NASA SP-82

Fifth National Conference on the
PEACEFUL USES OF SPACE

ST. LOUIS, MISSOURI

MAY 26-28, 1965

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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Proceedings of the Fifth National Conference on the PEACEFUL USES OF SPACE

Held in St. Louis, Missouri

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FOREWORD

"For every generation there is a destiny . . . ," President Lyndon B. Johnson said in his inaugural address, and it is now clear that for this generation and for future generations, man's destiny lies within the context of the new era which many call the "Space Age."

Man now has the capability to leave the surface of his home planet, Earth. He has before him the opportunity to obtain a fundamental understanding in the many areas of scientific interest which perplexed past generations. Today, he can concern himself with the Sun and its influence on the Earth, the origin and the nature of the solar system, the nature of the stars and galaxies, and the origin of life itself.

In the brief course of eight years, all the world has felt the impact of the Space Age. At times this impact has been remote or indirect, but the portent for all has been clear. During this short interval of time, insights into the relationships between the Earth and the Sun, and the streaming radiation that permeates all space have been acquired. Much has been learned about the Earth's atmosphere and the relationship of solar activity to weather and other phenomena on the Earth. Electronic measurements of Venus have been made, and the Moon has been photographed. Global weather has been observed from a perspective unavailable before the advent of satellites, and the techniques of global communications have been improved. These achievements and others have been made at the frontier where science and technology are indivisible.

Progress in space exploration is both a product of and a leading edge for the general advance of science and technology. The talents, the skills and the resources required for space exploration are drawn broadly from our society, and they feed back into our society on the forefront of scientific and technical progress. The knowledge gained by scientists and engineers active in space exploration feeds back into our scientific and technical communities and into our industrial laboratories. The revolutionary changes taking place in scientific and technological perspectives through the mastery of space open vast new realms for the creative act of invention, and for the translation of invention to practical use-innovations that can be primary influences in stimulating economic growth.

The interest of the scientist ranges from the interior of the Earth to the distant galaxies, from the structure of the atomic nucleus to the structure of living cells, through the nature of the chemical materials of which the universe is composed. The most significant enterprise in which all the sciences come together is space exploration.

The Space Age has many characteristics that make for international action of wide benefit. Regardless of its country of origin, an orbiting spacecraft is truly international. It is a scientific and technical tool free of physical, geographical, and political limitations, and its fullest exploitation requires international collaboration between scientists and technicians, between peoples, and between governments. Its rewards, especially those of the psyche, are shared by men of all nations.

It is also clear that some of the emerging scientific and technological possibilities in the field of communications will exert great influences on our lives, on our behavior, and on the welfare of mankind. The communications satellites, the linking of voice communications and data communications, and the combination of the computer with long-range communications, all foretell a world of the future which will be different from the world we see about us—a world that can be highly integrated without being centralized. The ultimate contributions of communications and weather satellites to mankind cannot now be evaluated, but few question that these contributions will be very great indeed. These satellites bring problems with them, but the solution of these problems brings us closer to a cooperative world society.

This St. Louis meeting, held under the auspices of the National Aeronautics and Space Administration and the St. Louis Bicentennial, was a forum for discussing what our space accomplishments have been to date, and what impact space exploration will have on science, industry, the economy, communications, education, and world peace.

It is hoped that this meeting provided a new understanding of the contributions to world peace and human betterment that are sure to flow from America's great programs of space exploration.

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FIFTH NATIONAL CONFERENCE ON THE PEACEFUL USES OF SPACE

Chairman of the Conference:
David S. Lewis
President
MCDONNELL AIRCRAFT CORPORATION

WELCOMING REMARKS

David S. Lewis

On behalf of the Committee of St. Louis Bicentennial Celebration and the Steering Committee for this space symposium, I welcome you to the Fifth National Conference on the Peaceful Uses of Space. We are honored to have this conference in St. Louis and are particularly grateful that it could be held during our Bicentennial celebration; this, of course, is not a coincidence. We are greatly indebted to the National Aeronautics and Space Administration for their fine support and cooperation, and we are indebted also to the many business and industrial firms in St. Louis and a number of companies large and small all over the nation for their sponsorship and very strong financial support.

In conjunction with this conference, we made a very real and considerable effort to develop a better understanding of our national Space Program by the people of this area. Two weeks ago, selected high school students from St. Louis and nearby communities in Missouri and Illinois attended a meeting at Kiel Auditorium where NASA speakers outlined the opportunities and challenges of the Space Age that will be available to the young men and women who develop their technical skills and capabilities. Three thousand five hundred students attended this session which was considered to be a very real success.

A second facet of our program is a large and extremely interesting exhibit of spacecraft and boosters provided by NASA. This exhibit, probably the most extensive ever displayed at a meeting of this type, opened May 14 in a beautiful setting in Forest Park at the McDonnell Planetarium. I am confident you will find a visit to this exposition a very worthwhile event and, to give you an indication, in the first week and a half of this exposition, we have had 43,000 St. Louis people visit this show, which I think would be very, very helpful in helping them understand the impact and importance of the Space Age program.

As many of our visitors have read in national magazines, the City of St. Louis is currently undergoing a dynamic revitalization which merits your scrutiny while you are here. Tremendous progress has been made and many more developments are on their way. The unique 630-foot Jefferson Memorial Arch is nearing completion on the water front. A new sports stadium is under construction and will be finished within the next year. Many, many new buildings have been built or are now being erected, and new industry has been brought to St. Louis. The man who is most deeply involved in this program of progress is our Honorable Mayor, Mayor A. J. Cervantes.

WELCOME

A. J. Cervantes
Mayor
CITY OF ST. LOUIS

We are pleased to have you in our City for any reason, the distinguished speakers and attendees of this conference and symposium on the Space Age. But the purpose for which you have come to St. Louis and the spirit in which you are gathering makes me especially proud.

This is a meeting to consider in an unusually broad scope the implications of the great Space Age, which is opening up so rapidly with so many potentialities. The stated goal of your sessions is to provide a new understanding of the contributions to world peace and human betterment that are sure to flow from America's great program of space exploration.

I can envision no more worthy a purpose, and I can assure you that no city is more eager to use this understanding for even a greater good than the City of St. Louis. In the 200-year course of our proud history, we have often gone exploring for new understanding and have contributed to the explorations undertaken elsewhere. In the earliest days, St. Louis served as a Cape Kennedy of the fur traders, whose pioneering treks have many similarities to the astronauts' first orbiting.

From St. Louis, the Lewis and Clark Expedition set out to unlock the secrets of the West, jumping quickly across more than a century of adventure. Here Charles Lindbergh found the spirit and financial backing for his epic flight. And as America moved into the Space Age, it was St. Louis that gave the Nation its first manned spacecraft, the Mercury and the Gemini.

We, St. Louisans, today are looking forward to our next contributions just as you are looking forward to the next three days. May your sessions be in keeping with the Spirit of St. Louis and the spirit of our great Nation, so uniquely equipped to lead the world in space and to useful peace.

SPACE EXPLORATION ACCOMPLISHMENTS

Chairman
William L. Davis
President
EMERSON ELECTRIC COMPANY

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LOOKING TOWARD MATURITY IN THE SPACE AGE

Hugh L. Dryden [1]
Deputy Administrator
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The Fifth Annual Conference on the Peaceful Uses of Space here in St. Louis is a three-day program of talks by representatives of industry, the scientific community, and Government. They will bring us up to date on our Nation's accomplishments in space, and they will outline our goals and potential future programs, the impact of space exploration on industry, on the economy, on science, and on education.

My assignment is to set a framework for these discussions by examination of the rapid growth to maturity of our space activities and their relation to and interaction with the growing role of science and technology in our society.

Communication between the scientific community and the general public historically has been difficult and usually slow. It is difficult for the scientist and the nonscientist alike to adjust to new ideas, to evaluate them fairly, and to see their application to human affairs clearly.

In the past we could, perhaps, afford a leisurely pace in adjusting scientific progress and our social, economic, and political institutions. Today the pace of new discoveries has accelerated at such a rate that we are constantly faced with newness. And this stepped-up tempo imparts a quality of its own that requires new and more efficient methods of communication.

In examining the early history of science and technology, we find that more than twenty centuries elapsed between Aristotle and Galileo. From Galileo to Newton was one century, and in rapid order following Newton's time was a roster of the great modern mathematicians, chemists, and physicists, culminating with Einstein in our own time.

We are accustomed to talking about the lag between science and the community as retarding progress, and we can call to mind Galileo's forced recantation or the Luddites, who attempted to hold back the industrial revolution in England by smashing the machinery they saw as menaces to their way of life. There have been these gaps in understanding; yet, it is equally true that government and science have worked hand in hand through the ages for human advancement.

One author has pointed out that Archimedes operated a one-man bureau of standards and national defense research committee for Heiros, the King of Syracuse, by determining the amount of gold in a crown and by building engines of war.

In the 17th century, Charles II of England founded Greenwich Observatory to obtain better data on the movement of the Moon with the hope of finding a precise means of determining longitude. Later, in 1712, the British government offered a prize of 20 000 pounds for an accurate method of determining longitude. After much delay and haggling the prize was won by a John Harrison for his chronometer, which served, basically, as a navigational instrument from 1764 until the 20th century and the development of radio time signals.

In the 17th century, France, under Louis XIV and Louis XV, sought to encourage the merchant marine and manufacturing through the encouragement of inventors. And in the 19th century the British Association for the Advancement of Science was established to "promote the intercourse of those who culti-

[1] Died December 2, 1965.

vate science with each other," and later the National Physical Laboratory, to handle the increasing demand of a growing science and technology.

In our own country, the rationalism of such men as Jefferson and Franklin made itself felt in our Constitution, which carries the following provision: "The Congress shall have the power to promote the progress of science and the useful arts, by securing the authors and inventors the exclusive right to their respective writings and discoveries." As a result, the Patent Office was created in 1790. Many other agencies followed to keep pace with the growing scientific community. Among them was Coast and Geodetic in 1807, and the National Bureau of Standards in 1901.

As science and technology have come to play an increasing role in National affairs, science-oriented agencies in the Government have multiplied, and agencies have come increasingly to add science advisory staffs. In the executive branch they play outstanding roles in such departments as Commerce, Interior, Agriculture, and Health, Education and Welfare. Independent agencies include, of course, the National Aeronautics and Space Administration, the Atomic Energy Commission, the Civil Aeronautics Board, the Federal Aviation Agency, the Federal Communications Commission, the Maritime Commission, the Federal Power Commission, the National Science Foundation, and the Smithsonian Institution.

In the Congress, the Senate has an Aeronautical and Space Sciences Committee and the House of Representatives its Science and Astronautics Committee.

There are in addition 1600 scientific and technical societies listed in the United States, and as of 1962 some 320 private foundations made grants of $45 million for research in the sciences. Thus it is readily seen how science and technology have grown in our public life and have been the subject of governmental attention from the earliest days.

In the present century governmental responsibility in the newer fields of aeronautics, atomic energy, and space has become more direct and more massive. We have shortened the time between an original scientific and technological development and a corresponding acceptance of responsibility in the public sector. Thus, in aeronautics the Wright brothers flew their first plane in 1903; 12 years later, in 1915, the National Advisory Committee for Aeronautics was established. In October of 1957, the first Sputnik was successfully orbiting the earth; 1 year later the National Aeronautics and Space Administration was established to explore the peaceful uses of space.

Growing responsibility and competence on the part of news media have helped bring new awareness to the public of the degree to which science and technology are changing the fabric of our society. This was not always true. Like many another citizen, the editor of a newspaper was often inclined to be skeptical of new-fangled ideas and scornful of notions that violated what I am sure he would call common sense.

An example is this section from an editorial in *The New York Times* in 1920 when Dr. Goddard was experimenting with rockets:

"As a method of sending a missile to the higher and even to the highest parts of the earth's atmospheric envelope, Professor Goddard's rocket is a practicable, and therefore promising device. . . . It is when one considers the multi-charge rocket as a traveler to the moon that one begins to doubt . . . for after the rocket quits our air and really starts on its longer journey, its flight would be neither accelerated nor maintained by the explosion of the charges it then might have left. Professor Goddard, with his 'chair' in Clark College and the countenancing of the Smithsonian Institution, does not know the relation of action to reaction, and of the need to have something better than a vacuum against which to react—to say that would be absurd. Of course he only seems to lack the knowledge ladled out daily in high schools."

Perhaps the moral is that in times of rapidly expanding knowledge and new discoveries, it never pays to be all that positive.

An excellent job is being done today in explaining the facts of science and their importance to the layman. We also have at present many well-established lines of communication among government, the scientific world, and the general public.

Perhaps the best evidence of growing support for research and development is the increased amount of money expended for it.

In 1954 total expenditures for R&D amounted to $5 660 000 000. In 1964 that figure had grown to an estimated $19 360 000 000. In 1954, the government provided 55 percent of R&D funds and performed 18 percent of the research in-house. Last year the government was the source of 65 percent of R&D funds and performed only 14 percent of in-house research.

Thus, while there has been a growing obligation for public support of science and development, there has been a corresponding shift to private industry as best qualified to carry out the work. At NASA more than 90 percent of the $\$5\frac{1}{4}$ billion it administered in 1964 went to private industry.

The rate of growth of space activities in the first 6 years of the space age has been unprecedented in the history of a new field of science and technology but there are signs of attainment of a certain degree of maturity. The most obvious is the establishment, following several years in which available funds nearly doubled each year, of a level of five to five and a quarter billions for congressional appropriations to NASA, or about seven billions for space activities of all agencies as the suitable level, somewhat less than that considered optimum by those engaged in the program. This action represents the results of consideration by the Congress of the many factors concerned, including estimates of the funds required to meet national goals and commitments, the social, economic, and national security benefits to be obtained, and other competing demands for national resources.

Maturity is also indicated by the drastic reduction in the number of unsuccessful missions, the result of increased knowledge and experience in the previously unknown field of space. Thus, in calendar year 1958 in the first 3 months of NASA, four missions were attempted without a single success. In the following year 8 of 14 were successful, whereas in 1964, 25 of 30 more difficult missions were successful, a percentage of 83 which has been maintained now for 3 years. In the early years there was little knowledge of space, no facilities for simulating the space environment on the ground of sufficient size to actually test equipment in advance, and the necessity of using hardware immediately available even though of uncertain reliability in space. Today we have precise information about the strength of vibrations in launch vehicles under rocket thrust and the characteristics of the space environment itself at various distances from the earth. We have ground test equipment such as vibration stands and environmental chambers which permit us to make tests on the ground under the conditions to be encountered in space to verify the adequacy of the performance of the equipment before launch.

We have also reached a certain degree of maturity in that practical applications of spacecraft have been made in the form of weather satellites and communication satellites whose benefits to every citizen of every nation are now widely appreciated. Furthermore, in both cases we are now engaged in the development of operational systems for service to the public.

Another indication of growing maturity is the organization of the very large government-industry-university team of highly competent people of many professions and skills required to carry out the very large effort necessary for a broad program of space exploration and the development of capabilities for operation on this new frontier. The cooperation of many organizations and people is required. During fiscal year 1964, 94 percent of our work was conducted by American industry and involved a total of about 380 000 people in industry, universities, research institutes and government installations. Great progress has been made and we have all worked together toward increased efficiency, better cost control, and better utilization of the total resources of the country. We have had the strong support and cooperation of the Department of Defense. They have undertaken the management of many of our contracts, the handling of the construction of many of our facilities through the Corps of Engineers, the assignment to NASA of astronauts, outstanding project leaders, and other specialists from the military services, furnishing of tracking support through the national ranges, and provision through the Navy of many services, including the recovery of astronauts. Many other government agencies are cooperating in various aspects of the space program.

The third member of the national space team is the university in which much of our most advanced research is going forward. About 185 universities are working on NASA-sponsored research, and 142 universities in all 50 states and the District of Columbia are now participating in the predoctoral training program.

The nature of the team, the management complexity involved, and the success of the system may be illustrated by the second Orbiting Solar Observatory, OSO-2. Involved in this program were the Douglas Aircraft Company, Ball Brothers Research Corporation, NASA's Ames Laboratory and Goddard Space Flight Center, Naval Research Laboratory, Harvard College Observatory, and the Universities of New Mexico and Minnesota.

The Government-industry-university team has matured in capability to provide launch vehicles, spacecraft, and equipment and experiments for any desired mission. But other tools are needed to carry out the space program such as test stands, launch pads, ground test equipment, and a worldwide tracking and data acquisition network to return information from objects in space, since this information is the reason for the whole enterprise. Some of the necessary tools are provided at the plants of manufacturers and at the universities but many more, particularly those of large size and unusual capability, must be provided at central Government locations. These facilities represent the longest lead-time items requiring preparation for several years in advance of their use. Another sign of the growing maturity of the program is that most of these necessary large facilities have now been provided.

The largest facilities are needed in connection with the manned space flight program aimed at developing the capability to operate with large payloads in space out to distances of the Moon and to demonstrate this capability by landing two men on the Moon within this decade and returning them safely to Earth. I mention only a few of the larger facilities required in this enterprise. The first is Michoud Assembly Facility in New Orleans in which the very large Saturn boosters are assembled prior to their test and launch. Nearby is the Mississippi Test Facility at which static tests can be made of the Saturn IB and Saturn V launch vehicles. The actual launch of spacecraft toward the Moon will be made from the Merritt Island Launch Area just north of the Cape Kennedy area. Here we find the Vertical Assembly Building, said to be the largest structure ever built by man. It is the building within which the sections of the huge Saturn V launch vehicle and the Apollo spacecraft will be assembled vertically and checked out for launching. The building is 524 feet high, covers 8 acres, has a total volume of more than 125 million cubic feet, and has doors 456 feet high. The rocket will be assembled vertically on a giant earth crawler which is the largest land vehicle in existence, patterned after somewhat smaller vehicles used for strip earth surface mining. When the rocket is ready for launching, the earth crawler will transport it over an eight-lane highway to a launching pad 4 miles away. With the astronauts safely aboard, the 350-foot Saturn V will hurl about 120 tons into orbit, the equivalent of 80 capsules the size of John Glenn's Friendship 7, and send some 45 tons off to the Moon.

Transportation between Michoud Assembly Facility, Mississippi Test Facility and the Merritt Island Launch Area will be by water. These great facilities will form the basis of our national strength in space for many years to come.

A group of business leaders from the non-space industries, on inspecting these large facilities and the progress being made on launch vehicles in spacecraft in the manufacturing plants of the country, exclaimed, "How could all this be taking place without our becoming aware of it?" Great progress is being made in the Apollo project. Last year was the year of filling the pipeline, and this is the year of ground test. Next year will begin the early preparatory flight stages.

As we approach maturity, our achievements indeed are many and our capability is great—so great, in fact, that today we are faced with an embarrassment of riches. The many opportunities for flight missions within our developing capabilities are far greater than we can hope to finance, and there is opportunity for debate as to the wisdom of specific choices. Nevertheless there is general agreement on the general scientific and technical goals of achieving a growing capability to send unmanned spacecraft for various purposes in Earth orbit, on trajectories in interplanetary space and to the Moon and planets, ultimately to the outermost planets approximately in the plane of the ecliptic as well as to corresponding distances at an angle to the ecliptic; and to achieve a growing capability in manned space flight in Earth orbit, to the Moon, and to other planets.

