Both industry and the university would, perhaps, like to keep complete control. However, both must be willing to yield some control in order to coordinate their functions and to establish a joint research laboratory. I am assured without any equivocation that the establishment of such scientific laboratories, particularly in the electronics field, would enhance the opportunity to secure Department of Defense and NASA contracts. This has happened in California, in Texas, and in New England. To cope with the problems of profit and risk taking, I have suggested that this be a nonprofit corporation so that industry and the university would share in the loss or profit in the general interests of the development of such a complex.

LOGELIN: Mr. Halligan, where do the graduates, both new and old, of our technical universities go upon leaving the Midwest and what, in your opinion, are the most significant reasons for these migrations? Who employs these individuals?

HALLIGAN: Many graduates of our engineering colleges are staying here in the Midwest. Some of them are migrating to the west coast and some of them are going to the east coast. It is obvious that we cannot prevent scientists from going to different areas if they like the climate better. However, it would help us retain our scientists here in the Midwest if there were more challenging problems to face. There is, for instance, a challenge in space and defense work. A scientist is looking for something brand new that has never been done before. He is going to follow the challenge wherever it is. When you put a billion dollars a year into one state, as in California, in projects that entice scientists, I can assure you that the scientists are going to go there. This explains our continuing concern with how do we get a little more of our share of this kind of dollar and of these kind of problems. If we had some help from the Government on research programs, we would maintain and retain in the Midwest many more scientists than we have today.

LOGELIN: This panel discussion is an easy one to summarize because it is a note of faith—faith in Chicago, faith in Illinois, faith in the Midwest, and faith in the industrial and educational complex. I was particularly impressed by two things that Dr. Rubenstein said. He pointed out that the timelag to payoff of research and the tremendous dollar cost of research and development must lead to an attitude which prevents us from becoming discouraged easily and which encourages persistance until the goal is attained. Thus, this subject is not one in which there will be speeches on research and development today, inauguration of a research and development department tomorrow, and payoff by a week from Saturday. Any company, as Dr. Rubenstein pointed out, that goes into this type of R&D must aim for long-range results. He also suggested that research and development, if it is to be successfully carried out in private industry, must have a voice in top management. I think more and more annual reports of leading industrial companies indicate that research and development is beginning to get that type of voice in top management.

Mr. Halligan sounded a note that Midwesterners can be proud to echo—that we do have capabilities, the potentials here in the Midwest. It is a question of translating capabilities into achievements, of making a team of industry, education, and government.

Governor Kerner sounded a note of courage and determination to move ahead with solid achievements. The time for more scientific application in the Chicago area is upon us but time for talking about it is over. This is a challenge to government, to industry, to education to meet, to work together, and produce results.

CLOSING REMARKS

OTTO KERNER

Governor of Illinois

This is a time for decision. Do we in the Midwest have the will, industry, universities, and government to pull together to place Illinois in the age of space in a major way? This question can be answered affirmatively in only one way. The time for educational meetings, for civic banquets, for the preliminaries is over. It is time now to secure or create the vehicle through which the role we hope for can be transformed from wish into reality. What is to be the vehicle that will take Illinois from the launching pad of an aroused and informed public opinion into a well-conceived, adequately powered, and sustained flight in space?

To those who have studied the matter, it is no secret that getting into space in a major way comes high. It requires heavy investment of highly trained personnel in the costly development of proposals whose success depends not only on basic scientific and industrial capabilities but also on the perilous task of divining the critical directions that space research will take and the means for their implementation. The competition that has already developed for NASA contracts is keen, well-financed, and sophisticated. This is a field in which those with limited resources or lack of contacts and prior know-how must proceed with caution.

The odds against attaining a major role in space at this late date can be overcome only by the whole-hearted efforts of industry, university, and government. They can be overcome only if NASA and the Government of the United States recognize that there is a public interest in their being overcome.

The government should recognize that a lopsided concentration of procurement, draining the Midwest of its scientific talent, and a lopsided concentration of contracts in a few giant government-oriented businesses are unhealthy. We are disturbed at the drain of scientific talent that we produce from our region with no compensating return. We are convinced that this situation is unhealthy for the state and for the Nation. We believe that the Government of the United States, as well as we, should do everything in its power to correct it.

Three things, combined if possible but severally if not, seem immediately worth doing. First, the major corporations of Illinois who have a stake in the state's future—a future that depends on our developing, attracting, and holding our share of the Nation's brains—should consider the advisability of accepting a role in leading a cooperative effort of the universities and medium-sized industry to find a significant place for the state in space. Only a sophisticated major prime contractor can afford the investment in developing proposals that can bring major systems contracts to Illinois. We have such corporations in Illinois. Our difficulty is that the space part of their business is not done in the state. We cannot, in good conscience, ask that they do anything contrary to their best business judgment. We can ask that they give full and earnest consideration to whether their own best interests do not coincide with the state's in seeking to broaden the base of our economy with major science-oriented capabilities.

Boston and Massachusetts have been plagued with some of the difficulties that confront us. They, like Illinois, possess splendid universities and a fine electronics base. Boston industries and universities are reported to be actively considering the investment of their own money in a not-for-profit corporation that can remedy their lack and provide the needed advisory role for universities and smaller companies. It is impressive that banks, insurance companies, and universities in Boston, as well as electronics firms, have concluded that they need to pool resources and share the risks of developing major proposals that are the necessary prelude to systems contracts. This is an example that we would do well to study and perhaps, if study shows it wise, to imitate.

A third and immediately possible step can be taken. A major NASA in-house capability in Illinois would give a tremendous—and perhaps the one needed—boost to getting the state and the region into full-scale participation in the Nation's space program. The reception of an Electronics Research Technical Center would be warm and hearty here in Illinois. Indeed, we would like to know what conditions NASA feels we must meet to justify the placing of a major in-house capability in the state. If we are told the conditions, I am sure we will meet them.

A nuclear propulsion center to study the best methods of harnessing nuclear power for space is a natural for this area. At the present time there is no other power source that can meet the known requirements. While the difficulties in harnessing nuclear power for space use are formidable, they are not beyond our scientific and engineering capabilities.

There is poetic justice in the idea that Chicago and Illinois, which opened the nuclear age, should develop the nuclear power devices for space travel. There is a sound scientific basis for locating the center in the area of the Nation's foremost peacetime nuclear laboratory—Argonne. With its preeminent capability in this field, Illinois also can capitalize on the capabilities of the University of Chicago, the University of Illinois, Northwestern University, Illinois Institute of Technology, Armour Research Foundation, and three of the Nation's 12 materials research laboratories. In addition, of course, there is our magnificent industrial base. There seem to be ample reasons why a major NASA in-house capability to explore the use of nuclear power for space should be located adjacent to Argonne National Laboratory in the Chicago area.