At NASA we are learning to operate within the framework of a restricted budget, manpower ceilings, and available physical facilities. We are trying to learn how to choose, within these limits, how to apply our resources and select our projects in the best interests of the country. Of the trials and errors of the early days of the program we have endeavored to build management techniques that meet the hard criteria of best meeting the Nation's objectives in space, on schedule, and at minimum cost. We have evolved what we call *phased program planning* as an integrated approach to the conduct of our advanced mission studies, flight mission selection, preliminary project planning, the definition and fabrication of flight hardware, and, finally, the conduct of space operations.

We do not think that the planning of future space programs is the prerogative of NASA alone. In addition to refining our techniques for making the most efficient use of our resources, we must constantly redefine and examine our goals in terms of the national interest. The cost of the Nation's space program and its importance to national progress require that decisions regarding it be the subject of informed national discussion. The participants should include not only those who are presently engaged in the program, and not only scientists and engineers, but also men in other walks of life, informed citizens, national political and intellectual leaders. Such a national dialogue requires that all concerned be informed about the space program and understand the needs, the limits, and the potential of science. Similarly the scientist must understand that he operates between the bounds of national priorities established by the citizen whose welfare and tax money after all are involved. In spite of a major effort on the part of NASA, the rapid growth of the program, its size and ramifications, are such that many who should participate in this dialogue are not acquainted with what is actually taking place, the results being accomplished, and the policies being followed. Meetings such as this conference will help to increase the number of persons who do have some first-hand knowledge of the space activities of this Nation of which every citizen may well be proud.

Within the past 2 years the subject of the broad national goals of the space program has emerged as a subject of public debate. Many of the participants mistakenly assume that there is a single such goal, but in fact there are many. In March 1958 the President's Science Advisory Committee listed four major goals: exploration of outer space in response to "the compelling urge of man to explore and to discover"; national defense; national prestige; and knowledge and understanding of the Earth, the solar system, and the universe. Recently, Vernon Van Dyke of the University of Iowa published an analysis of motivations which adds to the four stated above. One expressed by President Johnson is that "the avenues of space offer man's best hope for bringing nearer the day of peace on earth." Another, broadening the scientific motivation, is progress in science and technology, emphasizing engineering as well as scientific progress at the frontiers of knowledge. Another is economic and social progress. Still another is national pride, the achievement motive, which Van Dyke distinguishes from national prestige as our own beliefs about whether we are achieving goals responsive to the opportunities and challenges of the time as contrasted with our reputation among other nations. Finally, Van Dyke mentions a variety of special interests of individuals and groups which are, however, not to be construed as national goals. It is because of the sum total of all of these goals that the nation has so far supported and will continue to support a comprehensive program to explore space.

Any public debate must take cognizance of the need for basic research and must encourage the exploration and development of new ideas. In the absence of undirected basic research, new missions will run up against old limitations, and forward movement in space exploration or any other scientific discipline will wither and die.

No doubt, much scientific accomplishment has come about by planned programs, but the history of science indicates time and again that what seems idle curiosity has turned out to be highly valuable in application, although the immediate application is not readily apparent and the time lag is sometimes long. It should be further pointed out that new discovery has often appeared in unexpected lines of inquiry.

We are extremely conscious these days of crash programs—for the atomic bomb, for polio, cancer, or heart disease cures. Yet, Roentgen discovered X-rays accidentally, and Becquerel discovered gamma ray radiation because his photographic plates fogged accidentally while they were left in a drawer with some uranium ore.

Indeed, for all of the crash programs oriented toward some specific national objective, new discovery has come often without planning and without fanfare. As Albert Camus once pointed out, "Great ideas come into the world as gently as doves. Perhaps, then, if we listen attentively, we shall hear, amid the uproar of empires and nations, a faint flutter of wings, the gentle stir of life and hope."

One final thought: In the midst of our new awareness of the role of science in our lives we are still inclined to see it as a means to immediate, discernible ends. Yet goals must be beyond accomplishment. What we now call goals we should in better conscience refer to as short-term objectives.

The growth of science and technology culminating in the rapid rise of space science and technology and the impact of science and technology on our society have stimulated discussion of still another aspect of national goals, that of their contribution to the welfare of mankind or, more broadly, their characteristics in terms of ethical and moral values as well as knowledge and material contributions.

Such considerations lead to a restatement of the national goals for the space program in terms such as the following:

1. to obtain maximum benefit to the welfare of the Nation and to all mankind.

2. to provide not only material benefits to free men in a peaceful world but also incentives for mental and spiritual growth and accomplishment.

Growing up in the space age, we are growing up to understand this. Our programs are tools. Our goals are progress.

MANNED SPACE FLIGHT: PROGRAMS, PROGRESS, PROSPECTS

George E. Mueller
Associate Administrator
for Manned Space Flight
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION

NASA's manned space flight programs constitute the largest and most complex engineering, scientific, and technical undertaking ever attempted. This is a particularly appropriate time to discuss the progress and prospects of these programs, for it was 4 years ago—on May 5, 1961—that Alan Shepard became the first American to fly in the new environment of space. And it was 4 years ago that President Kennedy proposed a long-range program—later endorsed by Congress—to expand and accelerate U.S. space activity. This program included a national commitment to advance manned space flight to a stage at which, by the end of the decade, it would be possible for man to fly outward a quarter of a million miles from the Earth, to land on and take off from the Moon, and return safely to Earth. This was the beginning of the Apollo Program.

As we approach the halfway mark in this program, it is appropriate to assess what we have accomplished so far, where we stand now, and where we are going in the future.

In the past 4 years the United States has made great progress in achieving its goals in space. In the Gemini III mission, for example, Astronauts Virgil Grissom and John Young achieved a historic milestone in manned flight when, on four occasions during their flight, they steered their spacecraft into measurably different orbits. In addition, they conducted four other maneuvers that demonstrated the spacecraft's ability to make small, precise changes in speed. The proof of the maneuverability of the Gemini spacecraft is a significant step in developing the ability to rendezvous and dock in space, scheduled for next year.

All preparations are going smoothly at Cape Kennedy for the second manned Gemini flight, Gemini IV, scheduled to be launched on June 3 with James McDivitt and Edward White as the pilots. This flight, scheduled to last up to 4 days, was originally scheduled for the third quarter of this year. It is a tribute to the enthusiasm, confidence, and dedicated efforts of the thousands of people at work on the Government-industry Gemini team that we will be able to launch this flight more than a month ahead of schedule.

One of the important objectives of the Gemini program is to determine the effects of weightlessness during long-duration missions. Before, during, and after this flight, as in all Gemini flights, controlled physiological studies will be conducted, and careful monitoring of blood pressure, pulse rate, and other physical reactions will be maintained.

Another of the prime objectives of the Gemini program is the development of man's capability to step out into the nothingness of space and do effective work. As in all of our space activities, we are proceeding in a step-by-step manner with the preparations.

Finally, the ability to launch within a narrow time span, to rendezvous with another craft in space, and to dock firmly with it is essential for manned operations in space. Beginning with the fourth manned Gemini flight, scheduled for early 1966, we will explore and develop these capabilities. The data and experience obtained will be fed into the training of the astronauts, verification of the Apollo system, and the design of future space systems.

Moving to the Apollo program, a very great momentum has been built up, leading to the first unmanned flights with the Apollo three-man spacecraft in 1966. To accomplish our objectives in Apollo, we have established a development program that is broadly based and are proceeding with deliberate speed to a manned landing on the Moon before the decade is over. At present, we have completed design and are in the phase of ground testing of subsystems and major systems. This ground testing leads naturally to unmanned flight testing to verify hardware performance under actual flight conditions. Successful unmanned flights lead to manned flights, first in Earth orbit and later to the Moon.

Development was completed in 1964 of the $1\frac{1}{2}$-million-pound-thrust Saturn, the most powerful launch vehicle we know to exist in the world. In fact, the Saturn I was declared operational after only six test flights.

The 10 Saturn I flights will be followed by flights of the "second-generation" Saturn I launch vehicle together with the Apollo spacecraft in an "all-systems-up" configuration. The first launch of the Apollo/Saturn IB will take place early in 1966. Later flights with this vehicle, scheduled for 1967, will place the first manned Apollo spacecraft in Earth orbit.

The payoff in the Apollo launch vehicle series, of course, is the Saturn V. This vehicle is the one that will launch the Apollo spacecraft on the actual lunar mission. The first launch of the Saturn V is scheduled for 1967, with manned flights to start in 1968, first in Earth orbit, and then to the Moon.

To give you some feel for the sheer size and power of the Saturn V/Apollo space vehicle, it will stand 364 feet in height on the launch pad—as high as a 36-story building—and weigh some 3000 tons fully fueled—as much as a Nautilus submarine or a Navy light cruiser.

It will be capable of placing a payload of 140 tons in Earth orbit—the equivalent of about 95 Mercury spacecraft, those employed in the earlier U.S. orbital flights, such as that of John Glenn. The first stage alone of the Saturn V generates $7\frac{1}{2}$ million pounds of thrust—more than the combined thrust of over 100 Boeing 707 jet-liners.

A major milestone in the Apollo program and in rocket technology was passed on April 16, 1965, when the first stage of the Saturn V was test fired for the first time for a duration of $6\frac{1}{2}$ seconds. This firing was accomplished almost 3 months ahead of schedule. A second firing of 15-second duration took place early in May, 1965. In addition, test firing of the 1-million-pound-thrust, liquid-hydrogen-powered second stage of Saturn V has begun, also ahead of schedule.

These accomplishments are indicative of the present rate of progress in the Apollo program. This rapid progress, in Apollo as well as Gemini, gives us great confidence that our development concepts and management methods are sound, and that we will be able to meet all of our major milestones on schedule.

The Apollo spacecraft, the portion of the space vehicle that will journey to the Moon, is a maneuverable vehicle capable of carrying three men for periods of up to 2 weeks. It is composed of the command module, service module, and lunar excursion module (LEM). The command module houses the astronauts in flight from Earth to an orbit about the Moon, and back to Earth. The service module contains the power supply and the propulsion systems and fuel for maneuvering and making midcourse corrections during the lunar flight. The two-stage lunar excursion module separates from the command module in lunar orbit and lowers two of the three astronauts to the surface of the Moon. After the initial exploration is completed, it lifts off from the Moon and reunites the two lunar explorers with the third astronaut, who has been circling the Moon in the command module.

What does the future hold in store? First, let me emphasize that the lunar mission is only one of many possible missions utilizing the capabilities that are being created in the Apollo program. In the Apollo program, the United States is developing the capability to send manned vehicles anywhere within a zone extending at least a quarter of a million miles from Earth. The possession of this national capability is more important than the exploration of any particular astronomical body or natural manifestation.

In addition to the launch vehicles and spacecraft, the capabilities being created by Apollo include launch and test facilities, a Mission Control Center and a worldwide net of tracking stations, operational experience, trained people, an established Government-industry team, and the management capability to direct large research and development programs. All of these elements constitute a national resource of enduring value. Added together, they will provide the Nation with freedom of operation in space, making possible a wide variety of missions that may be required by the national interest. With this competence, we will be able truly to explore and utilize space.

NASA Administrator James Webb, in a letter to President Johnson on February 16, 1965, made an extensive appraisal of possible future space programs. He noted that "two objectives for the years just ahead appear to stand out above other possibilities." First of these is the exploration of Mars through the use of large unmanned soft-landing spacecraft. In such a program, one or more flyby or orbiting test flights could be launched to Mars in 1969, with operational landing missions to follow in 1971. In these missions, the Saturn IB, using the Centaur as a third stage, could launch a 10 000-pound Voyager spacecraft with a 5000-pound landing vehicle to Mars.

The second objective, Mr. Webb told the President, is a systematic program to capitalize on the capabilities being developed in the Apollo Program for a "wide variety of worthwhile scientific and technical missions in near-Earth and synchronous orbits, in lunar orbit, and on the lunar surface."

The launch vehicles and spacecraft being developed in the Apollo program are of such size, versatility, and efficiency as to be of decisive importance in achieving and maintaining preeminence in space for some years to come. As now planned, the Apollo program will provide the capability to produce and use eight Apollo-LEM spacecraft annually. The Apollo spacecraft's command module will provide a "shirt-sleeve" environment and sufficient room for three men to live and operate for periods of at least 2 weeks in space. The propulsion system of the service module will enable the pilots to carry out very extensive maneuvers and course changes in space and to land within a few miles of any chosen point on the Earth's surface.

The lunar excursion module has several potentialities. This spacecraft, the first designed and built for operation completely outside the Earth's atmosphere, has a number of structural advantages over spacecraft which must return to Earth. One of these advantages is greater internal volume, since it does not have to be equipped with the protective heat shield and other devices required for reentry through the atmosphere. By increasing the amount of supplies carried, it appears possible for astronauts to spend months rather than weeks in space.

In addition, the sensors and guidance system of the lunar excursion module will permit it to leave its mother ship, rendezvous with another satellite, "land" on the satellite, allow the crew to get out and inspect, repair, or test the other satellite, and then take off and return to its mother ship.

Further, by 1969 the present program will build up to a capability to launch six Saturn IB and six Saturn V launch vehicles annually. These powerful boosters in these numbers will enable this Nation for the first time regularly to launch large payloads in operational space systems for a wide variety of purposes, in manned and unmanned flights in the Earth-Moon region and for unmanned planetary missions. With the power of the Saturn V, for example, it would be possible to place a very large space station in Earth orbit; to launch a smaller space station into an orbit synchronized with the Earth's rotation like that of the Early Bird communications satellite; or to support extended lunar exploration from bases on the Moon. These possible missions will be discussed in more detail in later paragraphs.

The Apollo spacecraft, therefore, provides the Nation with a precursor to its first true space station. The lunar excursion module is a test bed with which it will be possible to evaluate the feasibility and demonstrate the solution of most of the operations required for space exploration of very long duration. And the Saturn IB and Saturn V will provide the launch vehicle power necessary to carry out whatever programs the national interest may dictate for many years to come.

A few examples will illustrate the broad spectrum of manned space flight missions that could be carried out in the years to come using this launch vehicle/spacecraft capability.

In near-Earth space, missions could include low- and high-inclination, polar, or synchronous orbits to accomplish research, technological, and applications objectives. Such missions would utilize the extensive maneuvering and extravehicular capabilities inherent in the Apollo system.

By increasing the amount of expendable supplies and propellants carried on board, it is entirely feasible to extend the manned Earth-orbital stay-time of the Apollo LEM to a month and possibly to as much as 3 months.

In a low-inclination orbit, below the Van Allen belts, the basic problems of keeping men in space for extended periods could be studied, rendezvous and resupply problems could be worked out, and scientific experiments could be conducted.

In synchronous orbit, where the spacecraft hovers over a fixed area of the Earth all the time, experiments could be carried out which involve manned observations over a given portion of the Earth or which use man to assist in the operation of various experimental systems.

In polar orbit, scientist-astronauts could monitor and observe the entire surface of the Earth as it passed beneath the spacecraft, mapping it and surveying most of the world's resources.

Similarly, the Apollo-LEM capability for lunar missions can be extended to permit detailed mapping and surveying of the Moon from lunar polar orbit for periods up to 28 days. Further, using the lunar excursion module as a "truck" to provide supplies, stay time on the Moon can be extended for periods up to 2 weeks, permitting increased exploration of the lunar surface.

With respect to longer range missions in the 1970's and 1980's, Mr. Webb wrote the President, those offering the "greatest promise in the manned area are systematic lunar exploration, large orbiting space stations, and manned exploration of Mars."

For example, it may be desirable for the United States to establish semipermanent or permanent lunar bases. An unmanned lunar excursion vehicle could be used to land a lunar surface transportation vehicle, or "jeep." This jeep would provide shelter and scientific equipment and would carry sufficient food, water, and oxygen, for extended tours of the lunar surface. Another long-range possibility would be the construction of large telescope or radio astronomy observatories for the investigation of the stars and galaxies, unobscured by the opacity of the Earth's atmosphere.

In Earth orbit, as an outgrowth of the long-duration Apollo missions described earlier, a "medium-size" manned orbiting research laboratory might be developed. Such a space station would accommodate six to nine men and remain in orbit for up to 5 years. Resupply vehicles, or "space shuttles," could be used for crew rotation and for delivery of equipment and supplies. The laboratory would provide roomy quarters with a "shirt-sleeve" environment for conducting a wide variety of experiments in space. It would also contain a centrifuge, should it be found essential for reconditioning crew members to withstand the effects of gravity after periods of weightlessness.

A larger permanent manned orbiting research laboratory accommodating 20 to 30 men might then be developed by assembling three or four of the medium-size laboratories in space. Artificial gravity could be provided in the laboratories by rotating them about their axes.

Possibly the most challenging long-term goal of the entire space program is manned exploration of the planets—especially of Mars. One of the most significant events in the history of mankind may well occur when man first sets foot on the planet Mars, possibly to view plant life and animal life unlike anything ever seen on Earth. Although tremendous strides in space technology and many preliminary unmanned and manned missions of various types must be carried out before manned exploration of Mars can be seriously considered, preliminary study has been given to such a mission.

In the words of Mr. Webb, "these missions, together with unmanned exploration of comets, asteroids, and the more distant planets, and of the inner and outer reaches of interplanetary space all portend a new era of understanding for man, particularly of the origin and evolution of the Sun and the planets, about which he has conjectured for so many centuries."

THE SCIENTIFIC EXPLORATION OF SPACE: A PROGRESS REPORT

John F. Clark
Director of Sciences, Office of Space Science and Applications
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The National Aeronautics and Space Administration was established nearly 7 years ago in the early days of the Space Age. Motivated by the intent to establish and maintain this country in a strong position in the space age, we have undertaken to develop a broad space capability that will secure to this nation strength, security, flexibility, and the freedom of choice in space matters. An essential part of this effort is a vigorous program in the use of rockets and spacecraft to advance human knowledge of the Earth and space and to develop practical space applications. This paper is concerned with the achievements of this vigorous program.

The NASA Space Science and Applications Program is large and diversified. Its present level of funding is almost three-fourths of a billion dollars per year. Since its inception our program has achieved 57 successful satellite and space probe flights. In addition, hundreds of successful sounding rocket flights, balloon-borne and aircraft experiments, ground observations, laboratory research, and theoretical work serve to round out the effort and to establish close ties between the space flight program and related ground-based activities which are essential to a valuable and productive space flight effort.

Of the 57 successful space flight missions, 33 were scientific satellites, 18 were applications satellites, and 6+ were successful deep space probes. The plus refers to Mariner IV, which on Friday, May 28, will have been en route to the planet Mars 6 months.

The program began with modest Explorer-type satellites. Since then, the spacecraft have become more complex in order to carry out their more ambitious missions. In the space exhibit at the McDonnell Planetarium are a full-scale Scout launch vehicle; models of the Ranger and Mariner IV spacecraft; and the Tiros, Nimbus, Orbiting Solar Observatory, Alouette, Echo, Syncom, Relay, and several different Explorer satellites. This is an extensive sampling of our launch vehicles and spacecraft, but there is an equally extensive list of models which are not here, including such major launch vehicle systems as the Atlas-Centaur, Atlas-Agena, Thor-Agena, and Delta; the Surveyor and Lunar Orbiter spacecraft; the Biosatellite; and the Orbiting Geophysical and Astronomical Observatories.

The tremendous scope and diversity of this program always present problems for the speaker who would summarize its accomplishments. The method most frequently selected is that of concentration on a few selected space flight projects or areas of science, generally those of particular interest to the speaker. But in following such a course, it is inevitable that most of the forest must remain unexplored and unnoticed while a few specific trees are sketched in considerable detail.