Such a nuclear propulsion center would move Illinois, Chicago, and the whole Midwest from the launching pad of talk and meetings into the exhilarating flight of meaningful action. With the industry and universities located here and the proven nature of their capabilities, we have an ideal location for such a facility. We produce the priceless ingredient, science and engineering Ph. D's in quantity. Why does it not make sense to move at least one major NASA operation to a prime source of its major requirement? Illinois' contribution in scientists and taxes makes it fully deserving of the location of a major facility that will employ some, at least, of both these scarce factors in its own backyard.

As Governor of Illinois, concerned with the future of its youth and its economy (they go together), I cannot urge too strongly the need for earnest consideration of effective, immediate action along these lines.

Appendix—BIOGRAPHIES

JOHN LELAND ATWOOD, Chairman and President, North American Aviation, Inc., received his A.B. degree from Hardin Simmons College in 1926, and a B.S. degree in civil engineering from the University of Texas in 1928. In 1955 he was awarded an honorary degree of doctor of engineering by the Stevens Institute of Technology. In 1960 he received the Distinguished Engineering Graduate Award from the College of Engineering at the University of Texas. Starting as a junior airplane engineer with the Army Air Corps at Wright Field in 1928, he left that position to become a design engineer with Douglas Aircraft Co. in 1930. Mr. Atwood joined North American Aviation, Inc., in 1934 as chief engineer and vice president. He became assistant general manager in 1938 and in 1941 was named first vice president. In 1948 he was elected president of North American. In 1960, Mr. Atwood was named chief executive officer, and chairman in 1962. In 1948, he was awarded the Presidential Certificate of Merit for his contributions to the war effort during World War II, and in 1955 the Republic of Italy conferred upon him that country's Commander of Merit decoration for his personal contributions to the aviation industry.

R. BOWLING BARNES is president of Barnes Engineering Company and a member of the Board of Directors. Dr. Barnes received his undergraduate degree from Birmingham Southern College in 1925 and a Ph. D. in physics from Johns Hopkins University in 1929. From 1930 to 1932, Dr. Barnes was a National Research Fellow at the Universities of Berlin and Breslau where he continued his work in infrared. In 1957, he received an honorary doctor of science degree from Birmingham Southern College. After serving as a physics instructor at Johns Hopkins and later at Princeton, he joined the Stamford Research Laboratories of American Cyanamid Company in 1936 as director of the Physics Division. In this capacity, Dr. Barnes pioneered in the application of physical instruments and methods to major analytical problems of the chemical industry. In 1948, he became vice president in charge of research and development at American Optical Company. In 1952, he was named president of Olympic Development Company, a research division of Olympic Radio and Television. In 1955, when Olympic Development Company became a separate corporation, its name was changed to Barnes Engineering Company. Barnes Engineering Company is engaged in the design, development, and manufacture of infrared and electro-optical components, instruments, and systems.

RICHARD J. H. BARNES was appointed Chief, Cooperative Programs, in the NASA Office of International Programs in January 1962. In this capacity he is concerned with the formulation and implementation of joint satellite, sounding rocket, and ground-based scientific programs established by NASA in cooperation with foreign space research organizations. Mr. Barnes joined the NASA Office of International Programs in 1961. Prior to this, he was affiliated with the Atomic Industrial Forum, Inc., where he was managing editor of the Forum's monthly news publication. Mr. Barnes previously served with the Atomic Energy Commission's Division of International Affairs and in the Bureau of Ordnance of the Navy Department. Mr. Barnes was graduated in 1951 from Dartmouth College, and received a Master of Public Administration degree from Harvard University in 1955.

GEORGE W. BEADLE was elected president of The University of Chicago in 1961. Dr. Beadle came to The University of Chicago from the California Institute of Technology, where he had been professor and chairman of the Division of Biology and acting dean of the faculty since 1946. Before that, he was professor of biology at Stanford University from 1937 to 1946, assistant professor of genetics at Harvard University from 1936 to 1937, and a research fellow and instructor at California Institute of Technology from 1933 to 1936. Dr. Beadle earned B.S. and M.S. degrees from the University of Nebraska and a Ph. D. degree in genetics from Cornell University. He has received numerous honorary degrees. Among these are: D. Sc. from Yale, Northwestern, and Rutgers Universities; M. Sc. from Oxford. Dr. Beadle is a member of: Genetics Society of America; American Association for the Advancement of Science; American Cancer Scientific Advisory Council; and National Academy of Sciences Committee on Genetic Effects of Atomic Radiation. He holds numerous awards. Among these are: the Albert Einstein Commemorative Award (1958) and the Emil Christian Hansen Prize of Denmark (1953). In 1958, Dr. Beadle was awarded the Nobel Prize for research in medicine.

RAYMOND L. BISPLINGHOFF has been director of the Office of Advanced Research and Technology, NASA, since August 1962. He marshals the planning, direction, execution, and evaluation of all NASA research and technological programs conducted primarily to demonstrate the feasibility of advanced concepts, structures, components, or systems that may have general applications to the Nation's aeronautical or space objectives. Before coming to NASA, Dr. Bisplinghoff was deputy head of the Department of Aeronautical Engineering at the Massachusetts Institute of Technology. His experience in aeronautical and space research includes a long association with the Department of Defense, NASA and its predecessor, NACA, and the aerospace industry. Dr. Bisplinghoff received the aeronautical engineer degree and M.S. degree in physics from the University of Cincinnati, and his Sc. D. degree from the Swiss Federal Institute of Technology. He is a Fellow of the American Institute of Aeronautics and Astronautics, the Royal Aeronautical Society, the American Association for the Advancement of Science, and the American Academy of Arts and Sciences, and a member of Phi Eta Sigma, Tau Beta Pi, and Sigma Xi.

ERNEST W. BRACKETT was appointed director of Procurement and Supply Division, NASA, in January 1959. The functions of this division include transportation and logistic planning. Prior to coming to NASA, Mr. Brackett was a Contract Specialist to the Director of Procurement and Production at the USAF Air Material Command Headquarters. A graduate of Cornell University, he received a bachelor of arts degree in 1925, and practiced law until 1942. After World War II he joined the Department of the Air Force as Chief of the Contracts Branch in the Procurement Division, transferring to the Air Material Command in 1950. He is a member of the New York State and District of Columbia Bars and has been admitted to practice before the U.S. Supreme Court.

EDGAR M. CORTRIGHT, Deputy Director of Space Sciences, shares responsibility with the Director in planning and directing all NASA programs for the unmanned scientific exploration of space including probes, geophysical and astronomical satellites and probes, biosciences, and development and use of light- and medium-class launch vehicles. Prior to this assignment, Mr. Cortright was Assistant Director for Lunar and Planetary Programs. Before heading that post, he was Chief, Advanced Technology Programs, in the Office of Advanced Technology where he directed initial formulation of the meteorological satellite programs, Tiros and Nimbus. Mr. Cortright earned his B.S. and M.S. degrees in aeronautical engineering at Rensselaer Polytechnic Institute in 1947 and 1949, resceptively. He joined the NASA Lewis Research Center in 1948 where he was chief of the 8- by 6-foot Supersonic Wind Tunnel Branch and later chief of the Plasma Physics Branch after attending Nuclear Reactor Training School at Lewis. He is an associate fellow of the American Institute of Aeronautics and Astronautics.