Today, I have chosen the alternate course of presenting a comprehensive progress report on our scientific exploration of space by dividing the total program into its component scientific and applications disciplines. I will take up first the discipline of stellar and galactic astronomy, followed by a discussion of the Sun, our nearest star and the source of energy for the solar system. The third discipline will be that of energetic particles and fields, including the solar wind and its interaction with the Earth's magnetosphere, and the Van Allen radiation belts. As we come closer to Earth, we encounter successively the fourth and fifth disciplines of ionospheres and atmospheres. This leads naturally to the three areas of meteorology, communications, and geodesy. We will then turn our eyes away from Earth—first to the Moon, then to other planets.

ASTRONOMY

As you will undoubtedly hear this afternoon from Professor van de Hulst, the astronomical community has been planning for many years to use large, accurately pointed telescopes above our atmospheric veil to explore the celestial sphere at wavelengths which cannot penetrate to the Earth's surface. However, while waiting for the large Orbiting Astronomical Observatories to be launched, sounding rockets have provided both exciting scientific results and data required to design effectively the future satellite investigations.

One such rocket experiment lead to an unexpected result. The amount of light at ultraviolet wavelengths was found to be about as expected for average stars such as our own Sun, but for hotter stars, the amount of UV radiation was found to be as much as 30 times smaller than had been expected. These findings have lead to a recent substantial revision downward of the temperatures for these hot stars, thus bringing their theoretical and experimental values of ultraviolet flux into agreement.

Even more recently, sounding rockets have lofted X-ray detectors, which have discovered and located the positions of ten separate X-ray sources to within 1.5 degrees of arc or better. The position of several of these sources are defined with sufficient accuracy to search optical photographs to locate their sources. The X-ray source in the Crab Nebula has an angular diameter of 1 arc minute as determined from the rocket observation of a lunar occultation of the Crab and is located within 1 arc minute of the center of that Nebula.

THE SUN

From the perspective of a solar physicist, the Earth is a body immersed in the atmosphere of a star which we call the Sun. The radiations from the Sun control the environment of interplanetary space, of our Earth, and of the other planets. The emission of radiation from the Sun, except in the visible region, is now known, primarily from rocket and satellite observations, to be variable. As a consequence, the Earth environment is variable. There is a systematic variation in solar activity, with a maximum and a minimum, each occurring every 11 years. We are presently in a period of minimum solar activity, with the next period of maximum activity expected to occur near the end of this decade.

The solar flare appears to be the most important part of the solar activity insofar as the effect upon the Earth environment is concerned. The flare is a sudden brightening of a large area of the solar surface occurring in a few minutes and then slowly decaying away over a period of hours. X-rays and enhanced ultraviolet light are emitted during the life of the flare, and these radiations increase the ionization in the Earth's ionosphere, thereby disrupting short-wave communications.

Measurements from the satellite OSO-I have provided an excellent correlation of the flux of solar X-rays with the passage of active regions across the surface of the Sun. From these data it was evident that even during a period of minimum solar activity the solar X-ray flux was highly variable. Out of several hundred hours of observation only about 6 hours were found in which the X-ray flux did not vary by more than 5 percent. Superimposed on this slowly varying component were rapid variations which, in one extreme instance, changed the flux by a factor of four in less than 1 second, thereby indicating a highly localized source of the X-radiation.

ENERGETIC PARTICLES AND MAGNETIC FIELDS

Next we move outward from the Sun to consider the solar wind and its interaction with the Earth's magnetosphere, which is that region of interplanetary space dominated by the Earth's magnetic field. The solar wind, first mapped in some detail by the Mariner II Venus probe, is a steady stream of charged hydrogen and helium nuclei, moving outward from the Sun with a velocity of some 400 km/sec and carrying with it a magnetic field. The strength of this field is roughly 1/10 000 as much as the field at the surface of the Earth, and its characteristics match closely those of the local magnetic field observed several days earlier on the corresponding region of the Sun.

Two boundaries are deduced by the interaction of this solar wind with the terrestrial magnetic field. Roughly 50 000 kilometers away from the Earth toward the Sun lies the boundary of the magnetosphere, which was observed by the satellites Explorers XII and XIV. Explorer XVIII found 25 000 kilometers closer to the Sun a second boundary, or shock front, which separates the region of undisturbed solar wind from the largely disordered flow produced by its interaction with the Earth's magnetic field. This phenomenon is, in many respects, analogous to that observed in a supersonic wind tunnel, as the flow of gas interacts with and goes around a blunt body, with a consequent production of a shock front very similar to that observed between the Earth and Sun.

Behind the Earth, that is, in the direction away from the Sun, the terrestrial magnetic field is swept out by the solar wind to very great distances. Instruments on Explorer XVIII had mapped this magnetospheric tail out to the limits of the satellite's orbit at 200 000 kilometers which is more than halfway to the Moon. Indications are that this tail extends well beyond the Moon and resembles in many respects the tail of a comet. During the flight of Mariner IV toward Mars. no evidence of Earth's magnetosphere was found at distances beyond Earth of some 30×10^6 kilometers.

Other interesting phenomena have been discovered in the region of Earth's magnetosphere behind Earth, including a magnetically neutral sheet separating the outwardly-directed magnetic field characteristic of the Southern Hemisphere from the incoming magnetic field characteristic of Earth's Northern Hemisphere.

The Van Allen trapped radiation belts are prominent features of the magnetosphere, and have been extensively mapped and studied over the past seven years, using satellites and space probes.

Explorer XVIII also discovered that the Moon possesses a wake analogous to Earth's magnetospheric tail, during a single penetration of the Moon's tail at a point approximately halfway between the Moon and Earth.

Historically an entirely different field of investigation has been the study of cosmic rays, which were discovered early in this century. Most of the observations had to be confined to the higher energy components of the cosmic rays because only these could penetrate the Earth's magnetic field to balloon altitudes. Forbush had found a rather surprising modulation of the cosmic ray flux by solar activity, in particular, a general decrease of this flux during periods of maximum activity of the Sun, and short-term decreases after larger solar flares followed by recovery in a few days.

Space probe and satellite observations have now produced direct measurements of the mechanism by which the Sun modulates the intensity of galactic cosmic rays. Specifically, the magnetic field imbedded in the solar wind, despite its small magnitude, acts over interplanetary distances so large that minute changes in direction accumulate so that primary cosmic ray particles with energies up to many thousands of billion electron volts are prevented from reaching Earth. Solar activity strengthens the field and decreases the cosmic ray flux. There was a substantial increase in observed cosmic ray flux between the 1962 flight of Mariner II to Venus, and the Mariner IV flight toward Mars $2\frac{1}{2}$ years later, at a period of minimum solar activity. Because of their importance in the dynamics of the universe, we are looking forward to the eventual measurement of the less energetic cosmic ray flux in interstellar space.

THE IONOSPHERE

Earth's ionosphere is that part of the upper atmosphere in which electrons exist in sufficient numbers to affect radio waves. It starts roughly 50 kilometers above Earth's surface and extends outward many hundreds of kilometers. It is produced primarily by the interaction of solar radiation with the neutral atmosphere. The atmosphere thus behaves as an absorbing blanket which shields Earth from radiation in the X-ray and ultraviolet regions, and a study of the ionosphere provides a method for investigating this absorbed radiation and the complex resultant reactions and dynamic processes in the ionosphere.

As in the other scientific disciplines, of prime importance to the progress made in ionospheric research in the past 7 years is the acquisition of new satellite data. The detailed measurement of electron density from above the ionosphere, made from the Canadian/U.S. Alouette I satellite, enabled this region to be charted for the first time, and established the nature of the topside ionosphere on a global scale. Associated with this satellite a new series of electromagnetic plasma resonances was also discovered which enabled both the magnetic field and the electron density to be determined with high precision in the vicinity of the spacecraft.

Helium was discovered to be an important constituent in the upper atmosphere. The development of techniques for measuring both neutral gas and charged particle temperatures resulted in the discovery that the charged particles produced by photoionization of the neutral atmosphere can have temperatures well in excess of that of the neutral gas.

THE ATMOSPHERE

Probably the most striking summary of our present understanding of the Earth's upper atmosphere is recognition of the variability in structure and composition that occurs with changes in latitude, altitude, time of day, season, and solar cycle. The upper atmosphere was found to be quite responsive to external energy inputs, principally but not exclusively of solar origin. For example, the temperature of the isothermal region of Earth's atmosphere above about 300 kilometers has exhibited values between 700 and 1800° K and higher.

The importance of molecular diffusion in determining the distribution with altitude of atmospheric constituents has been well established. Hydrogen and helium have been found to be important constituents of the Earth's upper atmosphere, and the density of the atmosphere at these extreme altitudes is much greater than previously expected.

A diurnal bulge in density of the upper atmosphere exists on the daytime side of Earth with the maximum occurring in the early afternoon. Strong windshear zones have been found in the region from 70 to 120 kilometers above Earth's surface.

METEOROLOGY

Cloud cover observations began with the launch of the satellite Tiros I in April 1960. Nine successful Tiros satellites have provided virtually continuous observations since that time.

These satellites demonstrated very quickly that the Earth's cloud cover is highly organized on a global scale. Coherent cloud cover systems are found to extend over thousands of miles and are related to other systems of similar dimensions. In this way, the integrated characteristics of the atmosphere on a global scale has been shown very clearly. Also, individual weather systems have been directly identified by their cloud structure, thus making it possible to identify and locate important atmospheric phenomena, such as fronts, storms, hurricanes, and cloud fields, and to chart their courses on a daily basis with high accuracy.

For example, during 1964 meteorological records list 62 tropical storms. Of these 62 storms, 45 were observed by meteorological satellites, and 17 of these 45 were located and identified by satellite before they were noted in the forecast bulletins issued by the cognizant forecasting centers.

The achievements just described were based on the TV cloud pictures provided during sunlight only. Infrared radiation measurements have provided some nighttime cloud cover data from which the height of the cloud tops could be inferred. Tiros IX, launched this past January, has demonstrated a capability to obtain global cloud cover data daily from a spin-stabilized satellite whose spin axis is maintained perpendicular to its orbital plane.

Command and data acquisition stations, communication links, and data processing techniques have been developed in order to permit the Weather Bureau to utilize satellite information in a timely manner in its routine weather analysis and forecasting operations. The space program is, in fact, playing an important role in providing the global data gathering capability needed to match advancing theory, moving us rapidly closer to the day when successful long-range weather forecasting will be possible.

It should be noted that satellites do not replace the ability of rockets to take measurements directly in the lower atmosphere. Thus, meteorological rocket data have indicated the existence of different circulation patterns above and below 80 kilometers, suggesting the possibility of different physical mechanisms to sustain these motions. A similar importance is attached to sounding rocket data in the disciplines of atmospheric and ionospheric physics.

COMMUNICATIONS

It is not necessary to recite to you in detail the outstanding successes achieved by Echo, Relay, and Syncom, because these successes are so familiar to every owner of a TV receiver. A session entirely concerned with the impact of space on communications is scheduled for this conference. In all likelihood, the chartering of a commercial Communications Satellite Corporation by the Congress, the successful launch of that corporation's first Early Bird satellite by NASA, and the inauguration of commercial service via Early Bird by the Communications Satellite Corporation are achievements which make unnecessary any further remarks on this topic.

GEODESY

A satellite's orbit is determined by the distribution of mass within the Earth. If the Earth were a perfect sphere, the satellite would move in an orbit whose plane would keep a constant orientation in space.

Actually, the plane of a satellite's orbit rotates slowly in space due to the additional force of attraction exerted by the Earth's equatorial bulge. Studies of the orbital changes of a number of satellites have yielded a very precise value for the height of this bulge. There exists a discrepancy between the observed value and that which should exist on the assumption of hydrostatic equilibrium. This implies that the interior of the Earth has sufficient interior mechanical strength to maintain its nonequilibrium shape in spite of the resultant stresses at the base of the outer mantle.

More detailed analysis of these gravitational variations yields a figure of the Earth in which the Northern Hemisphere contains slightly more material than the Southern Hemisphere, and in which there is a lump in the region of the southwestern Pacific, a depression in the Indian Ocean, and another depression in the Antarctic. Although these depressions and elevations have heights of only some tens of meters, the information is very important because of its direct bearing on our ability to deduce the processes by which the continents have been formed and by which mountain building continues.

For the first time in this century, a new set of astronomical constants involving major changes was adopted by the International Astronomical Union at its meeting at Hamburg in August 1964. These changes were due directly to an improvement in constants used in computing the orbits of satellites and space probes and will significantly improve astronomical predictions of the positions of celestial bodies in the future.

Although further analysis of satellite data should result in substantial additional improvements of our knowledge of the Earth's gravitational field, the most outstanding accomplishments expected in satellite geodesy in the relatively near future are in geometrical geodesy, which is the accurate location of various sites on the same Earth-centered reference frame. Observations of the new satellite series called GEOS and of its passive balloon satellite cousin PAGEOS will permit for the first time the accurate mapping of places throughout the world on a single coordinate system, and the accurate determination of the relative positions of the various geodetic datums which, in the past, have been derived separately for each country or region with little or no possibility of interconnection.

THE MOON

Telescopic pictures of the Moon have been collected and published in a single atlas so that the entire visible portion of the Moon is available for reference. By a clever technique, Professor Gerard Kuiper has been able to make rectified pictures of the lunar surface showing how even regions near the edges of the Moon would look if one were able to view them from the vertical direction. Careful Earth-based photometric studies of the lunar surface have made possible geological maps which indicate variations in the type of surface material. These maps have been and will continue to be useful in the selection of sites for Surveyor missions.

Earth-based radar measurements of the lunar surface characteristics show that the Moon's surface looks rather smooth to radiations of approximately 1 meter in wavelength. At shorter and shorter radar wavelengths, the surface becomes rougher and rougher, approaching the very great roughness observed in visible light. Laboratory attempts to duplicate these characteristics at radio and visible wavelengths have yielded a rather dark-colored, lightweight, porous material.

Earth-based infrared temperature measurements show that after sundown there are areas on the lunar surface which cool much more slowly than does the general lunar surface. This observation has been interpreted as showing that the slowly cooling areas are composed of material of higher conductivity than the general surface. More solid rock in the floors and walls of younger craters has been prominently featured in such interpretations.

In the first decade of the 19th century, Sir William Herschel reported seeing red clouds on the lunar surface. Few additional reports of lunar activity were received until 1957, when Kozyrev reported sightings of red clouds in the crater Alphonsus. Additional sightings were made in October, November, and December of 1963, and in June, 1964, near the crater Aristarchus. While no consensus has been reached concerning the origin of these phenomena, it is no longer believed that the Moon is a totally dead rock.

In 1959, the Soviet Lunik III photographed two-thirds of the Moon's far side at a resolution greatly inferior to that achieved by Earth-based photography of the Moon's near side. The Lunik pictures did show that the Moon's far side does not appear grossly different from the Moon's near side.

Within the past 10 months, the magnificently successful missions of Rangers 7, 8, and 9 produced photographs of the Moon at a resolution some 2 000 times better than that obtained from Earth-based telescopes. Considerably more time will be required for the full analysis of these thousands of pictures, but some facts are already clear:

1. The density of craters increases roughly exponentially with decreasing size, down to the smallest sized craters in Ranger photographs, and craters are the dominant topographic features to be seen at close range.

2. Small, relatively fresh primary craters in the lunar maria are strikingly similar in appearance to those of larger size.

3. Most of the craters smaller than 300 meters in diameter have smoothly rounded rims and show large variations in depth-to-diameter ratio.

4. The small-scale features of the "blue" mare, of which Tranquillitatus appears typical, the "yellow" mare, of which Cognitum appears typical, and the floor of the crater Alphonsus are strikingly similar.

5. The lunar surface appears to be virtually free of boulders or other protruding debris.

6. No small-scale sharply-defined surface cracks seem to exist on the Moon.

7. Two distinct types of craters exist on the Moon in all size ranges. The sharper primary craters appear to have been formed by high velocity impacts of extra-lunar material. The softer secondary craters are probably caused by debris thrown from the primary craters.

8. A third crater type, termed a dimple crater by Dr. Urey, is contained in a smaller number of the Ranger photographs. They appear to be depressions like those formed when an unconsolidated material like sand is allowed to flow into a crack or a crevice.

9. The dark halos around several craters within the large crater Alphonsus are deposits relatively newer than the floor material.

10. The crater walls, rims, and highland regions around Alphonsus appear smoother than the crater floor. The same is true of the central peak, and no central vent is apparent.

11. There is considerable evidence for fluid flows of some form in the mare floors and other regions.

12. Faint linear structures consisting of crater chains, elongated craters, shallow linear depressions, and ridges show predominant directional trends which generally coincide with the large-scale lineaments which have been observed from Earth's surface for a long time.

There is no question but that a new and exciting chapter has opened in man's search for knowledge of his nearest celestial neighbor. The detailed information on lunar topography to be provided by the Lunar Orbiter, knowledge on the strength and other characteristics of the lunar surface to be provided by Surveyor, and above all the ability of man to explore the lunar surface in person and to bring back selected samples of that surface will surely increase our knowledge of the Moon at an accelerating pace throughout the remainder of this decade.

THE PLANETS

Because the space program has provided *in situ* information about only one other planet, Venus, and may be about to produce information about one other, Mars, my next remarks will be confined to these two planets.

Ground-based radar measurements have determined that Venus rotates very slowly in a direction opposite to that of the other planets, so that from the Venus surface one would see the Sun rise in the west and set in the east twice each year—that is, if the thick cloud cover would permit. Mariner II spacecraft and the ground-based measurements are in agreement that the surface of Venus may be as hot as 700° K with very little difference in temperature between the sunlit and dark hemispheres. The Venus surface pressure appears to be of the order of 10 Earth atmospheres or greater. The absence of a planetary magnetic field or of trapped radiation at the closest approach to Venus of Mariner II has lead to the conclusion that if Venus has any magnetic field it is less than one-tenth that of Earth.

Although Mars is smaller than Venus and farther from Earth, its relatively clear atmosphere and better illumination by the Sun at times of closest approach to Earth have combined to provide us with more ground-based information about Mars than any other non-terrestrial planet. Crude maps of the Mars surface are available with resolutions of several hundred kilometers. The direction of rotation of Mars about its axis is the same as that of Earth, and the duration of the Mars day is very similar to that of an Earth day. Seasonal changes of Mars' surface features somewhat analogous to those of Earth also have been observed, with polar ice caps which wax and wane and color changes which have been attributed by some scientists to vegetative growth associated with seasonal water availability. Ground-based spectroscopic observations indicate that the surface atmospheric pressure on Mars is approximately 25 millibars rather than the formerly accepted polarimetric value of 85 millibars. Carbon dioxide is a prominent atmospheric constituent.

During its fly-by of Mars this coming July 14, Mariner IV, if all continues to go well, should transmit back to Earth some 20 photographs of portions of the Mars surface with a resolution of surface features as small as 3 kilometers. Of comparable importance, as the spacecraft is eclipsed by the planet, analysis of the strength and phase of its radio signals should yield accurate values for the Mars surface pressure. Measurements during the fly-by will determine the existence and strength of the Mars magnetic field and of trapped radiation analogous to the terrestrial Van Allen belts. The fluxes of solar protons and meteoroids will continue to be monitored. All of this information will be important in helping us define more precisely the investigations to be conducted by the larger Voyager Mars missions beginning 4 to 6 years from now.