RICHARD J. DALEY, Mayor of Chicago, was first elected mayor in 1955. Mayor Daley attended DePaul University and received an LL.B. degree in 1933. In the same year he was admitted to the Bar and became a practicing attorney. Mr. Daley was elected to his first public office as a member of the Illinois House of Representatives in 1936. He served a 2-year term in the house and was elected to the state senate in 1938 where he served two 4-year terms. Mr. Daley was appointed deputy comptroller of Cook County in 1946 and served in that post until 1949. He was appointed director of revenue in 1949. In 1950, Mr. Daley was appointed county clerk. He was elected to a full term in that office in the fall of 1950, and reelected in 1954. He is a member of the American, Illinois, and Chicago Bar Associations and of numerous civic organizations.

CHARLES L. DAVIS has been corporate vice president in charge of Minneapolis-Honeywell's Military Products Group since February 1962. The divisions headed by Mr. Davis employ nearly 18,000 persons and accounted for approximately 40 percent of Honeywell's 1962 sales. Prior to being named head of the Military Products Group, Mr. Davis was general manager of the Aeronautical Division from July 1958 and was appointed a division vice president in 1959. He joined Honeywell in 1955 as manager of planning for the Aeronautical Division following 14 years of management and staff experience with the U.S. Air Force. Most of Mr. Davis' service career was spent in staff and management positions at Headquarters, Air Force; Air Materiel Command; and Air Forces Europe in command posts for planning, procurement, and production of aeronautical equipment, aircraft, and missiles. Mr. Davis attended the School of Aeronautical Engineering, Alabama Polytechnic Institute, where he earned a bachelor of science degree.

ANTHONY DOWNS is a Senior Economic Analyst, and also Treasurer and a member of the Board of Directors, of the Real Estate Research Corporation. He received a B.A. degree in political theory and international relations from Carleton College and M.A. and Ph. D. degrees in economics from Stanford University. He formerly was a member of the faculty of the University of Chicago in the Economics and Political Science Departments. Mr. Downs is the author of the book "An Economic Theory of Democracy" and a staff writer for the "Journal of Property Management." Also, Mr. Downs is the staff writer for "The National Market Letter."

JAMES C. ELMS joined the NASA Manned Spacecraft Center in 1963 as deputy director for Development and Programs, charged with responsibility for all MSC manned spacecraft development projects. Prior to joining NASA, he was director of Space and Electronics for Aeroneutronics Division of the Ford Motor Company. He received his B.S. degree in physics from the California Institute of Technology and his M.A. degree in physics from University of California at Los Angeles, where he was a member of the faculty as a research associate in geophysics. His research at UCLA consisted of seismic investigations of the Earth's crustal structure and Earth tides. Prior to World War II he was employed as a stress analyst at Consolidated Vultee Aircraft Corp. He is a member of the Institute of Radio Engineers, American Institute of Aeronautics and Astronautics, and the Armed Forces Communications and Electronics Association. He is a registered professional engineer of California and has patents, both granted and pending, in armament and electronics.

WILLIAM L. EVERITT has served as dean of the College of Engineering at the University of Illinois since 1949. Prior to that he was a professor of electrical engineering at the university. Mr. Everitt received his B.S., M.S., and Ph. D. degrees from Cornell University, University of Michigan, and Ohio State University, respectively. He was awarded an honorary degree in engineering from Bradley University in 1959. Mr. Everitt began his teaching career at Cornell in 1920. After some industrial engineering experience, he continued teaching at the University of Michigan and Ohio State University prior to joining the faculty at the University of Illinois in 1944. Mr. Everitt has authored a number of handbooks and publications pertaining to electrical engineering. He has served on a number of service and government advisory committees and organizations, mostly related to engineering. He has been a member of the American Institute of Electrical Engineers since 1925, serving on the board of directors from 1947 to 1951; Institute of Radio Engineers, of which he was president in 1945; American Society for Engineering Education, president, 1956–57; Engineers' Council for Professional Development, president, 1958–61; Acoustical Society of America; National and Illinois Societies of Professional Engineers; and the Western Society of Engineers.

WALTER D. FACKLER, Associate Dean, Graduate School of Business, The University of Chicago, received an A.B. degree in economics from The George Washington University, 1950, and a Ph. D. degree from The Johns Hopkins University. He was formerly: Accountant, Public Service Company of Indiana, 1939–1942; Assistant Professor of Economics, Assistant to the Dean of Faculties, Director of Foreign Service Review Program, The George Washington University, 1950–1956; Instructor in political economy, The Johns Hopkins University, 1952–1954; Assistant Director, Economic Research Department, U.S. Chamber of Commerce, 1956–1959; Senior Economist, Cabinet Committee on Price Stability for Economic Growth (White House Staff), 1959–1960. Dr. Fackler is a member of the American Economic Association and the American Statistical Association. He has authored numerous publications. Among these are: "Government Spending and Economic Stability," 1957, and "Tax Policy and Economic Growth," 1959.

HAROLD B. FINGER, appointed director of Nuclear Systems, Office of Advanced Research and Technology in November 1961, manages all aspects of NASA's 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 is also manager of the joint AEC–NASA Space Nuclear Propulsion Office, and in this capacity is responsible for all aspects of the development of nuclear rocket propulsion. He received this appointment in August 1960. Mr. Finger joined the Lewis Research Center staff in 1944 where he progressively assumed the responsibilities of head of the Axial Flow Compressor Section, associate chief of the Compressor Research Branch, and head of the Nuclear Radiation Shielding Group. He has specialized in research in the fields of turbomachinery, nuclear rockets, and shielding. He earned a bachelor's degree in mechanical engineering from City College of New York in 1944, and an M.S. degree in aeronautical engineering from Case Institute of Technology in 1950. Mr. Finger is a member of the American Institute of Aeronautics and Astronautics.

LOUIS B. C. FONG was appointed Director of Technology Utilization, NASA, in March 1963. Prior to this he was Chief, Industrial Applications, Office of Applications. From 1935 to 1936 he served as technical assistant at Massachusetts Institute of Technology in electromedical research. Mr. Fong graduated from MIT in 1935 with B.S. degree in electrical engineering. He graduated from George Washington University (1962) with a master's degree in engineering administration. He was granted a Federal Executive Fellowship (1961–62) at Brookings Center for Advanced Study. In his present position he is responsible for the program to translate technological advances occurring from NASA programs into practical, industrial, and commercial applications and to evaluate the results of this program and its economic impacts. Prior to his NASA assignment, Mr. Fong was associated with the Diamond Ordnance Fuze Laboratories; the National Bureau of Standards; Submarine Signal Co.; Stone and Webster Corp.; Pilot Radio Corp., and General Communications Co.