BIOSCIENCE

Although the impact of the space program on bioscience is still developing, there appears to be much of promise in the space program for the bioscientist. Of particular importance is the area of exobiology, that is, the search for and study of extraterrestrial life. Should life be discovered on Mars this will be an exceedingly exciting event in the space program. Even if life is not discovered on Mars, however, the investigation of the chemistry of the planet, particularly of how far that chemistry may have progressed toward the ultimate development of life, will be of interest and importance. Finally, in near-Earth satellites there will be the opportunity to study living material under the conditions of outer space. Of particular significance will be the condition of weightlessness, and the removal of the living organisms from the normal periodicities experienced at the surface of the Earth.

CONCLUDING REMARKS

I hope that the division of this talk into individual disciplines has not obscured the unity of space science. Science in space is not separate from the rest of science, but is rather an extension made possible by the availability of spacecraft and rocket boosters.

Thus, because of the space program, geophysics is experiencing a tremendous resurgence and broadening of its horizons. On the one hand, the geophysicist finds in the satellite a new tool for investigating classical problems, such as the structure of Earth. In addition, he finds exciting new problems to tackle, such as the interactions between the solar wind and the Earth's magnetosphere. Moreover, geophysics is being carried forward to new domains as instruments reach other planets, giving to the discipline a perspective that it could never have achieved while confined to a single body of the solar system.

Similarly, the space program is giving a new dimension to astronomy. The ability to make observations above the filtering, distorting atmosphere in wavelengths not hitherto observable promises exciting new discoveries. The physicist also finds in the regions of outer space a laboratory of challenging opportunity. In interplanetary space, matter and fields exist under conditions unobtainable in a laboratory on the ground.

It is indeed interesting to observe that one of the impacts of the space program on geophysics, astronomy, and physics has been to draw these three disciplines together more closely than they have been drawn together in the past. In the investigation of Sun-Earth relationships and in the broader problem of investigation of the solar system, all three of these disciplines find themselves in partnership on problems of common interest.

In conclusion, I hope that I have been able to communicate to you a small measure of the excitement which has been seizing the scientific community in one discipline after another, as results from their space flight experiments swell from a trickle to a torrent. For me, the real importance of our program for the scientific exploration of space lies in the fact that its true potential for increasing man's knowledge is just beginning to reach fruition. And, in the Space Age, more than ever, "Knowledge *is* Power."

DISCUSSION

Hugh L. Dryden
George E. Mueller
John F. Clark

QUESTION: I would like to ask Dr. Dryden if he could characterize the Soviet accomplishments in both manned and unmanned space in comparison with the U.S. accomplishments.

DRYDEN: To do this, very briefly, I think in the field of weather satellites and communication satellites, we are quite far ahead in the scientific fields that you have heard Dr. Clark talk about. I think we have the lead, but they are increasing their effort so that, in time, they will be a serious competitor. In the manned space flight, they have had the advantage of the larger booster capacity which we have just succeeded in realizing. They have more hours in space and they put somewhat greater weights into space, but I think this is a lead that will disappear in time. Both of us are developing, as fast as we can, the same capabilities that are needed for man to operate in space. The order in which we happen to reach various items, I think, is relatively unimportant compared to the overall result. For instance, we did the first maneuvering of the satellite, and their man first walked in space. I do not think that it is significant insofar as the relative positions are concerned.

QUESTION: I would like to ask Dr. Mueller or Dr. Dryden where the Manned Orbital Laboratory fits into our space program? In some ways, it seems more reasonable to have it occur before Apollo, and in some ways it seems logical to have it somewhat following Apollo.

DRYDEN: First of all, note that Mercury was a one-man space laboratory of sorts; Apollo is a three-man space laboratory. We can do our so-called orbiting laboratory experiments that are necessary to go to the Moon with the three-man Apollo space station. Before we undertake travel of months to planets, a very large amount of experimentation in the Earth's space station or space laboratory will be necessary both on man and on machines. Now, very frankly, the reason for the selection of order was an assessment made at the time of President Kennedy's decision that the booster capacity which our competition had would enable them to accomplish such feats as soft land on the Moon and put up a space station before we could. They decided to do so and did it.

Now, they have, of course, not been able to do everything that they have been capable of doing anymore than we have, and they have not accomplished all their potential at as early a date. Our assessment, at the time, was that the nearest goal at which we could start more or less even in the competition was that of going to the Moon and, for that reason, we contented ourselves with Earth-orbit experiments on a three-man space station rather than the development of a larger one at this time.

MUELLER: I wanted to add just one thought—we have been looking rather carefully at the experiments that man can do and should do in space in the immediate future. One of the results of that look has been that it would appear that we need more unpressurized volume for the conducting of the experiments than we do pressurized volume. It is not just that a certain pressurized volume is needed, but rather what it is we need to do there. These thoughts have led us to the feeling that we can do all of the experiments we presently believe need to be done, at this phase of the development of the space program, using the basic Apollo and lunar excursion module hardware—for durations of several months, of course. For very long durations, we do not have enough knowledge to know just exactly what conditions man requires.

QUESTION: I am not sure to whom I should direct this—possibly Dr. Dryden. Could you put a relative price tag on Russian efforts compared to ours? Are Russian limitations possibly due to their lack of finances? In other words, do they have the money? Is this their problem?

DRYDEN: I do not think I want to pose as an expert on the economics of Russia, but from talking to Russian scientists and engineers, I gather they have trouble getting funds from their authorities—just as we do.

MUELLER: From whatever you can measure in the way of the activities in space, it is quite clear that the Russians are devoting a large amount of funds to their space program—probably comparable in terms of their economy to our efforts. It might be interesting to note that during the past year alone, the Russians launched about three times as many satellites in the Cosmos series as this country did. So, they have some very large programs which have not been adequately reported as yet.

We ought to make it very clear that the Russians are putting a large effort into space and that this effort has been increasing through the past few years, building up at a tremendous rate. I do not want to steal your luncheon speaker's talk, but he will say, "Do not underestimate the Russians."

QUESTION: Do we have a program for landing on the Earth—let us say on good solid Earth—that might be comparable to landing on the Moon? I recognize there is a big degree of difference due to gravitation and similar factors, but it does seem that landing on the Earth would add a lot to the commercial aspects of space.

MUELLER: Well, the hull of the space capsules, as you understand, are capable of landing on the Earth. They have to be because that is always one of our emergency landing spots. In order to provide for regular landings on the Earth, there are certain additional complexities that need to be added to the spacecraft and to the ground system. A rather careful analysis was made of this, and it was decided, in the case of both the Gemini and the Apollo, that since we needed to deploy ships to provide for both communications and for emergency landings, there were fewer complexities involved in a water landing than in a land landing.

We have been continuing the study of land landing methods—how to land on land, and whether it is quite feasible to do so. It does not appear, however, that we are quite ready to enter into commercial operation of the space system, and, until we do progress further, there do not appear to be overwhelming advantages in the development of an actual land landing capability. However, that is an open topic and one that we are working on quite hard at the present.

DRYDEN: May I just add one comment to go back before Dr. Mueller's time. The original decision was made because landing in the water is a much more predictable event. You do not have to worry about whether there is in the landing area a plowed field, a railroad track, a transmission line, or hard rock. Also, there is a considerable difference between real estate available to us in the United States and the vast areas in Russia in which the problems of, at least, civilization are a little less acute. We have, of course, had programs for developing land landings; their development did not proceed as rapidly as the development of the spacecraft. We are still making such experiments, as you know, if you read the papers.

QUESTION: I would like to ask a question of Dr. Clark. There was a paper published by a Dr. Bailey of Australia within the last year, I think, that proposed that the Sun has a large electrostatic charge—I have forgotten the exact figure, somewhere near 10^{18} or 10^{27} electrostatis units. What is your opinion of this theory and, if it is true, what is the possibility of using it as a source of propulsion for electrostatic charge spacecraft?

CLARK: That is a rather tall order. I am familiar with the paper, and I think that this is the sort of situation where, in the normal course of scientific research, one must simply wait for all the returns to be in. It is the sort of thing which is exceedingly difficult—well, it is impossible, I think—to measure directly, so it is necessary to make predictions based on what such a charge would do in terms of phenomena like the solar wind and then see if these predictions are verified. To date, no such prediction or test has been possible, and it therefore remains pretty much theory to the best of my present information.

If this theory should be proved, this sort of thing may well be analogous to the large electrostatic charge on the Earth from the 300 kv potential between the Earth's ionosphere and ground. Now, there is a tremendous amount of energy available to something like 2000 amp flowing in that system. When 300 kv is multiplied by 2000 amp, the product is quite a bit of kilowatts. But the problem is that the current is so widely diffused around the Earth that the actual current that one could collect and the actual number of watts that one could get at any flight over the Earth's surface is unfeasibly small by something like 10^{16} or 10^{7}. I would suspect it is the sort of a situation you would have if the same situation holds with the Sun, involving tremendously larger distances, and, of course, the tremendous problems of getting in close to the Sun would make such an undertaking a few orders of magnitude more difficult than that on the surface of the Earth.

QUESTION: I would like to address this question to Dr. Mueller. The next period of anticipated solar activity maximum is at the end of this decade which coincides with the time we are planning our manned lunar missions. What effect, if any, will this have on our manned lunar landing?

MUELLER: Well, we have spent a great deal of time evaluating both the magnitude and intensity of the solar flares and their number, and also examining the shielding offered by the command module, by the lunar excursion module and by the various clothing that the astronauts wear. There is a possibility that we would need to abort one of the landed missions in the event we were on the lunar surface at the time a flare developed. That possibility appears to be about—well, it is hard to predict at this point in time—but it is very small. During the rest of the course of the flight, the astronauts are adequately protected by the spacecraft, and it does not represent a danger to them. Now, this is true of the largest solar flare that we have ever observed, and includes all of the solar flares that we have observed to date.

QUESTION: Gentlemen, do we have proof that some of the Russian manned space flights were unsuccessful in their ultimate ends? In other words, was there any unsuccessful landing of a Russian space flight.

DRYDEN: I am not quite sure what you mean. We do not know of any Russian astronauts that were lost. There has been one landing within the space cabin. In all others, the astronauts have left the ship at about, I think, a few thousand, maybe tens of thousands, of feet and landed by parachute.

QUESTION: You have no knowledge of any Russian astronauts that were left floating in space?

DRYDEN: No, we do not.

THE SPACE CHALLENGE

(Luncheon Meeting)

Chairman
Brice R. Smith
President
SVERDRUP & PARCEL
AND ASSOCIATES, INC.

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THE SPACE CHALLENGE

Edward C. Welsh
Executive Secretary
NATIONAL AERONAUTICS AND
SPACE COUNCIL

This bicentennial space symposium is a tribute to the past, a salute to the present, and a beacon of hope for the future. It marks for our attention those whose enterprise and initiative have made St. Louis a thriving metropolis and those who have contributed their technical and managerial skills to the national space program. I take the opportunity afforded me today to congratulate those who planned and are responsible for this symposium.

DYNAMIC FORCE

The space effort is one of the most dynamic and constructive forces to have influenced this great country's growth. It combines exceptional abilities, private and public resources, the factor of competition, and the pioneering spirit. The future of our country may well rest upon our performance in space. Be assured that space, as a way of thinking and as a vigorous enterprise, is here to stay. It has become a permanent and an essential part of our Nation's institutional structure.

MISUNDERSTANDING

Optimism is fully warranted, but it is not so extensive as to leave room for complacency. There are contrary factors with which our national space program must contend both at home and abroad. The adverse forces at home are largely those nourished by misunderstanding. It is the responsibility of each of us to do what he can to dissolve such confusion—particularly the mistaken thesis that we have so many health and welfare needs for our resources here on Earth—so much unemployment, malnutrition and ignorance—that we cannot afford to spend our money on space exploration and particularly on the Moon project.

We should maintain a continuous campaign to improve our way of life, our state of health, our rate of economic growth, and our level of education. We should do everything we can do effectively and efficiently in those regards, but those needs must not be considered to be competitive with our space needs—any more than they are competitive with our national defense requirements. Rather, they complement each other. We can afford to do what is needed in space exploration just as we can afford to do what is needed for our general welfare and for our national defense. In fact, if we are both patriotic and prudent, we cannot afford to do less.

SPACE BENEFITS

It should be realized that resources devoted to space progress create more resources for other purposes. The way of space is the way of the pioneer, but it is also the way of the builder—the force which adds to the total rather than takes from one to give to another.

If we examine the long list of benefits from our space endeavors, we note particularly that they give stimulation to our economic and our technological growth. Properly managed, our space program can help significantly to pay for many of the other requirements of our Great Society and help strengthen our National security at the same time. Our position as a world leader depends substantially on our space program to do both.

It should be unnecessary to point out that funds devoted to the lunar program will be spent to develop our over-all National space capability and consequently have much greater significance than just the successful manned round trip to the Moon. Every dime of that money is spent right here on Earth, stimulating growth, employing personnel, funding new research, developing hardware, and building laboratories, and other useful facilities. And, above all, it strengthens our Country in this competitive world.

SPACE COMPETITION

The space program has to meet contending forces both abroad and at home. We have many excellent relationships with other countries in the form of cooperation in our space program. But, while we talk of cooperation (and we do mean it), we must at the same time recognize that there is competition between this Country and the Soviet Union in the field of space. It is well for us from time to time to take stock—to take a careful look—in order to see how we are making out in comparison with our main competitor. While it is correct to refer to this as a "space race," it is much too complex a venture to permit one to state categorically who is ahead and by how much in the over-all effort. Both space programs are broad in scope and are strongly supported. There are, however, differences in emphasis and in priorities. Making comparisons is also hampered by the secrecy which cloaks so much of the Soviet's activity and some of ours.

One major thesis should be emphasized before making any comparison—the United States should have a vigorous space program and would obtain many benefits from it even if no other nation were engaged in space technology. As Vice President Humphrey said at the Goddard Memorial Dinner this March: "If we were the only nation engaged in a space program, it would still be in our best self-interest to increase our efforts." His thesis is supported by the fact that the space effort helps raise our standard of living, increases our store of knowledge, and furthers world peace.

We should not forget for a moment, however, that we have very strong competition in space, and that we have therefore another big reason for a major space effort, namely prudence. Some well-intentioned but confused people have suggested that we should slow down in our space program, that we should gracefully accept second place to the Soviets. I cannot agree with that for a moment, either gracefully or gracelessly. Our National security alone would suggest reason enough for us to strive to maintain leadership in this space competition.

In examining the status of the space race, it should be noted that those who were predicting a slow-down in the Soviet space effort because of economic difficulties in that country were wrong—just 100 percent wrong. Not only have the Soviets stepped up their effort during the past year and a half, but they have accelerated even more than we have.

COMPARISON

In making a brief and meaningful comparison between the two programs, the following few points might be pertinent:

1. In number of Earth-orbiting payloads the U.S. has launched almost 3 times as many as has the U.S.S.R., although the 1965 rate is less than two to one.

2. In the weight of such payloads, the U.S.S.R. has put up almost three times as much as has the U.S.

3. In propulsion, the Soviets have from the beginning enjoyed an operational advantage over the U.S. However, we are currently making great strides in this regard and it is hoped that we will keep moving up the propulsion ladder so as not to be overtaken again.

4. In manned space flight, the U.S.S.R. is ahead of the U.S., not only in hours of flight but also in multi-manned flight and extravehicular activity. So far, the U.S. astronauts have completed 40 orbits of the Earth, the Soviet cosmonauts have completed 342 such orbits. Moreover, as our Gemini schedule proceeds and contributes continued progress, we must look for much more activity on the part of the Soviets.

5. In the application of space developments to directly useful purposes, the U.S. is well ahead, particularly in such fields as weather observations, navigation, and communications. However, the Soviets have potential capabilities of these types and have already begun to show some actual experience in space communications.

6. In lunar and interplanetary activity, the U.S. may have an edge with the spectacular success of the Rangers and Mariners. We have developed this advantage, even though the Soviets have made a greater relative commitment in this regard, both from the view of absolute numbers of launches and also in regard to weight of payloads.

7. Based upon clear knowledge of our own

program and upon assertions by the Soviets about theirs, one can reasonably conclude that both countries have manned lunar landing projects under way. It would be impossible to state definitely who is ahead in this regard but I am hopeful that we will turn out to be.

8. In the collection of scientific data from space, both countries have made impressive strides, resulting in a possible advantage to the U.S. regarding knowledge of space phenomena and the lunar surface, and an advantage to the U.S.S.R. regarding the effects of space environment on human beings.

9. Both countries are in a position to make many observations from space, but both countries have pledged not to orbit weapons of mass destruction and have stressed that their programs are dedicated to peaceful uses. I can only speak for this country in regard to our intent and do state that we will maintain our defenses while pledging not to use space for aggressive purposes.

In the comparison just outlined, as usual most generalizations are misleading. We are ahead in some regards, and they are ahead in others; and the future of the race depends so much upon how vigorously and how continuously we apply our capabilities to mastering the space environment and perfecting our space technology. There is one generalization, however, which we should constantly keep before us, and that is that we dare not be complacent even while pushing our space program vigorously.

ENERGY FOR SPACE

As we all know, one of the most important keys to space exploration is energy. If there is any area about which we should not become complacent, it is that of generating adequate power to accomplish our future missions. Energy is needed both in propulsion for producing the necessary vehicle velocity and in the auxiliary power for orientation, communications, experimentation, and other related tasks aboard the spacecraft.

We look with some satisfaction at our booster program. New vehicles are being developed for the larger payloads, while increasingly experienced and reliable vehicles are handling the somewhat lesser weights. In addition to the liquid technology, we can be encouraged with the development in solid propulsion as well as in nuclear propulsion. In other words, we have a formidable national launch capability both in use and under research and development. However, we must not be satisfied with what such programs promise and thereby waste the valuable time which should now be devoted to further advancement in research and development of these new technologies.

FUTURE MISSIONS

I stress the importance of energy conversion to useful work as a key to future space adventures, because it truly opens the doors to manned exploration and peaceful exploration of the universe far beyond our atmosphere. We will want to journey to and from the planets in weeks and/or months, not years, and on regular schedules any time in the year. Also, in addition to establishing large bases on suitable planets and logistically supporting them until they can be sustained totally or in part by the natural resources found on those planets, we will want to do many other things, including regularly resupplying and continuously orbiting the Earth with space stations. There are both scientific and military missions for which space stations seem to me to be ideally suited. Moreover, we will want to intercept and sample the resources of planetoids and maybe of comets; we will certainly maintain a growing interest in the search for extra-terrestrial life. All of these and many more worthwhile proposed future projects require power, as the more power we have guaranteed before the mission, the greater is the payload capability, the safety margin for the crew, and the chance of successfully completing the mission.

LONG-RANGE VIEW

It is, of course, necessary that many of us, particularly those in Washington, look at our space program with a somewhat short-range view, since we have to deal with the annual budgetary process. While I am optimistic about some things, my optimism does not stretch itself to the extent of predicting a less frequent budgetary exercise. Therefore, even though it is necessary that attention be given to the short run, I urge all who have the competence to look and plan ahead to do so as often and as thoroughly as possible.

WARNINGS

In conclusion, I would like to take this occasion to express several warnings in regard to the space program. Some of these repeat points already made, but I believe that they merit emphasis.

1. Let us not underestimate the Soviet capabilities or potential.

2. Let us not expect our space program to proceed indefinitely without some tragedy involving our astronauts.

3. Let us not overlook the National security insurance flowing from our construction of space competence.

4. Let us not become so blasé about our space accomplishments that we fail to thrill to the excitement of new goals reached.

5. Let us not expect a steady or automatic flow of increased benefits from our space program unless we invest increasing resources and efforts in that program.

SPACE EXPLORATION GOALS AND FUTURE PROGRAMS

Chairman
Edward A. O'Neal, Jr.
Chairman of the Board
MONSANTO COMPANY

INTRODUCTION

Edward A. O'Neal, Jr.

I am delighted to welcome you to this second session of the St. Louis Bicentennial Space Symposium and Fifth National Conference on the Peaceful Uses of Space.

The company for which I work, the Monsanto Company, is engaged in the business of developing, manufacturing, and selling useful arrangements of atoms and molecules. This activity involves us in some very interesting explorations of our own, of course. But most of these are at the molecular level. We have acquired quite a working knowledge of the *micro*cosm of *inner* space, but we do not have much useful knowledge yet about the *macro*cosm of *outer* space. I am sure that we will get there.

Come to think of it, though, that fits pretty well as a general description of the state of the whole body of science! We have been probing *inner* space for centuries now, but our probing of *outer* space has barely begun.

The goals and future programs of space exploration are the subjects that will be discussed at this session—by eminently qualified experts, I hasten to add, not by me.

As chairman of this session, I believe that I am responsible for at least providing a proper point of departure for the discussions that will follow.

These discussions will be developing ideas on the subject of where do we go from here. But I have to admit that I did not quite know how to tell you where "here" is, and "here" obviously has to be the point of departure. So I undertook a quick investigation of the subject, and this is what I found.

From the viewpoint of space exploration, "here" certainly is not this Khorassan Room. It is not even this hotel or the city of St. Louis; indeed it is not even the United States. "Here" means a planet—a fair-to-middling-size one as planets go—which we call the Earth. And we are hugging that planet for dear life while it spins us at a speed of about 1000 miles an hour. This helps to explain why the days are not long enough to finish all the things we start.

But there is more to this planet Earth that is important as our point of departure for space exploration. It is only one of nine planets which form a rather ordinary kind of solar system around an average-sized star which we call the Sun. The Earth is nestled up rather close to the Sun—only 93 million miles from it. But the Sun's whole solar system is about 7 billion miles in diameter. And it is whirling our planet Earth around in a solar orbit at a speed of about 1000 miles per second. That is why the *years* fly by so fast.

But the Sun and its planets, including Earth, are just one of an estimated 100 billion solar masses within our Milky Way galaxy. I am told that our particular Sun and its satellites are about 30 000 light years from the center of our galaxy—which seems like a comfortably safe distance to me. But I am also told that our galaxy is rotating and that, in doing so, it is dragging our solar system around at a speed of about 200 miles per second. (I trust, in giving you these figures, that my speedometer is registering properly.) Meanwhile, I understand that there are an estimated 100 billion *other* galaxies within the range of our present instruments.

Now, I realize that none of this is news to most of you, but I do believe that the perspective is important. It certainly impresses me to think about the almost infinite reaches of distance that constitute outer space—and then to reflect upon the fact that we are struggling mightily just to get a man on our Moon which is only 235 000 miles away. Nevertheless, I agree we have to crawl before we can walk! Earlier, our first speaker, Dr. Hendrik C. van de

Hulst, gave an equation in which a space trip to the planet Venus is to the center of our galaxy what the height of a door step is to the distance to our Moon.

Well, ladies and gentlemen, that is the doorstep which we stand upon today. That is our point of departure. The distance to be traversed is enough to make one dizzy even if the speeds of revolutions and rotations were not. But I, for one, am going to hang on and enjoy the ride.

THE FUTURE OF SPACE RESEARCH

Hendrik C. van de Hulst
Professor
LEIDEN UNIVERSITY, THE NETHERLANDS

I feel extremely honored to have been invited as the only speaker from abroad to address this distinguished audience on a subject which is difficult because it is so difficult to predict the future. There is always one way out and that is to talk about the past, anyhow.

My natural inclination is towards science rather than to technology. Therefore, I think, I would have been more biased in my answer to the question posed this morning to Dr. Dryden concerning the space efforts of the United States and of Russia. I would have said that in the fields I am interested in, as far as my observation goes, the United States' effort is well ahead of the Russian one in space science. The annual reports on the progress of different nations in the COSPAR meetings present a good opportunity to compare. Last week we had this meeting in Buenos Aires. The presentation by the American Vice President of COSPAR on behalf of the American scientific community was again a highlight. And so was the Russian presentation, which is usually looked forward to with a bit more curiosity. In that respect, the progress in the continent from which I come, Western Europe, is less exciting. We have recently established the European Space Research Organization (ESRO) which operates on a budget about 2 percent of the NASA. But I am not sure that we are yet as effective as NASA, so the output at present may be even less than 2 percent.

The title originally mentioned in the correspondence about this symposium was "Perspectives on Space Exploration." Though my profession is simply that of an astronomy professor, this title appealed to me. Astronomy, after all, deals with space, takes account of perspectives and is exploration. But astronomy is first of all the science of disproportions, that is, with ratios between the quantities one wants to measure and the units which one wishes to adopt. It does not really matter what units one uses, although I was a bit relieved that at least one of the speakers this morning was as advanced as to use metric ones. But without any units, that is, without any scale of measurement, it would not be a science. Too often in popular talks the fact is skipped over that a ratio between 10 000 000 light years and 1 000 000 is exactly the same as that between one dollar and a dime. Generally, these proportions are what makes astronomy literally "out of this world." They have no direct connection with experience and cannot be intuitively felt or guessed like the ratio of sizes of different animals or different plants. In my recent reading in astronomical literature I came across two numbers: the number $3548.1928906 \pm 0.0000020$ and the number $10^{55 \pm 2}$. They both occurred in scholarly papers but, of course, on different parts of astronomy. Their common property is that they cannot be grasped in any intuitive sense.

We have, indeed, gone a very far way from Keppler's concept that the entire astronomical world could be fitted into a pattern of geometrical figures which one could draw in mid-air. The same necessity to go outside our direct visualization shows up in the terminology. In what science would one talk about *subdwarfs, supergiants* or about *new* objects (novae) which are *recurrent?* Or in what science would one still call a chance event which may occur once in 11 000 000 years, like the transition of the hydrogen atom at 1420 megacycles, a "spontaneous" event? This is typical for astronomy and I do not even talk about the dozens of variable constants.

It is a familiar experience that, even in trying to visualize astronomy by scaling down, one does not get very far. For instance, if we take a scale factor of a billion (10^9), the Earth will become a cherry, the Moon will become a pea at the distance slightly over a foot, but the solar system does not fit anymore in this room, and the nearest star, even at the scaled-down distance, will not fit on the Earth, so we still are not very much advanced in our visualization.

The exploration of this strange world has been made possible by the penetrating thought of a number of great scientists throughout the centuries and by an ever increasing number of technical means which they could put to their use. The newest of these technical means definitely is rockets, satellites, big boosters, space probes, and spaceships. It will be up to the present generation of astronomers to harvest the fruits which these new tools promise. Since it is difficult to predict the future and to bring in some perspective that way, I shall go back in the past and by analogy, try to show you what kind of development I expect will be possible in the coming decades.

Perhaps I may first go back a very long time ago. When in 1609 Galilei heard about the construction of a telescope, he asked what in modern terms would be called his scientific attaché in the Netherlands for further information and obtained one for himself. Immediately he made a very important discovery, namely that the stars in the telescope still looked as stars. This meant that the famous observer, Tycho, had been wrong on one point and that the stars were indeed much further away than Tycho had thought, and this removed the main observational obstacle which still seemed to remain against the system of Copernicus. Thus, in the hands of someone who was thoroughly acquainted with the existing problems and arguments about the "world systems," one seemingly trivial observation that a star looked like a point could be made into a crucial test.

This is an example of how science always works. Space research is a new discipline with new possibilities and new problems. But it should never be considered as a discipline in itself. It makes part of the one large field of science, where certain well-chosen observations, in connection with the old questions will bring up the answers and will pose new questions.

It is tempting to talk some more of Galilei. "China and America are celestial bodies." This is a quotation directly from Galilei's work but, of course, it is taken entirely out of context. It occurs in the dialogues when the Copernican system is discussed and where Simplicius holds the point of view that everything in the sky is unalterable and everything on Earth changes. Galilei makes the opponent rightly say: "Well, you don't even know that that is true of the distant countries of the world, for you have never observed a change in countries like China and America." He goes on to say in a perfectly modern fashion that, while we have not observed any changes on the Moon, he doubts if it has ever been observed sufficiently accurately, and that perhaps "if something occurred on the Moon like a big shift of continents then we will observe only a slight difference in the luminosity of certain parts." This is the absolutely modern approach of weighing precisely how good the observations are. I think Galilei would have been terribly excited if he could come back 401 years after his birth and look at the beautiful sets of photographs which we possess now, thanks to the successful Ranger missions.

These points are relevant because, in the same context, Galilei takes for granted, like almost everybody up to the present generation, that all of these faraway worlds are indeed inaccessible to observation from nearby. One cannot go there and look. This is not true anymore. I hesitate to use these words because I firmly believed myself, about 10 years ago, that it would be impossible to go to the Moon. This was not based on the same kind of argumentation like the *New York Times* used in 1920 but it was based simply on the hunch that it would be too expensive (and I still wonder). This does not alter the situation that most of the celestial objects are inaccessible. Of course, there will be fringe objects. As we all know, for instance, to go to Jupiter is almost out of the question, although technically it might still be feasible. To go close to the Sun is similarly difficult. This defines the range of what might be called the accessible region. I think I am safe in saying that the stellar worlds, the galaxy, and the stars are indeed inaccessible, although some people argue differently.

This point may be illustrated by a close examination of photographs of the same object. In succession we may look at:

(a) A photograph made with the small Schmidt camera employed at Yerkes Observatory a number of years ago. This presents a good survey of nebulosities and other features of the Milky Way over a field of about 13°.

(b) A plate of the sky atlas made with the large 48-inch Schmidt camera at Mount Palomar, showing a smaller field of 6° but very much fine detail, including dark clouds with fine luminous edges in many of those nebulae.

(c) A photograph with the 200-inch telescope just resolving the distribution of luminosity across such a bright edge, thus permitting at least some kind of a check on our theories regarding the processes in cosmic gas dynamics which give rise to these edges.

The main point in this illustration is that every increase in resolution gives new clues. We should like to extend this series, but have reached a severe limit. Building much bigger telescopes on Earth seems to be virtually impossible. Sending telescopes into space closer to the object is entirely impossible because such objects are about a thousand light years away. Even if we would travel to the Moon—while we would be a bit closer—that would be doing just the same thing as trying to stand on a chair in order to be closer to the Moon. It just is that far out of reach. There is ample consolation in the fact that space research does give a gain in the spectral range. I shall come to that later.

Let me first go to the solar system for awhile. That is, stay in the accessible places. It is not saying too much that the knowledge of our solar system has already been revolutionized by the space research results of the past 7 years. To make you realize what that means, let me recall the zodiacal light. This can be observed without any instrumental means and shows that dust floats around the ecliptic in our solar system. This, for many centuries, was absolutely the only direct way in which we could observe that there was something between the planets. I had the pleasure to write some 10 years ago a review paper on this matter with over a hundred references. That review paper 5 years later was entirely out of date and could just be thrown away, because of space research.

A second observation which tells us something about interplanetary matter is the observation of comet tails. Of course, comets are not always present, but when they appear and when they happen to have nice tails then the shape of the tails and the change in shape of these tails tells us something about the interplanetary gas streaming by. This is now called the solar wind. In this way two fields, initially wide apart, have been linked: the zodical light and the solar corona, the motions near the Earth and the motions in the solar atmosphere. It is this bringing together of two rather different things observed by quite different observing techniques which is one of the most fruitful ways in which astronomy has advanced and can advance. This intermediate region, the solar wind, has now become a subject in its own right. New details are studied with every new space probe, including magnetic fields, velocity vectors, and particle content.

Other accessible places are, of course, the Moon and some planets. The study of the Moon has also been revolutionized by the space observations. We have heard that abundantly. For the planets the present situation is a bit more questionable. Of course, the results obtained by space missions to the planets so far are fine technical achievements of good scientific quality. But they are not so entirely unequaled as are the lunar observations. I remember the presentation, at the COSPAR meeting in Warsaw, of the first results of the Mariner 2 mission to Venus. It turned out that the radio observations then presented were just about equal in quality to what could be done with the best radio telescope available at that frequency, namely, the Poulkowo telescope. And the infrared observations were just about matched by what could be done and actually was done at Mount Palomar. But this, I must strictly say, is exactly like a boy who sees somebody off at the station and runs along with the train shouting, "See how I keep up." He will not keep up very long, provided the train actually continues and departs. In the same way the study of the planets will go far beyond everything we can do from the Earth. I am personally looking forward to all of the exciting news it will bring.

From here on let me make a big jump to the galaxy and the universe, where are the largest and perhaps most exciting problems which still challenge the astronomers. One of these problems definitely is the evolution of stars and galaxies. The keynote of all astronomical research in the past three decades, at least, has been evolution. The stars in our stellar system and in other galaxies are now sorted into young and old with various stages in between. In many cases we can trace paths in evolution and in some other cases we still wonder. It is certain that many of the stars must have been formed relatively recently from gaseous material which is present in space between the stars.

One very important subject to be studied is, therefore, the physical status of the matter between the stars. In some ways this subject can be studied and has been studied for about 50 years. Spectra of bright stars display occasional very narrow absorption lines due to ionized calcium and some other atoms and ions and also to some free radicals of carbon and hydrogen. It has been possible to study perhaps 100-200 stars in this way. The lines are often split. The different components are shifted by Doppler effect, arising from the fact that the line of sight passes through different clouds having different velocities with respect to us. So we know a fair deal about the motions of these clouds. But in fact we see very little—only a few lines caused by some impurities in the gas, which happen to have lines which are in the accessible region of the spectrum.

Hydrogen is by far the predominant element in space. The hydrogen atom was kind enough to us to present a line which does not need equipment in space because it happens to be emitted at 21 centimeters, which is in the region of wavelengths which penetrate the Earth's atmosphere very nicely. This has been put to wide use, but it still is only the hydrogen atom. What about the hydrogen molecule? There the situation is worse. It has a few rather weak lines in the far infrared which require at least balloon observations and it must have some more prominent lines, about 1100 angstroms, in the far ultraviolet which can be observed only from high-flown rockets or from satellites.

We are looking forward to the next few years hoping that it will be possible to observe first one star, and later (we hope) hundreds of stars to see how these molecular hydrogen lines are distributed. In the same way, of course, we look forward to seeing the lines of dozens of other elements which all have their most important spectral lines in the so far inaccessible ultraviolet region. Such observations require accurate pointing and command from the Earth. This is a lot of work; perhaps the orbiting astronomical observatory or perhaps a stabilized rocket will give the first useful results. In Europe we have also put equipment of this type as one of our main objectives.

Galactic research offers other, even more exciting topics. Probably, the object beyond the solar system that is the subject of the largest number of single papers in astronomy in the past decade has been the Crab Nebula. It was number 1 on the list which Messier made in 1780 when he listed nebulae for the use of comet observers so they would not be bothered by these useless things. This remnant of a supernova explosion is named the Crab Nebula because of its web of red filaments. What has lately more intrigued us is the white light inside, which has a perfect continuous spectrum.

The study of this white light is a perfect example of how different fields come together in astronomy. About ten years ago the Russian astronomer, Shklovsky, suggested on the basis of the radio spectrum of this object that its light might arise from the synchrotron mechanism, that is from relativistic electrons—let us call them cosmic ray electrons—moving in a large magnetic field. If this hypothesis were correct, the one crucial test would be to see if this white light shows polarization. This was indeed observed first in Russia, then at our own observatory, and then with much greater detail within the same year by Baade at Mount Palomar. Many areas of the nebula were nearly 100 percent polarized. This has led to mapping of the magnetic field in this object and to further speculation about its origin.

The graphical representation of such data from different fields linked together must be done on log-log plots covering many factors of 10. The most exciting plots are always on such large scales. The spectrum of the Crab Nebula, which I just described, went from 20 to 25 in the logarithm of the intensity and over a factor of 9 in the logarithm of the frequency. At one end were the radiofrequencies, and at the other end, beyond the visual light, was a point derived for the ultraviolet on the basis of the intensity of the red filaments. Since that time, the frequency scale has been extended by 3 more factors of 10. Space research now provides data also on the X-ray spectrum, and perhaps in the future on the gamma ray spectrum. This enormous range in frequency must be made the subject of ingenious measurements and then of a joint analysis. A previous paper discussed the beautifully conceived and performed experiment by Friedman where he shot up a rocket just during the occultation of the Crab Nebula by the Moon, in order to get a measurement of its angular size in the X-ray region.

The situation on the X-ray sources at present resembles rather closely the situation on the radio sources as it was 15 years ago. The papers presented at the COSPAR meetings in Buenos Aires showed these analogies strikingly. First of all there are so far only two positive identifications of X-ray sources with optical objects, namely the Sun and the Crab Nebula. The same was true for radio sources at that time. Secondly, there is a frantic effort to get better positions because better positions will enable the optical observers to make a more accurate search of a small region with bigger equipment. In getting at this accurate position it is not yet possible to pinpoint but receivers actually scan with parallel lines of maximum sensitivity like the pattern of an interferometer in radio astronomy. Although the results are accurate the exact line cannot be identified. The same situation prevails at this moment for some X-ray sources.

Further, the absolute calibration is a big question. It was so for the radio sources, and is at present so for the X-ray sources. The absolute calibration of the intensity is very essential to go down to the actual theoretical explanation. Very much depends on knowing the exact slope, or on distinguishing between an abrupt knee or a gradual bend. The common experience is that the change in slope occurs in the middle of the graph paper. It is necessary to get really accurate measurements before one can advance beyond this stage. In X-ray astronomy we have hardly started with absolute calibration.

A further analogy is the dilemma between the different philosophies of going at it the big or the little way. Some people say, "Let's shoot more sounding rockets," and others say, "Let us carefully plan the really big instrument which will definitely settle such and such points." I think both should be done. Then, of course, there are people quietly working away without saying much in the hope to get new and better technique, like observing the polarization, or getting more sensitive detectors. Again, this is in strict analogy with radio astronomy of 15 years ago.

I wish I could be absolutely safe in saying that a final analogy is that 15 years of further work suffice to give an enormous advancement. It is absolutely beyond expectation how much has now come out of these strange radio astronomy sources. I hope 15 years from now we can say the same thing about X-ray astronomy, but this is unpredictable.

With gamma ray astronomy we are in a slightly less favorable position. It is more difficult, and so far not much that is absolutely certain has been detected. But again, here is an open field which will give exciting results sooner or later.

Present-day astronomy shows an accumulation of surprises. There is no room for a complacent attitude that we know the main lines and still have to fill in details. Various types of completely puzzling objects have been discovered, like galaxies with exploding nuclei and quasi-stellar radio sources. Although ground-based optical astronomy still ranks first in importance for a detailed study of structure or spectrum, many of these new discoveries are a result of combined radio and optical measurements. This very close cooperation will in the future have to be extended to space projects. The general impression is that we may still underestimate the weirdness of these objects and the violence of the processes going on on such a large scale in some galaxies. In many nuclei of large galactic systems violent explosions seem to occur at a scale which has output in ergs which indeed can be best written as $10^{55\pm2}$. It is very difficult to guess where this energy comes from. Again the widest possible spread in observed frequencies gives the best basis for an explanation. Certainly, to go all the way to X-rays and gamma rays on these objects will help, because it is clear whatever happens is something of a highly energetic nature.