ROBERT F. FREITAG, Capt., USN, is the director of Launch Vehicles and Propulsion in the Office of Manned Space Flight, NASA. In this capacity he has the program management responsibility for the development and procurement of launch vehicles, engines and propulsion systems for Apollo, and future approved OMSF projects. Prior to joining NASA, Capt. Freitag was the Astronautics Officer for the Bureau of Naval Weapons. In that capacity he directed the Bureau of Naval Weapons space and astronautic systems development, supporting research, operational planning, and program management. He was graduated from the University of Michigan (B.S.E., aeronautical engineering) in 1941, and did graduate work in aeronautical engineering at the Massachusetts Institute of Technology. Capt. Freitag has been continuously assigned posts in the guided missile and rocket field since 1945. In addition to his primary assignments, he has served on numerous missile and engineering groups including the National Advisory Committee for Aeronautics Subcommittee on Propellers (1944–46), the NACA Special Committee on Space Technology (1958–59), and at present, the NASA Research Advisory Committee on Missile and Spacecraft Aerodynamics. From 1956 to 1958, he was a member of the Secretary of Defense Special Committee on the Adequacy of Range Facilities. From 1960, Capt. Freitag has been a member of the Launch Vehicle Panel of the NASA/DOD Aeronautics and Astronautics Coordinating Board. He is an Associate Fellow of the American Institute of Aeronautics and Astronautics, and an Associate Fellow of the British Royal Aeronautical Society. In 1959, Captain Freitag was awarded the Legion of Merit.

ARNOLD W. FRUTKIN was appointed director of the Office of International Programs, NASA, in September 1959. This office has the primary responsibility for NASA's programs of cooperation with foreign governments and scientific communities in space science and technology. Prior to this, Mr. Frutkin was affiliated with the National Academy of Sciences where, since May 1957, he was director of the Office of Public Affairs of the U.S. National Committee for the International Geophysical Year and, in addition, deputy for International Affairs to the executive director of this committee. During 1958–59, he was secretary to the International Relations Committee of the Space Science Board. He has been an advisor to the National Academy of Sciences Delegate to the International Committee on Space Research (COSPAR), since COSPAR's first meeting in 1958. He was been a member of the U.S. Delegation to the UN Committee on the Peaceful Uses of Outer Space and participated in the bilateral negotiations on cooperation in outer space matters with the Soviet Union. From 1945 to 1957, Mr. Frutkin was a managing editor and member of the Board of Directors of the Bureau of National Affairs, Inc., a private publishing company in Washington, D.C. Mr. Frutkin's undergraduate work was done at Harvard and his graduate work at Columbia University.

HOWARD M. GADBERRY, Assistant Director, Midwest Research Institute, earned a B.S. degree in chemical engineering from the University of Kansas and continued in graduate studies at the University of Kansas City, University of Kansas. He joined Midwest Research Institute in 1946 and was named Assistant Director, Chemistry Division, in 1957. Some of the programs in which he has been involved are: chemistry of propellants, plastic films, printing processes, cosmetics, emulsion technology, corrosion, paints and protective coatings, textile chemistry, cement and concrete, insecticides, germicides, and mildew proofing. From 1943 to 1946, he was with Phillips Petroleum Company. He was engaged in refinery process improvement studies involving corrosion, boiler, and steam problems; also, he worked on anhydrous hydrofluoric acid alkylation and catalytic isomerization. From 1941 to 1942 he was with Cook Paint and Varnish Company. His work included testing and evaluation of raw materials and pigments; comparison testing of competitive products; and reformulation of coatings fo rimproved performance and lower cost.

ROBERT F. HALLIGAN, President, Hallicrafters Co., graduated from the U.S. Military Academy in 1947 with a bachelor of military arts and sciences degree. He joined Hallicrafters in 1950 after serving as an Air Force officer for 3 years in the Proof Test Division of the Electronics Branch. From 1950 to 1954, he worked in the engineering, finance, production, and purchasing departments of the company. In 1954, he became Production Manager, in 1955, Operation Manager, and in 1956, Vice President of Operations. After serving in that capacity for 3 years, he was elected Executive Vice President in 1959 and President in 1961.

JOHN A. HORNBECK, before joining Bellcomm, Inc., in 1962, as president and a member of the Board of Directors, was Executive Director, Semiconductor Device and Electron Tube Division at Bell Telephone Laboratories, Inc. Dr. Hornbeck joined Bell Laboratories in 1946 as a research physicist in the Physical Electronics Department. In 1951 he transferred to the Transistor Research Department. He headed groups specializing in Semiconductor Physics from 1952 to 1953, and in Solid State Device Development in 1955 and assumed the position of Executive Director, Semiconductor Device and Electron Tube Division, in 1958. Dr. Hornbeck graduated from Oberlin College in 1939 and received a Ph. D. degree in physics from Massachusetts Institute of Technology in 1946. Dr. Hornbeck is a Fellow of the American Physical Society, a Fellow of the Institute of Electrical and Electronics Engineers, and a member of the American Association for the Advancement of Science.

JOHN E. HORNE became Administrator of the Small Business Administration in February 1961. Mr. Horne was formerly Administrator of the Small Defense Plants Administration, the predecessor agency of SBA, and was for many years Administrative Assistant to Senator John Sparkman, Chairman of the Senate Select Committee on Small Business. Mr. Horne was graduated in 1933 from the University of Alabama. He returned to the university to obtain his M.A. degree while studying under a history fellowship. Mr. Horne became Administrative Assistant to Senator Sparkman in 1947. In 1951 he took leave of absence to serve as Deputy Administrator of the Small Defense Plants Administration, and later was appointed by President Truman as Administrator of that agency.

LEONARD JAFFE was appointed Director of Communications Systems in the Office of Applications, NASA, in November 1961. In this capacity he is responsible for program direction of the NASA Communications Satellite Research and Development efforts. Under his direction programs have been established for the development of the Echo, Relay, and Syncom satellites. He is also chairman of the NASA International Ground Station Committee, which coordinates and plans the cooperative testing of experimental communications satellites. 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. 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. He is a senior member of the Institute of Radio Engineers, a member of Tau Beta Pi, Eta Kappa Nu, and the Ohio State Society for Professional Engineers.

SIDNEY L. JONES, Assistant Professor of Finance, Northwestern University, received a B.S. degree in economics from Utah State University in 1954 and an M.B.A. degree in 1958 and a Ph. D. degree in 1960 from Stanford University in finance and banking. Prior to coming to Northwestern Dr. Jones was on the Systems and Procedures staff at Lockheed Missile Systems Division; research assistant at Stanford University. Dr. Jones received the Ford Foundation Pre-Doctoral Fellowship 1958–59. He is a member of Phi Kappa Phi and Alpha Kappa Psi. He served as program coordinator for the Third National Conference on the Peaceful Uses of Space.