Since I am the only speaker from abroad, the Chairman has given me permission to state a few more words about the international cooperation. Astronomy has always been a truly international science. But never before the present age of space research has this been demonstrated so vividly. There are vast amounts of scientific and technical data which have to be sent from one part of the world to the other. Some have to be transmitted almost in real time. This has been followed immediately by communication between parts of the Earth via space vehicles, a fruit from linking the world together. Scientists and engineers and administrators in many countries in the world, almost all countries of the world, get a real satisfaction in participating in these programs, pure or applied. Almost without exception they also take a real pride in their own share, even though it may be a small part in tracking or recording some telemetry. So this world-wide cooperation is not only a matter of technical potentialities or of system engineering, but first of all it is a matter of human relations.

I hope you will realize, as I have come to realize at many international meetings, that this cooperation must occur in a world in which there are by no means uniform standards. In a world in which there are differences in temperament, in natural resources, wealth, and in the ideals for life. In the majority of these countries in the world it is not obvious that a meeting will start on time and it is not obvious that there will be a Xerox machine at hand to copy a number of documents or even a typewriter to copy them. In this same world, St. Louis is known, not for McDonnell Aircraft or Washington University but for the "St. Louis Blues."

In a poor community, a rich man is naturally envied and is sometimes made the subject of suspicion. The United States is somewhat in that position among the countries of the world. This requires not just normal but more than normal diplomacy of all the people involved in these international relations. I should like to take this opportunity to state, first of all as a representative of the European countries, how extremely grateful I am for the generous opportunities offered to us by the Americans to put scientific instruments in American rockets or satellites and to cooperate in many other ways. For instance, the little publicized matter of the satellites which transmit at real time is very important in making people in some countries enthusiastic about doing real space research, receiving, and decoding these telemetry signals. And, secondly, I should like to state that I personally admire the way in which the NASA Office of International Relations has generally, within the field of my observations, handled these international relations with more or less advanced countries in a diplomatic, efficient and patient manner.

In your own display in the hall, Saturn 5 is compared with the Statue of Liberty. I have used a similar slide in which it is compared with the Martinitoren in Groningen, which is the second highest church tower in the Netherlands. It is in good Gothic style, with also about five or six stages, but not planned to be launched. It is very interesting to watch the reactions of different people in different countries, and with different backgrounds in culture, to this slide. Some say, "It cannot be true," and some say, "It is nice; this is progress. I must say I admire the courage of the people who have indeed started on this enormous project.

ATMOSPHERIC SCIENCES FOR THE SPACE AGE

Walter Orr Roberts
Director
NATIONAL CENTER FOR
ATMOSPHERIC RESEARCH

Most people think of the Space Age as having begun on that evening of the 4th of October 1957, when Sputnik I went up. I do not think I shall ever forget that evening. I had come home from work about 6 o'clock and my wife was preparing dinner when a telephone call came, with news that the Russians had launched a satellite and that it was due to come over Boulder in a few hours, transmitting on a frequency of 20 megacycles per second.

Most of us are impressed, as I am, by the fantastic progress that has occurred since. George Mueller pointed out, in his talk, the fantastic rate of change and development of the Space Age. But the Space Age is something more than an age of satellites; it is an age of science and technology. It is the revolution that Julian Huxley has spoken of.

Philosophy has become as important as ever it was in the Golden Age of Greece, as important as ever in the time of Pericles. Now, as never before, we must be concerned with what the "good life" is, and what constitutes the "good society." This Nation, of course, has always been vitally concerned, from its very foundations, with science and with the application of science to human welfare. Benjamin Franklin, for example, at just about the time of the founding of St. Louis, made a quotation that I think is very significant to our concern today. He said, "The first drudgery for the settling of new colonies which confines the attention of people to mere necessaries is now pretty well over, and there are many in every province in circumstances that set them at ease and afford leisure to cultivate the finer arts and improve the common stock of knowledge." Then he went on to exhort his fellow citizens through scientific activities to increase "our power over matter and to multiply the conveniences or pleasures of life."

I like also to recall, especially when we become concerned about hunting for funds to support our research activities, that in 1769, just before the transit of Venus across the face of the Sun, The Pennsylvania General Assembly voted 450 pounds for expeditions to observe that astronomical event. Also, I think of what William Smith said to the Philadelphia Assembly in the year 1773, referring to the observation of the transit of Venus, "It hath done a credit to our country which would have been cheaply purchased for 20 times the sum." I have heard that language used in more recent cases, too.

The Space Age revolution, the most important fact of life today, is here. It promises food and shelter to the people of all of the Earth, the fruits of medical progress, education for all, and the freedom to enjoy the relief from the drudgery that has been in the past associated with the difficulty of eking out a living on this planet.

Enormous new computers can now be built; and far from making us mere numbers in a system, they offer the humanization of all mankind. I think that Ben Franklin would have understood this. So would David Hume, with his concept in revolutionary times of the science of man, and his faith that we could govern ourselves rationally and with justice.

To me, some of the most exciting opportunities of the Space Age are contained in the over-all opportunity to understand the atmosphere, to understand the cause of weather change, to forecast the progress of storms, and, possibly, if indeed it proves to be in the cards, to control some of the disasters produced by great tropical storms or by persistent droughts. Many are sharing in the efforts to make attacks on these goals, to realize these opportunities—in the work of NASA that you have heard about at this conference, at the Weather Bureau, the Central Radio Propagation Laboratory of the National Bureau of Standards, and especially in the universities, in efforts coordinated, planned, and carried out through the National Science Foundation, with the National Academy of Sciences participating in setting up and revising goals and objectives. This is a unique way, devised in America, to make progress through a diversity of mechanisms.

One of the most challenging ideas to spring from the potentiality of the Space Age is the possibility of understanding the circulation of the global atmosphere. I commend to you a concept of this now being developed by Jule Charney of the Massachusetts Institute of Technology and his colleagues on a panel of the National Academy of Sciences. Their report, which will soon appear, deals with the potentialities of a global weather-observing system, combining tools of the Space Age to give us an enormous and exciting opportunity, in which many, many nations will cooperate, to observe the Earth's weather completely enough to open up revolutionary possibilities of weather forecasting and opportunities to perform experiments in large-scale weather modification.

Let us consider, for example, some of the spectacular changes in climate that have occurred in times past. One of the most striking of these was the drastic reversal of northern European climate that occurred around 550 BC, a time when the growing season in Northern Europe, in a period of 3 years or less, decreased by perhaps as much as 15 days. This change, causing a very great hardship in Northern Europe and a change of storm patterns in the Mediterranean, was of very spectacular proportions and occurred abruptly. Northern Europe emerged from it only gradually over a substantial portion of a millennium. (This is the change, by the way, that is probably responsible for the legend of the Twilight of the Gods and of the Three Summers that Never Came.)

Another striking climatic change occurred in the late Middle Ages and the Renaissance. One can see it by contrasting the climates of the 11th and the 16th centuries. The key single change of climate may have been the one that occurred in the wind circulation of Northern Europe just about the time of the birth of Shakespeare, around 1562, causing an abrupt worsening of the climate in the 16th century. More recently, we can point to the rise in temperature in the northeastern portion of the United States—approximately 3° F. in the average winter temperatures between 1900 and 1950 and to the very substantial drought that I am going to find evidence of this evening in New York when I try to take a bath and read the sign that sits at the foot of the bathtub about conserving water.

It is not hard to find evidences, for example, of the spectacular impact of climate on political affairs. Mr. Khrushchev, for example, was quite aware of this after two severe wheat crop failures of recent years. I have often speculated whether this had something to do with the serious straits of the collective farms which, in turn, may have had something to do with the change of leadership in the U.S.S.R.

Nor is it difficult to appreciate the impact of climatic change on industry—the oil industry, for example. People say that it is now impossible to forecast the climate—for example, the temperature of the coming winter—and I think this is true. Nevertheless, the oil industry makes a fantastically big risk forecast, every fall, when it determines how much fuel oil to make for the winter; if it has overproduced, the fuel oil must be re-refined to gasoline in the spring. Storage space is too expensive to allow the oil to be carried over to the following winter. In short, we are now at a level of technological development where we cannot avoid decisions based on climatic forecasts.

The present state of science and technology also makes it possible to consider the integrity of the global atmospheric system as a whole. We can now consider making observations on a global scale, and to make calculations in a large computer—perhaps 100 to 1000 times the capacity and speed of an IBM 7094, for example—to make forecasts on a time scale of perhaps 2 weeks with the kind of accuracy that is now possible with a time scale of two to three days. But as Charney has pointed out, because of the global interactions and because of the nonlinearity of the interactions of this system (that is, you cannot separate the different cause-effect relationships), we must look at the system as an integrated whole. If we can have an observing system that will give us the three velocity vectors of the wind, two in the horizontal and one in the vertical; temperature distribution; and moisture content at several levels in the atmosphere on a global scale on a grid of about 500 kilometers, and with sufficient time resolution, we can do this. The result, Charney then believes, will be the ability to make 2-week, and perhaps even 3-week forecasts of the day-to-day progress of storm systems. In addition, we may be able to predict certain statistics of weather—such as the average rainfall over an area or the average temperature over an area—as much as 3 months in advance.

What kind of observing system might supply the fundamental observational data which, coupled with a large computer and the development of an adequate numerical model, might give us this opportunity? The Charney report suggests a system consisting first of two satellites, one in a polar orbit and one in an equatorial orbit, each having data-recording capabilities and sensing devices to produce an infrared map of the outgoing radiation from the Earth to space, as well as the capability of interrogating a global system of weather sensors which I shall now describe.

The second element in this system is a series of free-floating balloons—present calculations suggest 6000 to 10 000 of them—distributed around the entire globe of the Earth. It looks as if the present state of technology gives such balloons a realistic life expectancy of at least a 6-month period. (One of the members of my own research staff will begin in September to fly 100 of these new type balloons in the Southern Hemisphere, to obtain actual data of atmospheric circulations there in a pilot feasibility test of the operational balloon.)

These balloons are constant-density balloons made of a rigid plastic. When they have risen to the level at which they are expected to fly, the balloon has achieved its spherical shape, and the helium inside can expand no further. At this point, the density of the balloon, including its transmitter, is equal to the density of the displaced air, and thereafter it flies at that altitude, unaffected by the changes in the temperature of the gas in the balloon as a result of the sunlight or the darkness through which it is flying.

These 6000 to 10 000 balloons, all free-floating, are interrogated by the satellites. Each balloon then transmits to the satellite the code name of the balloon, its position, the time of interrogation, and certain observations, most likely internal pressure of the balloon, so we know its height and the temperature and humidity of the environment in which the balloon is floating. When the same balloon is next interrogated and its position again derived, we can determine from that observation the integrated velocity of the air parcel in which the balloon was embedded over the time between the first and second observations.

Other components of the global observing system are ocean buoys, transmitting the temperatures of the ocean surface and of the air just above it, and a system of fixed, unmanned stations, distributed around the world in areas where access is difficult.

Finally, there is the data capability of the satellite to record the data from this vast network of stations, and to read them all out to a few giant, ground-based computers capable of accepting them and making weather forecasts from them.

It is now hoped that a feasibility experiment of this system with a large number of balloons—several thousand—and with one or two satellites, can be conducted within 5 years or so. If the feasibility experiment turns out well, later it might serve as the basis of an operational system of world observations which, supplemented by the conventional means of observing, will give us a tenfold increase in world weather surveillance. Add the concept of the examination of the global atmospheric system as a whole, and we may then have a cooperative world weather observing and predicting system, with at least three central stations to do the readout and the forecasting, one in the Soviet Union, one in the United States, and one in the Southern Hemisphere.

I firmly believe that this will come about; I see no economically feasible alternative for observing the world's weather adequately to make these forecasts. If it does, the computer, together with mathematical models of the atmosphere, will become great tools for further research, too. The computer becomes the analogy of the 200-inch telescope or of the giant accelerator, for the atmospheric sciences. Its role would be, hopefully, to let us conduct experiments in large-scale weather modification. We may then examine the influence of changing various factors in the atmosphere and finding out what the consequences of these changes are. The odds are that it is beyond man's prospect or possibility ever to modify the large-scale circulation of the atmosphere. But there is also the bare possibility that the climate changes of the past have been triggered off by minor forces capable of being released by man's intervention in the atmosphere.

If so, it is very important for us to understand these by studying their action in a mathematical model before we attempt to bring about changes in the real atmosphere.

There is a potential catch, however. It is not certain that if we modify the atmosphere in one direction and initiate a chain of events leading towards a climatic change, we can then easily reverse the trend. It is also a fact of life today that man is, indeed, governed by his very everyday operations—at least on a scale that makes it only prudent to investigate quantitatively by experiments of this kind. When we build great cities, like the megalopolis that stretches from New York to south of Washington; when we put a tremendous concentration of dust and smog into the atmosphere, modifying the radiative balance; when we pave larger and larger portions of our country and change the albedo, or reflectivity, of the Earth; when we fly jet airplanes that eject materials into the atmosphere which on many occasions increase the cirrus coverage or trigger off the more prompt occurrence of cirrus clouds (in turn altering the radiative loss from the Earth out to space)—in each of these cases we are altering the atmosphere, and we are far from understanding the full implications of these events, some of which *may* have irreversible effects.

If we do soon get into supersonic air transport, where large amounts of water are injected into the atmosphere, it is conceivable, as Dr. Verner E. Suomi has recently suggested, that these bands of ice clouds behind the airplanes will not dissipate between flights, but instead we will have permanent bands of cirrus along certain of the major routes of aircraft. It is important for us to be able to ascertain whether the resulting change in the radiative balance of the atmosphere will be sufficient to have some effect on other atmospheric processes. At the present time, one can only speculate that no change will occur, but it would be so much better to know! That will be certainly one of the objectives of the operation of the global weather system as a laboratory of atmospheric experimentation.

If the weather changes in one place, either through natural cause or through human intervention, it will probably change to some extent in all places. If a great storm system develops as one did in December 1962, out of a small low-pressure area over the Gulf of Alaska, and when it reaches the Central United States it suddenly deepens as that particular system did, it can alleviate a drought in the Great Plains, bringing snow and valuable moisture to the central part of the country. But it can also continue to amplify, as that particular system did, and make the temperature in Orlando, Florida, fall from 51 to 28° F. and, in so doing, wipe out a substantial part of the Florida citrus crop. I do not mean to suggest necessarily that man will be able deliberately to trigger off such a chain of events as this, but it is important for us to know for sure what the full effect might be.

The following figures illustrate some of the points I have tried to make. Since I am an astronomer and here among my colleagues, I have to show an astronomical picture as the first (fig. 1). This is the Sun's corona, the outer atmosphere of the Sun in which the Earth is embedded. Some of us suspect that materials ejected from the Sun streaming out into space producing the solar wind have influences lower down in the Earth's atmosphere, and may even possibly, on some rare occasion, have significant altering influences on the circulation of jet streams and the like.

The next figure (fig. 2) also reveals some sentimentality for my old profession. This is the giant prominence of the 4th of June 1946, a huge hydrogen gas cloud. Some 500 000 kilometers in length and some 200 000 kilometers in height, it is the largest ejection that has ever been observed in this cross-section area of prominence gas shooting out from the Sun. I took that picture myself, and I get a thrill every time I think about it today. We had a new observer on duty that day—Jack Evans, who now directs the Sacramento Peak Observatory. He was starting to take pictures. He came to me and said, "What do you do when the prominence gets so big

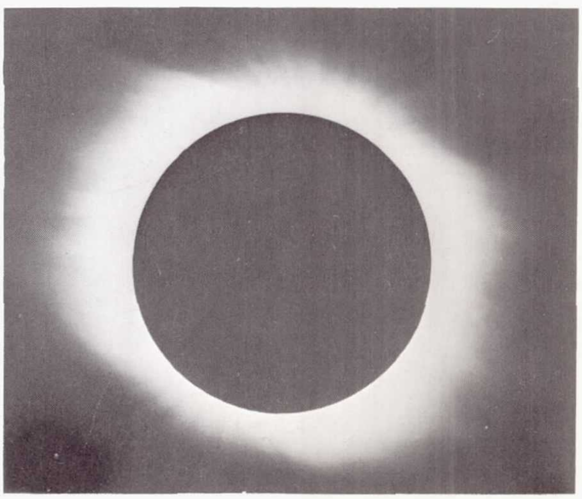

FIGURE. 1.—*Corona of the Sun.*

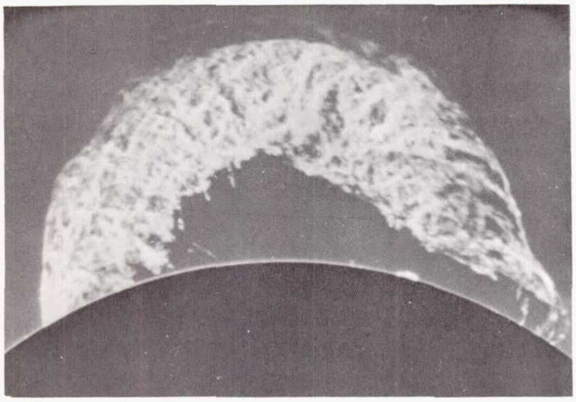

FIGURE 2.—*Hydrogen gas cloud ejected by Sun, June 4, 1946.*

it goes out of the screen?" I said, "Forget it, it never happens." He said, "Well, you just better look inside the telescope." I looked in and saw that. I nearly fainted. Nothing nearly so big had been seen before, and nothing so large has been seen since.

One of the consequences of solar-ejected corpuscles streaming into the Earth's atmosphere is the aurora borealis. Figure 3 is a graph that shows my reason for stating that perhaps auroras and their solar corpuscles do influence weather, which, of course, occurs far lower in the atmosphere. This is a graph of the persistence of weather patterns in North America preceding and following brilliant displays of the aurora borealis and a few magnetic disturbances. In the few days following the zero day—the day of occurrence of aurora or magnetic storm—there is first a rise of persistence, until it passes the 1 percent level of significance at the top of the curve, and then a drop in the succeeding 14 days to a minimum well

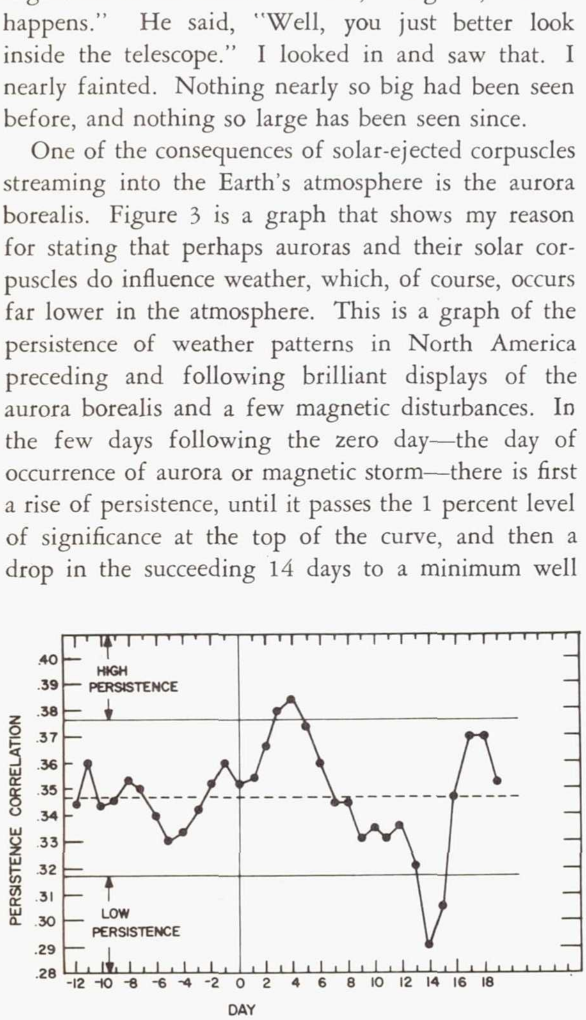

FIGURE 3.—*Persistence of weather patterns in North America preceding and following aurora borealis displays and magnetic disturbances.*

below the 1 percent line in persistence. This suggests that the trend of the persistence of barometric pressures at the surface of the Earth is not necessarily random following occurrence of a solar-induced event like the aurora.