MURRAY JOSLIN, Vice President, Commonwealth Edison Company, is a graduate in electrical engineering from Iowa State College, and has been employed in the electric utility industry by Commonwealth Edison Company and its associated company, Public Service Company, for 40 years. Among his past positions in the public utility field have been: Division Operating Superintendent, Division Vice President, Assistant to Executive Vice President, and Assistant to the President. In 1951 he was placed in charge of the Nuclear Power Study Group which, working under an agreement with the Atomic Energy Commission, developed designs for several different types of nuclear power stations. In 1953 he was elected Financial Vice President, and in this position had responsibility for the financial and corporate activities of the company. In 1955 he became vice president in charge of Engineering, Construction, Production, and Research and Development. In February 1960, he was named vice president in charge of Division Operations and Nuclear Activities. In October 1961, he became vice president in charge of Finance, Accounting, and Nuclear Activities. In September 1962, he was appointed to direct the administration of the seven divisions of the company. Mr. Joslin is a Fellow of the Institute of Electrical and Electronic Engineers and a member of Western Society of Engineers and The American Society of Mechanical Engineers. He also belongs to Tau Beta Pi, Eta Kappa Nu, Phi Delta Phi, and Phi Kappa Theta fraternities.

OTTO KERNER, Governor of Illinois, received his bachelor of arts degree in 1930 from Brown University. From 1930 to 1931, he studied at Trinity College, Cambridge University, in England. He attended Northwestern University School of Law and was graduated Juris Doctor in 1934. Admitted to the bar in May 1934, he began working for the firm of Cooke, Sullivan, and Ricks. In 1935, he became a partner in the firm of Kerner, Jaros, and Tittle. In 1947, he was appointed U.S. attorney for the Northern District of Illinois. He served in that office until selected to run as county judge of Cook County. Elected that year, he was reelected in 1958. He was then nominated for and elected Governor of Illinois in 1960.

LYLE H. LANIER is executive vice president and provost, and professor of psychology at the University of Illinois. Dr. Lanier received his A.B. degree at Vanderbilt University (1923) and his M.A. degree (1924) and Ph. D. degree (1926) at George Peabody College. He was formerly head of the Department of Psychology (1950–59 and Dean of the College of Liberal Arts and Sciences (1959–60) at the University of Illinois. Before coming to the University of Illinois, he held the following positions: professor and head of the Department of Psychology, New York University (1948–50); professor and chairman of the Department of Psychology, Vassar College 1938–48); and instructor and assistant professor of psychology at New York University and Vanderbilt University. Dr. Lanier was formerly editor of the *Psychological Bulletin* and chairman of the Policy and Planning Board of the American Psychological Association. He has also been a director of the Social Science Research Council (1949–51, 1956–62) and member of the Division of Anthropology and Psychology of National Research Council (1949–52, and currently a member). He is at present a member of the Defense Science Board and of the Executive Committee of that Board.

RICHARD E. LASSAR, Chicago Regional Director of the Small Business Administration, directs all SBA programs and activities in Region 7, which includes Iowa, Indiana, northern Illinois, and southern Wisconsin. Prior to his appointment with SBA, Mr. Lassar was sales manager of the Combustion Division of the Enterprise Heat and Power Company of Chicago, a position he held since 1948. From 1946 to 1948 he was vice president and general manager of the Chicago Automatic Stoker Company and president of Production Control Institute. From 1939 to 1946 he served in several supervisory positions with the International Harvester Company. Mr. Lassar received his B.S. degree in commerce from Northwestern University in 1939 and also took post-graduate work at Northwestern University and Illinois Institute of Technology.

HALDON A. LEEDY joined the Armour Research Foundation in 1938 as a physicist. He became chairman of the Physics Research Department in 1944, director of the Foundation in 1948, and executive vice president in 1950. Mr. Leedy received his B.A. degree in physics from North Central College, Naperville, Ill., in 1933 and his M.A. and Ph. D. degrees in physics in 1935 and 1937, respectively, from the University of Illinois. He served as an assistant in physics at the University of Illinois from 1933 to 1938. He is a member of Chicago Area Research and Development Council of the Chicago Association of Commerce and Industry, Board of Directors, 1962; Citizens of Greater Chicago, member of the Board of Governors, 1962; Midwestern Air Pollution Prevention Association, Inc., president, 1951–60; Mayor Daley's Citizens Committee for a Cleaner Chicago; and several other organizations. He holds a number of directorships and trusteeships in local and national corporations and technical societies.

EDWARD C. LOGELIN is president of the Chicago Association of Commerce and Industry, United States Steel Corporation. He attended Northwestern University. He has held his present position since 1954. Before that time he was director of public relations. Actively engaged in many civic, religious, and charitable organizations, Mr. Logelin is serving his second term as president of the Chicago Association of Commerce and Industry. Among many other posts, he is civilian aide to the Secretary of the Army, Fifth Army area, chairman of the Chicago Mayor's Non-Partisan Committee for the 1964 Political Conventions, treasurer of the Illinois Manufacturers' Association, and a director of the Community Fund.

J. ROSCOE MILLER was named president of Northwestern University in 1949. Dr. Miller received an A.B. degree from the University of Utah, 1925, an M.D. degree from Northwestern University, 1930, and an M.S. degree from Northwestern University, 1931. He has received numerous honorary degrees. Among them are: LL.D. from the University of Utah, 1949, Northwestern University, 1949, and the University of Michigan, 1957; Sc. D. from the University of Arizona, 1951. Dr. Miller was dean, Northwestern University Medical School, 1941–49. He also has been assistant dean, assistant professor, and associate professor of medicine. Among the organizations for which Dr. Miller is a trustee are: Passavant Memorial Hospital, Chicago Wesley Memorial Hospital, and Chicago Natural History Museum. He is a director of: Sears, Roebuck and Company; Illinois Bell Telephone Company; Museum of Science and Industry; and General Dynamics Corporation. Dr. Miller was a member of the Hoover Commission, Medical Task Force, 1952–55.

NEWTON N. MINOW became chairman of the Federal Communications Commission in March 1961. Mr. Minow received an LL.B. degree from Northwestern University School of Law in 1950. He then joined the Chicago law firm of Mayer, Friedlich, Spiess, Tierney, Brown & Platt. Early in 1951, he was appointed law clerk to Chief Justice of the Supreme Court, Fred M. Vinson. In 1952, he was appointed Administrative Assistant to Illinois Governor, Adlai E. Stevenson. Mr. Minow returned to private law practice from 1953 to 1955; in 1955 Governor Stevenson asked him, with W. Willard Wirtz and William McC. Blair, Jr., to establish a new law firm in Chicago. In Chicago Mr. Minow's activities included the Junior Board of the National Conference of Christians and Jews, the Board of the Jewish Community Centers, and the Chicago Bar Association, for which he wrote several publications on the local court system. Mr. Minow has received numerous awards, among which are the George Foster Peabody Broadcasting Award, the National Audience Board Award, the Lee De Forest Award of the National Association for Better Radio and Television, and a citation from the YMCA. Mr. Minow is a member of the United States National Commission for UNESCO: he serves on the Conference on Public Service. He was named one of the Ten Outstanding Young Men in the Nation of 1961 by the U.S. Junior Chamber of Commerce.