Figure 4 shows a jet stream pattern that brings very cold air far south into Florida, similar to the 1962 situation I described before, when a killing frost occurred. These sudden amplifications in the wave pattern of the jet stream are, of course, related to the hydrodynamics of the atmosphere, but why a sudden amplification occurs in some cases and not in others is not fully understood. However, through experiments of the kind that I have described, using data from the global weather system, we are confident we can uncover the reason.

Figure 5 shows long-term influences in the atmosphere which suggest that there may be causes yet to be uncovered that make possible, or potentially possible, long-range forecasting. Balboa, Kwajalein, and Canton Island are some equatorial stations; the easterly or westerly strength of the winds in the stratospheric level above these stations is plotted. The time scale indicates that these are oscillating rather regularly, with a period of approximately two years, or more accurately about 26 months, suggesting long-term interactions perhaps between ocean surfaces and wind systems that are yet not explained.

Figure 6 shows another very spectacular and unexplained phenomenon, the frequency distribution of peak rainfall in various phases of the Moon. This correlation was worked by Bradley, Woodbury, and Brier in 1962 and has been subsequently even more firmly substantiated. Shortly after the new Moon and the full Moon at most stations in North America (a very large observational sample was used), there is an increase in the probability of occurrence of peak rainfall, with minima in the interim between new and full Moon. When the tide-producing force of the Sun and the Moon are at a maximum, and on the days following that, there is a probability of increased rainfall, for reasons unknown.

Figure 7 is a circulation pattern of the 11th century, deduced as best we can from historical records, showing that there was one storm belt with a mean path far down into the Mediterranean region, and another storm belt going well north of England and Scandinavia, producing a period of warm equable climate in Europe—in fact, very nearly a climatic optimum in recent centuries.

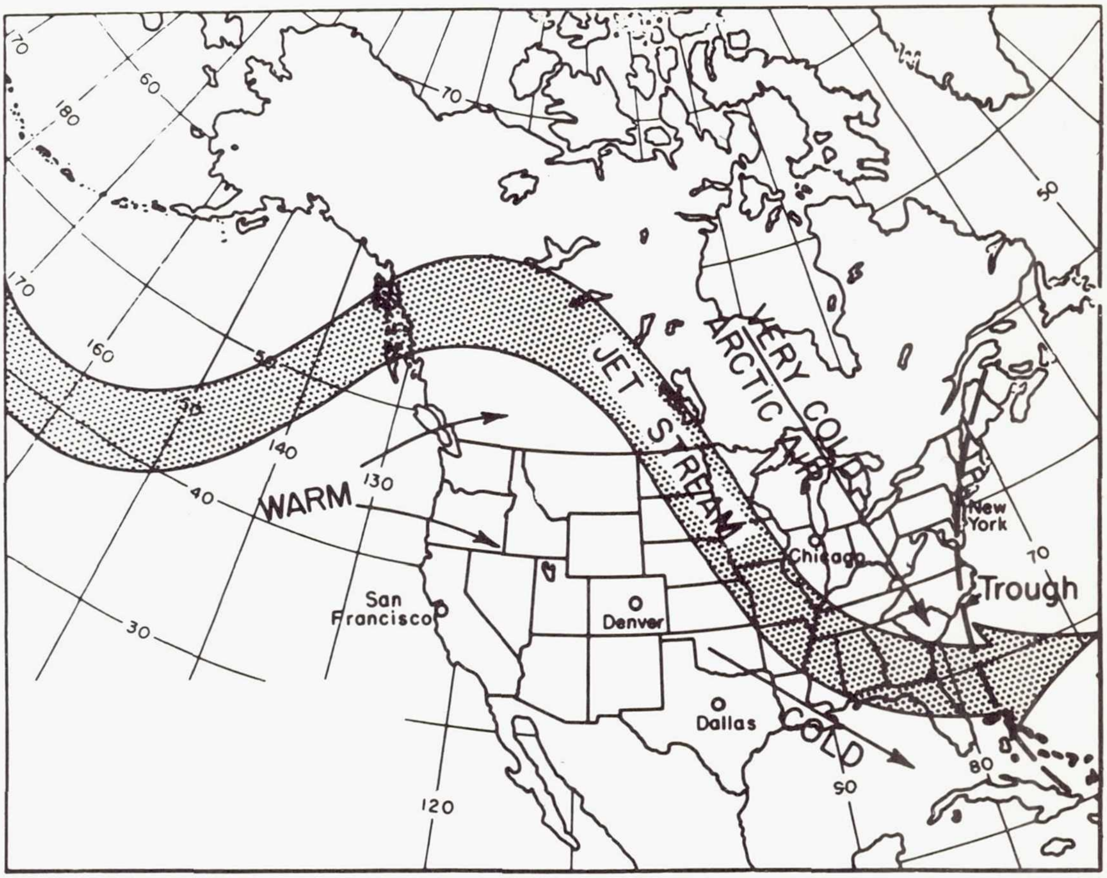

FIGURE 4.—*Jet stream pattern of Arctic air moving into Florida, as in 1962.*

Figure 8 shows what happened about the time of the birth of Shakespeare. This is the half-century from 1550 to 1600, and you can see a very much different pattern of average storm tracks, with Holland sort of getting it in the neck.

Figure 9, shows the giant tropical storm Tillie photographed from a Nimbus observational system. This is the kind of large-scale observations that we can now take—just a hint of what is in the future with the kind of system I have described.

Figure 10 is a plot of the distribution of global upper air observation stations today. The observing points are poorly distributed over the Earth with sparse distribution in the Southern Hemisphere and great concentrations only in Europe, the Soviet Union, China, United States, and Canada. The Southern Hemisphere is almost untouched. Such a pattern represents only 10 percent of the global coverage required to produce the forecasts and carry out the computer experiments mentioned.

Figure 11 is a prototype of the superpressure balloon that is to be flown this summer; table I gives the specifications. Since time is short I will not go into detail, except to say that the balloon will be anywhere from 5 to 35 feet in diameter and that it will float at an altitude in the atmosphere from 700 millibars, about 18 000 feet, on up to about 10 millibars, or 100 000 feet, and will transmit information continuously on 15 megacycles which could be monitored up to a range of 4000 miles by radio amateurs who can track the position of the balloon and give us the weather observations that are being transmitted in this passive system.

Figure 12 is the photograph of one of the balloons. Its surface is very hard when it is inflated to full pressure. If it is struck by an aircraft, it simply shatters instantly.

Figure 13 is a photograph of the transmitter. This transmitter could be injected into the intake of the jet airplane without damage to the plane; moreover,

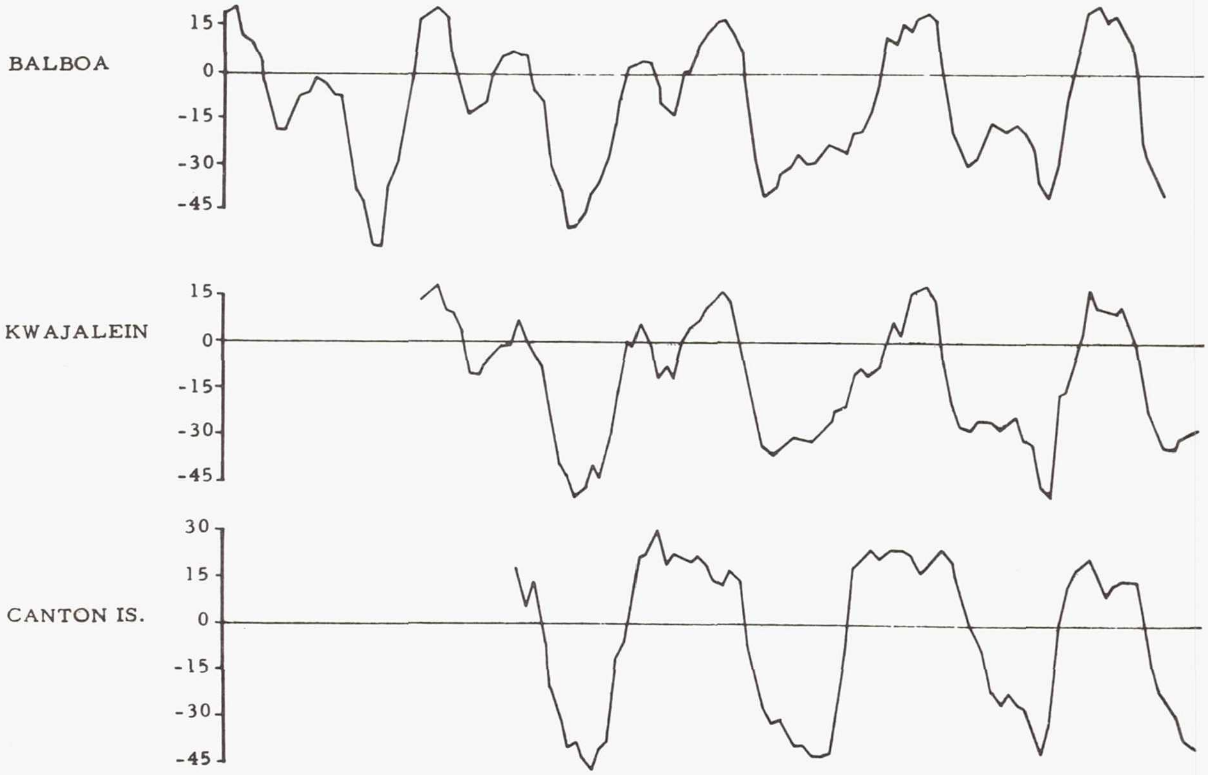

FIGURE 5.—*Long-term influences in the atmosphere.*

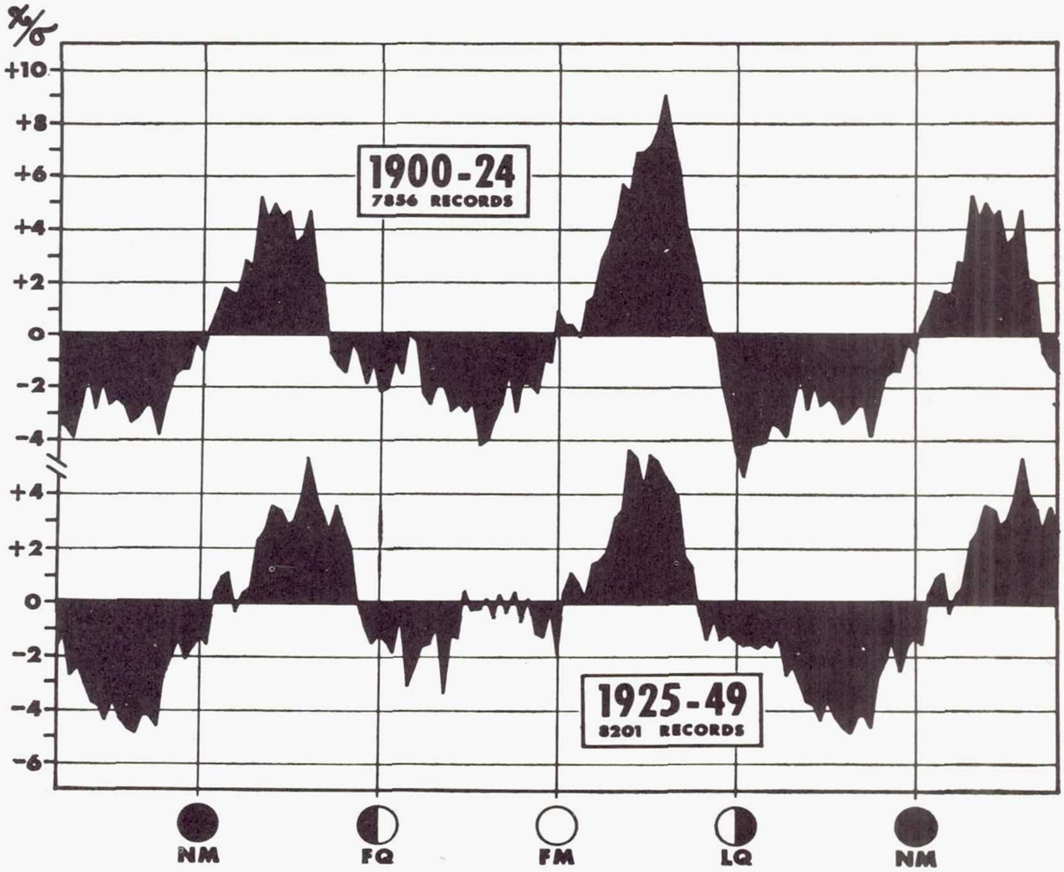

FIGURE 6.—*Frequency distribution (1900–1949) of peak rainfall related to various phases of the Moon.*