KENNETH H. MYERS, professor of Production and Operations Management and chairman of the department, Northwestern University, received his bachelor's and M.B.A. degrees from Harvard University and his Ph. D. degree from Northwestern University. He has been a consultant to business concerns for problems of manufacturing, marketing, and general administration. His business experience includes affiliations with the General Electric Company and the Illinois Tool Works. Professor Myers has been a faculty member of many top management and middle management programs and seminars, including the Institute for Management (Northwestern University), the Institute for Business Economics (University of Southern California), Industrial Management Institute (Lake Forest College), and seminars for Japanese top management jointly sponsored by the International Cooperation Administration of the U.S. State Department and the Japan Productivity Center. Professor Myers is the coauthor of *Design for Digging*, a study of the development of a major manufacturer of excavating machinery, and is the author of many articles in the fields of industrial management and business history. He has also been active in case research and collaborated in developing the first business policy cases ever written on Japanese business.

JOHN E. NAUGLE, as director of Geophysics and Astronomy Programs, Office of Space Sciences, is responsible for planning and direction of NASA's geophysics and astronomy programs, using satellites and sounding rockets to explore the Earth's environment, for studies of the Sun and its effect on the solar system, and for astronomical observations. Dr. Naugle is a graduate of the University of Minnesota, receiving a bachelor's degree in physics in 1949, M.S. degree in 1950, and Ph. D. degree in 1953. Specializing in cosmic-ray and upper atmosphere research, he has taught at the University of Minnesota, been Senior Staff Scientist at Convair Scientific Research Laboratory, head of Nuclear Emulsion Section at Goddard Space Flight Center, and Head, Energetic Particles Program, Satellite and Sounding Rocket Programs, Office of Space Flight Programs, NASA, prior to his present assignment. He is a member of Sigma Xi, American Physical Society, and the American Institute of Aeronautics and Astronautics.

HALE NELSON has been vice president of Illinois Bell Telephone Company in charge of public relations and advertising since September 1946. He attended Washington University in St. Louis. His early career included editorial work for the St. Louis *Post-Dispatch* and for several California newspapers. In 1927, he joined Southwestern Bell Telephone Company where he served for 10 years in a variety of public relations and advertising positions. In 1937, Mr. Nelson transferred to Illinois Bell Telephone Company. He has had an interest in a wide variety of business and civic organizations. Currently, he is a director of United Charities of Chicago and the Economic Club of Chicago; trustee for the Foundation of Public Relations Research and Education; commissioner on the Chicago Commission on Human Relations; and a member of the Mayor's Committee on New Residents. He is a member of the Public Relations Society of America and received the PRSA Presidential Citation for Meritorious Service in 1955, 1956, and 1960, and the PRSA Distinguished Service Citation in 1959. Mr. Nelson was general chairman of the Third National Conference on the Peaceful Uses of Space and the Midwest Space Month, which was held in Chicago in April–May 1963.

ORAN W. NICKS, Director, Lunar and Planetary Programs, Office of Space Sciences, NASA, is responsible for the overall headquarters program management of lunar and planetary programs, including program planning and development and maintaining cognizance of essential technological advancements. He is concerned directly with program execution by JPL and other NASA centers, in addition to overall coordination between NASA, industry, and other Government agencies. Mr. Nicks came to NASA as head of Lunar Flight Systems, Office of Lunar and Planetary Programs, in March 1960 from the Vought Astronautics Division of Chance-Vought Aircraft, Inc. There he had served as project engineer for advanced space systems concepts, and was Scout project engineer from concept to hardware. Prior to this he worked with North American Aviation, Inc., where, among other assignments, he was project engineer of missile design study. He is a member of the American Institute of Aeronautics and Astronautics and the American Astronautical Society. In 1943, he received an A.A. degree in aeronautical engineering from Spartan College, and in 1948 his B.S. in mechanical engineering from the University of Oklahoma. He has done graduate work at the University of Southern California.

WALTER T. OLSON is an assistant director of the Lewis Research Center of the National Aeronautics and Space Administration at Cleveland, Ohio. His current responsibilities include technical counseling with industrial, educational, and governmental leaders regarding participation in aerospace programs, university programs related to the Lewis Center, and technical consulting for the director. Dr. Olson graduated from DePauw University in 1939 with a bachelor's degree in chemistry. He earned a master's degree in chemistry in 1940 and a Ph. D. degree in chemical engineering in 1942 from Case Institute of Technology. Dr. Olson joined the Lewis staff in 1942 and shared in completing and reporting the center's first experimental research project. After World War II, he was in charge of the fuels and combustion program for turbojet, ramjet, and rocket engines. Dr. Olson has directed research into such areas as chemical rockets, high-energy fuels, altitude-chamber tests of rockets, high-performance liquid propellants, electric rockets, fuel cells, and solar energy conversion. Dr. Olson has served as a consultant to the Department of Defense in various activities both here and abroad. He is a Fellow of the American Institute of Aeronautics and Astronautics, a director of the Combustion Institute, and a member of the American Chemical Society and Sigma Xi.

DAVID PACKARD, President, Hewlett-Packard Co., received a B.A. degree from Stanford University in 1934 and an E.E. degree in 1939. He took the advanced course in engineering, Colorado University, 1934–36. He was with the Vacuum Tube Engineering Department of General Electric Co. from 1936 to 1938. From 1939 to 1946, he was cofounder and partner of Hewlett-Packard Co. and in 1947 became president of the company. His directorships have included the following: Crocker-Anglo National Bank, 1957; Granger Associates, 1957; Pacific Gas and Electric Company, 1959; Stanford Research Institute, 1958; Stanford University, president of board, 1958 to 1960; California State Chamber of Commerce, 1962; National Airlines, Inc., 1962. Mr. Packard's professional and community activities include: American Institute of Electrical Engineers; American Management Association, 1956 to 1959; Institute of Radio Engineers; The Business Council.

WILLIAM H. PICKERING is director of the Jet Propulsion Laboratory of the California Institute of Technology. Dr. Pickering received the B.S., M.S., and Ph. D. degrees in physics from the California Institute of Technology in 1932, 1933, and 1936, respectively. He is a member of the faculty of California Institute of Technology, having been appointed professor of electrical engineering in 1946. Under Dr. Pickering's direction, JPL has developed Explorer I and Pioneer IV. JPL is now conducting the Ranger-Surveyor lunar programs, and the Mariner planetary program. Dr. Pickering has served on Air Force and Army scientific panels and with the U.S. Geophysical Year program. He is a Fellow of the American Rocket Society, a Fellow of the Institute of Radio Engineers, and a member of the American Institute of Aeronautics and Astronautics, the American Astronautical Society, and the American Institute of Electrical Engineers. He has been associated with the Jet Propulsion Laboratory since 1944 and has been director since 1945.

JOHN T. RETTALIATA was named president of the Illinois Institute of Technology in 1952. He is also president of IIT Research Institute and the Institute of Gas Technology. Dr. Rettaliata received a bachelor's degree in engineering, 1932, and a doctor's degree in engineering, 1936, from Johns Hopkins University. He has received honorary degrees from: Michigan College of Mining and Technology, Doctor of Engineering, 1956; Valparaiso University, Doctor of Science, 1959; De Paul University, Doctor of Laws, 1962. He is a member of Pi Tau Sigma, Sigma Xi, and Tau Beta Pi. Before becoming president of IIT, Dr. Rettaliata was: head of department of mathematics, Baltimore College Center, 1934–35; laboratory technician, U.S, Department of Agriculture, 1935; with Allis-Chalmers Company, 1936–45; professor of mechanical engineering, director of mechanical engineering department, and subsequently dean of engineering and vice president of academic affairs, Illinois Institute of Technology, 1945–52. He is a member of numerous organizations. Among them are: American Association for the Advancement of Science, Fellow; American Society of Mechanical Engineers, Fellow; Western Society of Engineers; American Council on Education; and Chicago Plan Commission. Among his directorships are: American Motorists Insurance Co.; The Atchison Topeka & Santa Fe Railway Co.; and Western Electric Co., Inc.

ALBERT H. RUBENSTEIN, professor of industrial engineering, Northwestern University, earned his B.S. degree from Lehigh University and his M.S. and Ph. D. degrees from Columbia University in industrial engineering. He was on the industrial engineering staff at Columbia from 1950 to 1953 and on the faculty of the School of Industrial Management at M.I.T. from 1953 to 1959. Since 1959 he has been professor of industrial engineering at Northwestern University. He has worked in the chemical equipment industry and in management consulting, specializing in organization and economics of research, development, and engineering. His research interests are in organization theory with special reference to R&D. He is editor of the *Transactions on Engineering Management* of the Institute of Electrical and Electronic Engineers. He is Director of Studies for the College of Research and Development (COLRAD) of the Institute of Management Sciences, a contributing reviewer to *International Abstracts in Operations Research,* and a member of the Advisory Committee on Economic and Statistical Studies of Science and Technology, National Science Foundation.

RALPH A. SAWYER, vice president for research and dean of faculty, University of Michigan, joined the staff of the University of Michigan as an instructor in physics in 1919. Since 1930 he has served as a professor of physics and, from 1946, as dean of the Horace H. Rackham School of Graduate Studies. Prior to joining the University of Michigan faculty, he instructed for 1 year at The University of Chicago. Mr. Sawyer received his A.B. degree in physics from Dartmouth College in 1915, a Ph. D. from The University of Chicago in 1919, and honorary degrees from Dartmouth College (1947) and Wayne State University (1954). He was a John Guggenheim Fellow in Germany in 1926–27. From January to October 1946, he was Technical Director of Joint Task Force One, engaged in carrying out the "Crossroads" atomic bomb tests at Bikini Atoll. He is a member of numerous technical societies and has authored many scientific articles.

ROBERT C. SEAMANS, JR., was appointed Associate Administrator of NASA in September 1960. In this position, he is responsible for the general management of NASA's operations which include laboratories, research centers, rocket testing and launching facilities, and a world network of tracking stations. Previous to joining NASA, Dr. Seamans was chief engineer of RCA's Missile Electronics and Controls Division. A graduate of Harvard with a bachelor of science degree in 1939, he earned an M.S. degree in 1942 and a doctor's degree in 1951 from the Massachusetts Institute of Technology. Dr. Seamans has been active in the fields of missiles and aeronautics since 1941. He held teaching and project-management positions at M.I.T., including associate professor of the Department of Aeronautical Engineering, chief engineer of Project Meteor, and director of the Flight Control Laboratory. Dr. Seamans is a member of Sigma Xi the American Institute of Aeronautics and Astronautics, the Institute of Radio Engineers, and the American Ordnance Association. He received the Naval Ordnance Development Award in 1945 and the Lawrence Sperry Award in 1951.

FREDERICK SEITZ, president of the National Academy of Science, has served as head of the Department of Physics at the University of Illinois since 1957. His field of work consists of research on the theory of solids and nuclear physics. Mr. Seitz received his A.B. degree in mathematics from Stanford University in 1932 and a Ph. D. in physics from Princeton University in 1934. He was a Proctor Fellow in 1934–35. Mr. Seitz holds honorary degrees in science from the University of Ghent (Belgium), University of Reading (England), Rensselaer Polytechnic Institute, and Notre Dame University. He taught at the University of Rochester in 1935, at University of Pennsylvania, and at Carnegie Institute of Technology prior to joining the faculty at the University of Illinois in 1949. In 1946–47 he served as director of the Training Program in Atomic Energy at Oak Ridge National Laboratory. He also served as science advisor to the North Atlantic Treaty Organization in 1959–60. Mr. Seitz is a member of American Academy of Arts and Sciences; American Crystallographic Association; American Institute for Mining, Metallurgical and Petroleum Engineers; American Institute of Physics; and many other organizations.

JOSEPH F. SHEA was appointed Deputy Director for Systems of the Office of Manned Space Flight in January 1962. He is in charge of the entire systems engineering effort for the manned space flight program. Before joining NASA, Dr. Shea was Space Program Director of the Space Technology Laboratories. He earned his B.S. degree in mathematics in 1949, M.S. degree in engineering mechanics in 1950, and Ph. D. degree in engineering mechanics in 1955 from the University of Michigan. Dr. Shea's earlier association was with the A.C. Spark Plug Division of General Motors where he served as director of the Advanced System Research and Development Division and Manager of the Titan Inertial Guidance Program. Prior to that he was employed by Bell Telephone Laboratories as military development engineer. He is a member of the American Institute of Aeronautics and Astronautics, the American Society of Mechanical Engineers, and the Institute of Electrical and Electronic Engineers.

GEORGE L. SIMPSON, JR., Assistant Administrator for Technology Utilization and Policy Planning, NASA, was appointed to the position of Assistant Administrator for Public Affairs in September 1962. He was appointed to his present position in March 1963. Dr. Simpson received his A.B. degree from the University of North Carolina in 1941, an M.A. degree in sociology in 1944, and a Ph. D. degree in sociology in 1951. Dr. Simpson has specialized in regional development for a number of years, and in 1956 he was named executive director of the Research Triangle Committee of North Carolina. The committee drew together the resources of the state government, industry, and the research potential of the University of North Carolina, Duke University, and North Carolina State University for the expansion of scientific activity in the South. Dr. Simpson has served as a consultant on area development to the Governor of North Carolina, and was his representative at the Conference of Appalachian Governors. He has served as a member of the National Public Advisory Committee on Area Development, U.S. Department of Commerce. At the University of North Carolina, Dr. Simpson has been a member of the Institute for Research in Social Sciences since 1947 and just prior to joining NASA he was a professor of sociology.

EARL P. STEVENSON is presently a consultant to the National Aeronautics and Space Administration and member of the Advisory Committee on Applications. He is also Consultant to Arthur D. Little, Inc., international engineering and industrial research company. He was president of the company from 1935 to 1956, and Chairman of the Board, 1956 to 1961. He is president of the Board of Trustees of Wesleyan University, a member of the Corporation and Trustee of Northeastern University, and a member of the Corporation and Trustee of the Woodrow Wilson National Fellowship Foundation. A graduate of Wesleyan University in 1916, Mr. Stevenson received his M.S. degree from the Massachusetts Institute of Technology. Wesleyan conferred an honorary master of arts degree on him in 1941 and an honorary doctor of laws degree in 1952. He received an honorary doctor of engineering degree from Drexel Institute of Technology in 1959, an honorary degree of doctor of science from Lowell Technological Institute in 1960; and in 1962 he received an honorary doctor of engineering degree from Tulane University. During World War II, Mr. Stevenson was Chief of the Chemical Engineering Division of the National Defense Research Committee. For this service he received the award of Medal of Merit. He has been a consultant to the Atomic Energy Commission, the Office of the Secretary of Defense, the Chemical Corps, and served a 5-year term as a member of the Board of the National Science Foundation.

DAVID H. STODDARD, Assistant Director for Medical Operations, Office of Manned Space Flight, NASA, obtained his premed training at Stanford University and earned an M.D. degree from the University of Oregon Medical School. He interned at Northwestern University. Dr. Stoddard attended the School of Aviation Medicine, Randolph AFB, and received an M.S. degree in environmental medicine from the University of Cincinnati. Prior to joining NASA, Dr. Stoddard was Research Assistant, Department of Physiology, University of Oregon Medical School; Flight Surgeon, U.S. Army Air Force; and Commander, 121 Tactical Hospital. He also had a private practice at La Grande Clinic. Dr. Stoddard is a reserve officer presently assigned to the Air Force Surgeon General's office in the Bionucleonics Division.

WERNHER VON BRAUN is the director of the George C. Marshall Space Flight Center, NASA, at Huntsville, Ala. Dr. Von Braun received a bachelors degree from the University of Berlin in 1932 and a doctorate in physics from the same institution in 1934. 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. He became technical director of the Peenemuende Rocket Center in 1937. Dr. Von Braun came to the United States 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, N. Mex. Later he became project director of a guided missile development unit at Ft. Bliss, Tex., which employed some 120 of his Peenemuende colleagues. In 1950 the entire group was transferred to Huntsville, Ala., 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. In 1959 Dr. Von Braun was presented the Distinguished Federal Civilian Service Award by the President of the United States.

JAMES E. WEBB was appointed by President Kennedy as Administrator of NASA in February 1961. He is also a member of the Federal Council for Science and Technology, the President's Committee on Equal Opportunity, the National Aeronautics and Space Council, and is Chairman of the Distinguished Civilian Service Awards Board. An attorney and businessman, Mr. Webb has been active in aviation and education. He is a former director of the Bureau of the Budget and a former Under Secretary of State. He has been a vice president of Sperry Gyroscope Co., chairman of the board of directors of the Republic Supply Co., a director of Kerr-McGee Oil Industries, and a director of the McDonnell Aircraft Co. Mr. Webb holds a B.S. degree in education from the University of North Carolina, and numerous honorary degrees. He studied law at George Washington University and was admitted to the District of Columbia Bar in 1936.

ARTHUR M. WEIMER became dean of the Indiana University School of Business in 1939. Dr. Weimer joined the I.U. faculty in 1937 as professor of real estate and land economics, a position he continues to hold. Prior to this, he served as a teaching assistant at The University of Chicago; head of the Department of Economics and Social Science at Georgia Institute of Technology; and housing economist for the Federal Housing Administration. He received the A.B. degree from Beloit College; the A.M. and Ph. D. degrees from The University of Chicago, and the honorary LL.D. degree (1950) from Beloit. Dr. Weimer is president of Beta Gamma Sigma national business honorary (1961–63); past president of the American Finance Association and the American Association of Collegiate Schools of Business; and a member of the American Economic Association and the American Institute of Real Estate Appraisers.

JULIAN M. WEST is Managing Director, Systems Engineering Center, Bellcomm, Inc. Mr. West was graduated from the U.S. Military Academy in 1927 and served in the Coast Artillery Corps until he joined the Bell Telephone Laboratories in 1930. As a Member of the Technical Staff, he worked on various aspects of the coaxial cable system until 1941. Then he supervised projects for the Army, Navy, and National Defense Research Council, including radar and proximity fuse research and development. In 1943, he became a full time consultant to the Army Air Forces on the application of radio countermeasures in air operation. From 1945 to 1952, he worked on the Nike guided missile system. Since then, his work has involved supervision of military research and development on a wide variety of projects for all three military services. He became Director of Military Systems Engineering in 1953 in charge of studies and exploratory work which precede development. During 1954–55, he served as a member of the Killian Committee. From 1961 until his transfer to Bellcomm in April 1962, he was Executive Director, Military Systems Division, in charge of underwater sound and ballistic missile guidance development. Mr. West has served as consultant to the Office of the Assistant Secretary of Defense R&D Technical Advisory Panel on Electronics, the Office of Defense Mobilization Science Advisory Committee, and Advisory Group on Electronic Warfare ODDRE. He has been serving as consultant on the Continental Air Defense Panel of the President's Science Advisory Committee from 1959 to date. He is a member of the Institute of Electrical and Electronics Engineers and the American Institute of Aeronautics and Astronautics.

DEMARQUIS D. WYATT was appointed Director, Office of Programs, NASA, in November 1961. Previously he was Assistant Director, Program Planning and Coordination. Mr. Wyatt earned his B.S. degree in mechanical engineering at the Missouri School of Mines and Metallurgy. He joined the NACA, predecessor of NASA, at the Lewis Laboratory, where he specialized in supersonic propulsion research, and ultimately was named Associate Chief of the Propulsion Aerodynamics Division. He was transferred to NACA headquarters in Washington, D.C., in 1958. Mr. Wyatt is a member of the American Institute of Aeronautics and Astronautics.

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