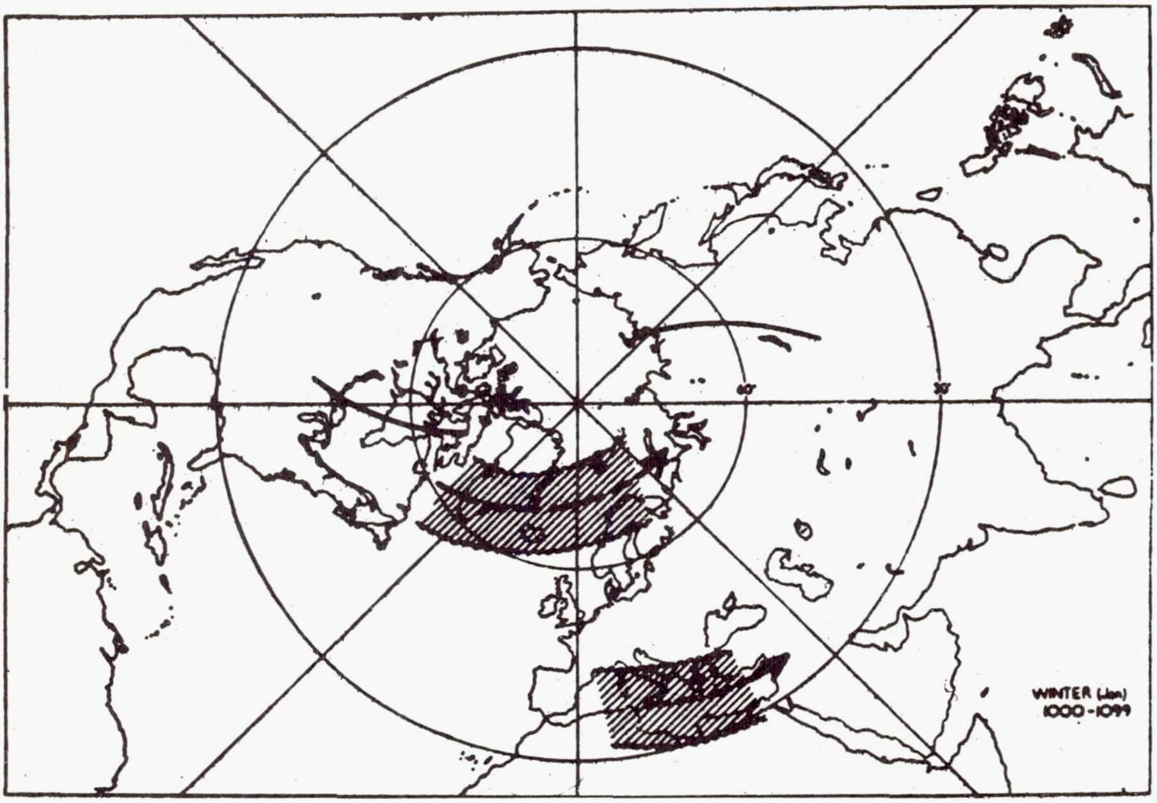

FIGURE 7.—*Probable circulation pattern of 11th century winters.*

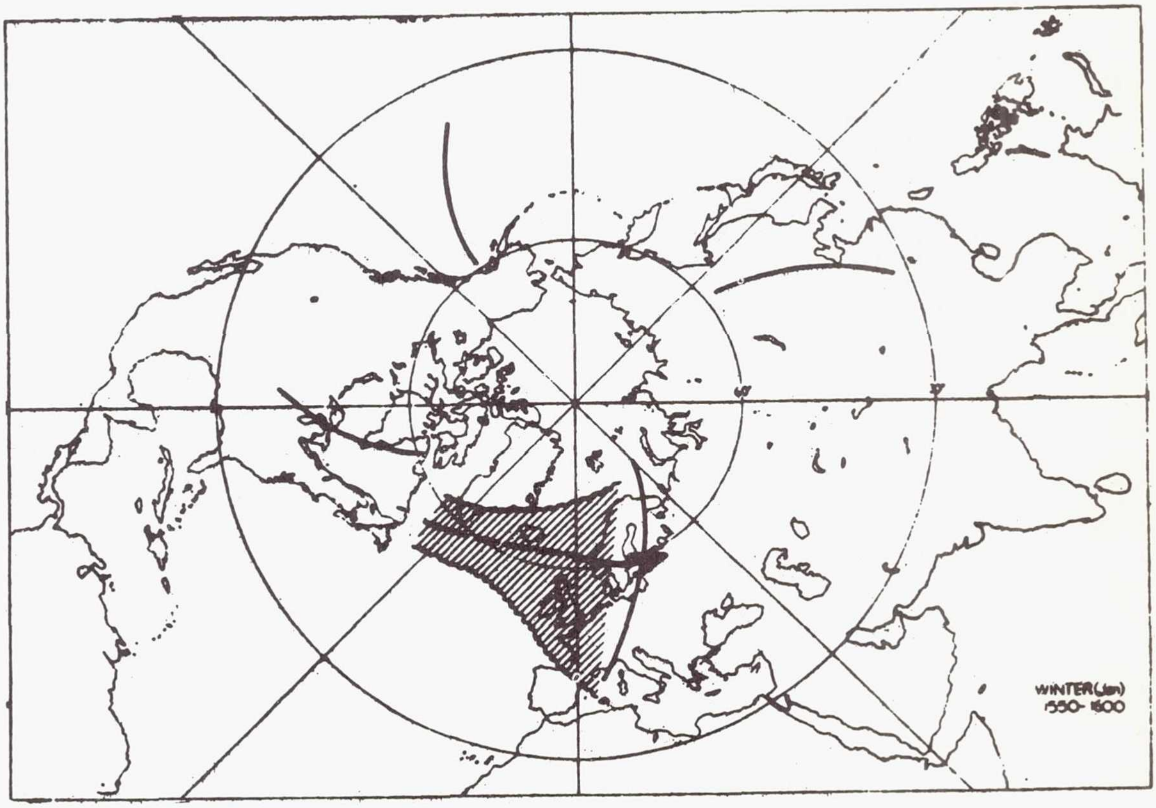

FIGURE 8.—*Probable circulation pattern of winters from 1550 to 1600.*

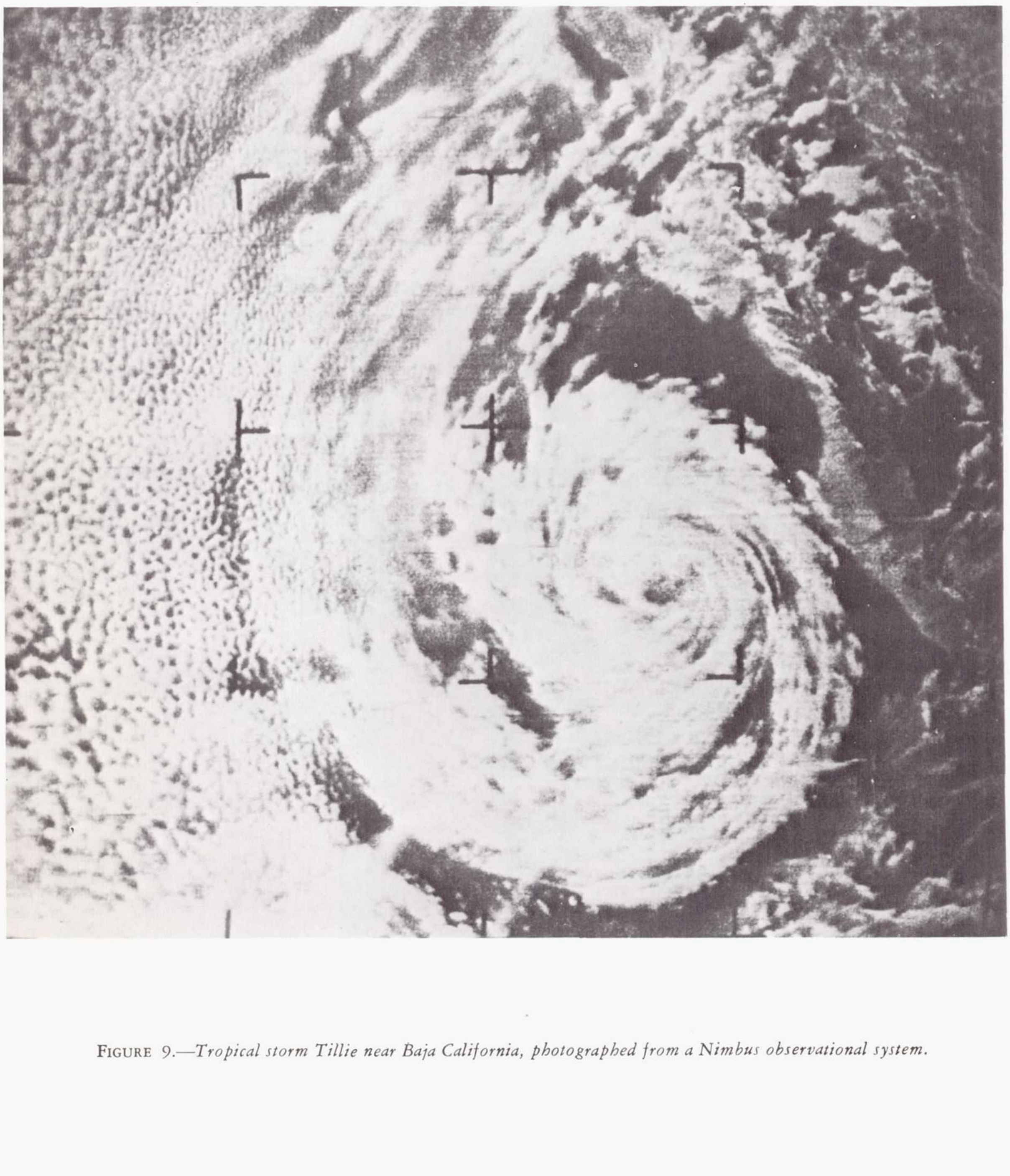

FIGURE 9.—*Tropical storm Tillie near Baja California, photographed from a Nimbus observational system.*

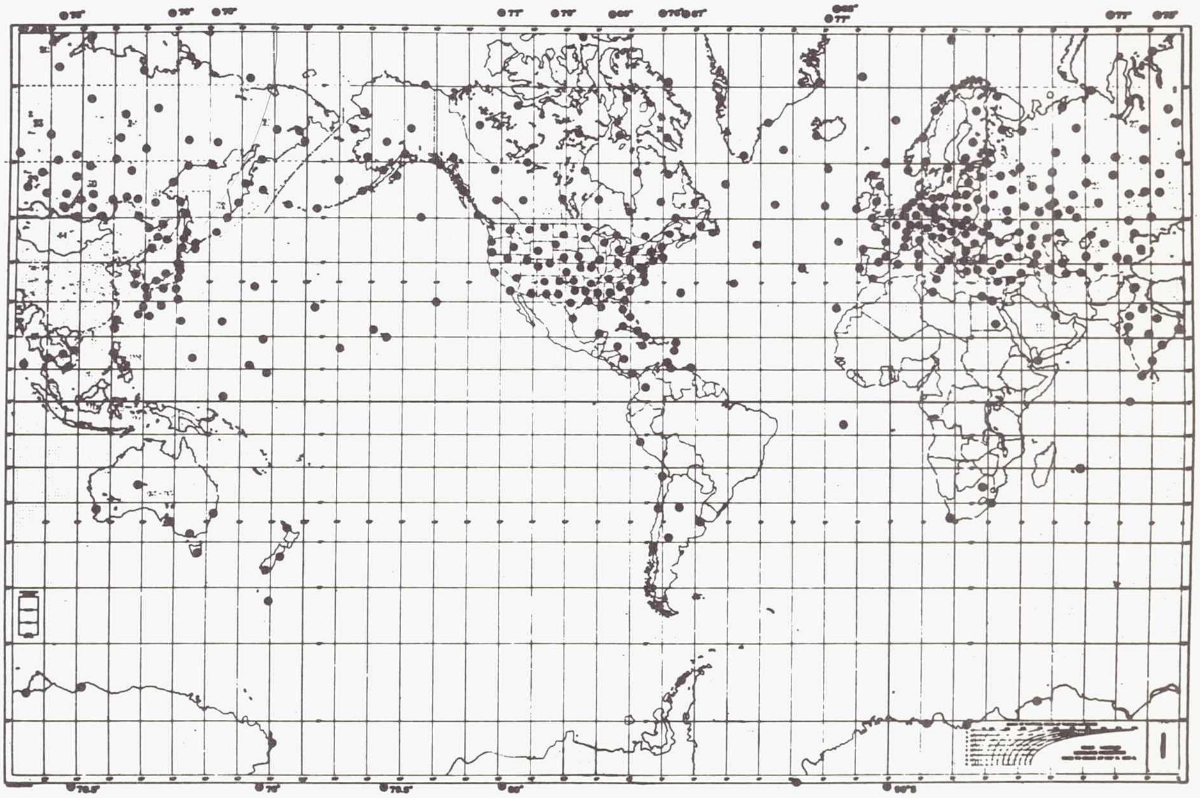

FIGURE 10.—*Global upper air observation points today.*

the probability of one of these ever hitting a jet airplane is practically trivial. We suspect that this will have a maximum threat less than 1 "sparrow power." We have, however, under development another one which is printed like this one but which has about a 1 "bumblebee power" threat.

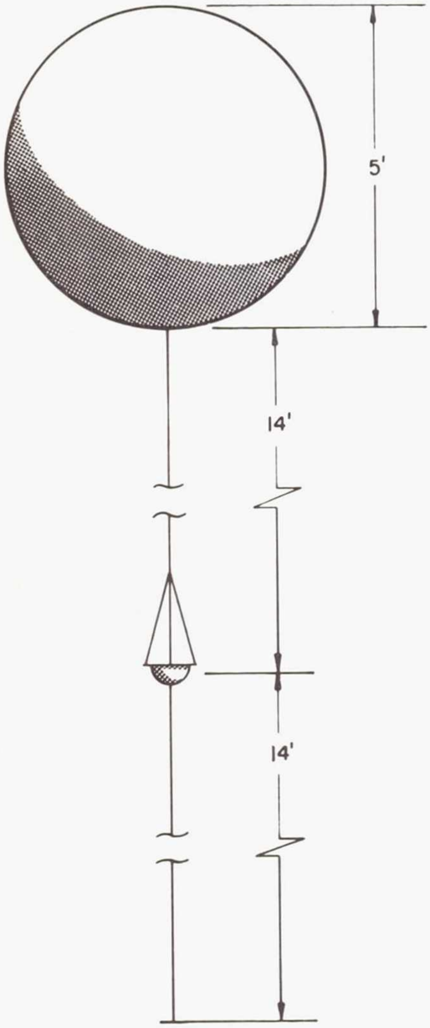

FIGURE 11.—*Ghost balloon system.*

Figure 14 is a picture of the solar cells from the top. The instrument operates in daylight and will transmit observations continuously. We will be flying 100 of these starting in September.

Table I.—Specifications for Ghost Balloon System

Balloon specifications for 300-g load

Pressure altitude, mb	Balloon diameter, ft	Balloon mass, g
700	5	970
500	5	775
300	6	950
200	7	820
100	8	820
30	13	1080
10	34	7460

Electronic Specifications

Power: solar cell panel
System weight: 140 g
Frequency of operation: 15.025 mc
Transmitted power: 1.5 watts at noon
Telemetry range: 4000 miles (skip propagation)
Method of telemetry:
- CW transmission
- Morse code letter identifies parameter being measured and balloon platform
- Code rate identifies parameter value

Typical parameters measured:
- Sun angle
- Air temperature
- Balloon gas temperature
- Air pressure
- Balloon over-pressure
- Humidity

Method of tracking balloon: measuring Sun angle as a function of time of day

FIGURE 12.—*A superpressure balloon.*

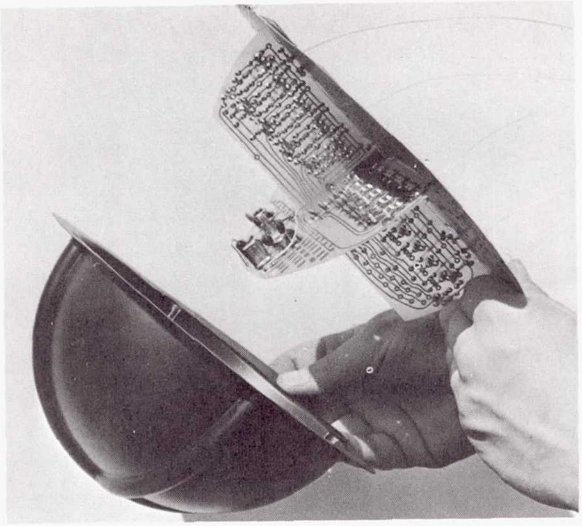

FIGURE 13.—*Transmitter.*

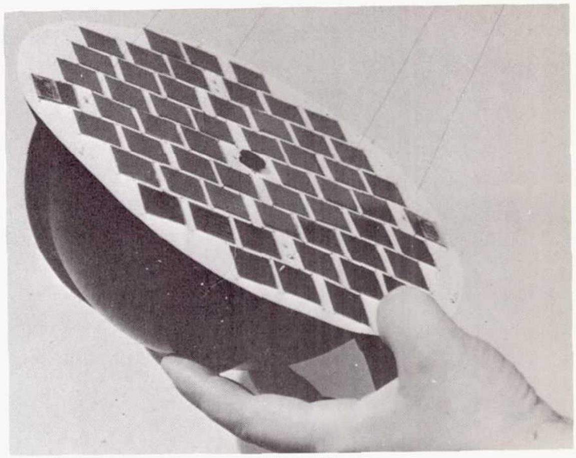

FIGURE 14.—*Solar cells.*

SCIENTIFIC EXPLORATION OF THE MOON AND PLANETS

Gordon J. F. MacDonald
Professor, Institute of Geophysics and Planetary Physics
UNIVERSITY OF CALIFORNIA, LOS ANGELES

The comparative study of the planets doubtless will provide critical data for the understanding of the subtle biochemical processes which have led to the present life forms.

The origin of the solar system and the course of its history must be included among the great problems of natural philosophy, comparable in general interest to questions regarding the origin of life and the development of man. Indeed the study of the origin of life and the development of man cannot be separated from cosmological considerations. An understanding of the history of the Sun, the Earth and the other planets is required in order to fix both the conditions requisite for the development of primitive life, and the changing conditions which stimulated the evolution of those forms of life now present.

A number of developments in the past few years have produced increased interest in the nature and origin of the solar system. A multitude of new studies as well as the revival of older theories demonstrate the renewed concern with cosmology. In the 19th and 20th centuries the investigation of the solar system utilized the concepts and method of celestial mechanics. In the past few years the application of radar methods has permitted the determination of orbital characteristics of certain members of the solar system with a new degree of precision, and thus several questions considered closed 50 years ago are reopened.

The advent of artificial satellites has further heightened interest in dynamical astronomy. The orbital parameters of the planets and their satellites depend in part on the distribution of mass within these bodies. Observation of artificial satellites leads to a determination of the moments of the mass distribution. The study of many earth satellites has provided a detailed description of the terrestrial gravitational field. Shortly we can expect that lunar orbiters will yield comparable data about the Moon, whose internal constitution is at present only a matter for speculation. In the more distant future, orbiters will provide us with data on the interiors of Mars, Venus, and Mercury.

The chemical development of the solar system was first emphasized by Harold Urey 15 years ago. During the intervening time this chemistry has been studied in many investigations of meteorites, as well as spectroscopic studies of the Sun, comets, and planetary atmosphere. These works have demonstrated the constraints that can be placed on the early history of the solar system, particularly by combining the chemical observations with new considerations from nuclear physics. But these chemical investigations have raised numerous new questions. Is the solar system in its solid phases homogeneous or are there differences within the planets due to their mode of formation? Are the planets chemically differentiated like the Earth? What are the conditions required for a planet to segregate its chemical elements, so as to produce a terrestrial crust rich in the radioactive elements? These and many more questions vital to discussion of the origin of the solar system can only be answered by the chemical study of the moon and planets.

The above brief survey of recent developments in the investigation of the solar system clearly shows the importance of the study of all the bodies of the solar systems to the question of its origin. A further point should be emphasized. The understanding of our Earth, its constitution and development, will require a study of the other members of the solar system. The Earth is but a single example of a number of enormously complicated heat engines. As in the case of the study of the origin of life, a comparative study of the planets including their atmospheres will lead to an increased understanding of our Earth. How does the Earth differ from its neighbors? As an example, does the Moon release seismic energy in the same way as does the Earth? Or are earthquakes the result of processes in a highly chemically differentiated body, which possesses continents and oceans of greatly differing substructure? A seismic study of what appears to be a more nearly chemically homogeneous body, the Moon, will provide important data for the investigation of our own planet.

I have emphasized the importance of space investigation to the problem of the origin and development of the solar systems and to the understanding of the Earth. I wish to underline a further generalization. The study of the solar system by space vehicles is only a part, an essential part, of the grand project on which we are embarked. A variety of tools are required to determine the nature of the solar system. Some of these will be ground based, others will be carried in satellites or probes. The emphasis on one kind of platform should not be allowed to hinder the development of those other instruments capable of obtaining essential and often complementary data.

Let us consider a number of specific problems, whose answers are prerequisite to a proper study of the solar system. In discussing these problems, it will become clear that studies of the Earth and its near environment have heavily influenced the questions to be asked. As we broaden our knowledge of the solar system, the questions will be different. Let us first look at the general question of the dynamics of the solar system, then the dynamics of the planets and then those of the satellites as they move about their primaries. These considerations lead naturally to questions of the rotation of the planets; how have the planets achieved their present rotational configuration as defined by the magnitude and orientation of the axis of rotation? The rotational characteristic of the planets are in turn dependent on their internal constitution. I will examine briefly the major problems in understanding the internal structure of the planets and how the planets obtained this structure. The properties of planets can in part be described by the fields in nearby space which originate within the planet. The magnetic field is of great importance to the understanding of planetary interiors. Certain necessary conditions for a magnetic field in a planet have been established; the sufficient conditions remain a mystery.

DYNAMICAL DEVELOPMENT OF THE SOLAR SYSTEM

Today the planetary system is a highly organized one in which each member follows a monotonous journey about the Sun. Was the solar system always so highly organized? Are the paths now traveled by the planets the same as the paths traveled 4 billion years ago? Is it possible to begin with the present configuration of the members of the solar system and trace the changes in their orbits back in time? Such a program requires a detailed understanding of how the individual members of the solar system interact with each other. The greater part of the interaction can be described in terms of rigid masses attracted to one another by gravitational forces. For the solar system we have only a primitive understanding of the long-term dynamic consequences of the many-bodied interactions. This lack of understanding stems from a fundamental difference between systems held together by gravitational forces and the more familiar systems of the laboratory. In the laboratory, containers restrict the volume occupied by the system of interest. In gravitational systems there is no container and thus there is no potential barrier at their outer boundaries. A direct result of this is that gravitationally held systems cannot reach a state of statistical equilibrium. This is fundamentally the reason why we cannot determine whether or not the solar system is secularly stable.

Table I lists the orbital characteristics of the planets. Several features are of importance in considering the dynamical development. With two exceptions the orbits are of low eccentricity and inclination. The two exceptions are the innermost planet, Mercury, and the outermost, Pluto. We do not understand why the inclinations and eccentricity are small nor do we understand the exceptions. The mass distribution within the solar system is also of great interest. There is very little mass between the planets. It would appear that the planets have been very efficient in cleaning up the solar system.

In addition to the direct gravitational forces, there

Table I.—Orbital Elements of the Planets

Planet	Semi-major axis, AU	Eccentricity	Inclination to ecliptic, deg
Mercury	0.387	0.205	7.0
Venus	0.723	0.007	3.38
Earth	1.000	0.017	0
Mars	1.524	0.093	1.85
Jupiter	5.20	0.048	1.30
Saturn	9.54	0.056	2.48
Uranus	19.18	0.047	0.77
Neptune	30.07	0.008	1.77
Pluto	39.44	0.249	17.17

is another kind of gravitational interaction dependent on both the deformability of the planets and satellites and on the existence of friction. The frictionally retarded tides influence the long-term evolution of the elements.

The nature of the tidal friction interaction is illustrated in figure 1. In the upper diagram, we suppose the Earth to have perfect fluidity in its liquid parts and perfect elasticity in its solid parts. With these conditions the maxima in the tidal protuberances, both toward and away from the tide-raising body, lie along the line of centers of the tide-producing body. Because of symmetry, no torques are exerted and there is no change in the orbital elements or the rotational parameters.

If friction accompanies the deformation, the rotation of the primary will carry the lagging tide forward. The tide is not overhead when the tide-raising body is directly overhead, but is high some time later as is illustrated in the lower half of figure 1. The gravitational attraction of the tidal bulge on the secondary is asymmetric with respect to the line of centers; a torque is exerted with angular momentum transferred from the rotational motion of the primary into the orbital motion of the secondary. In addition to the interaction sketched above in two dimensions, there is also a component of torque tending to tip the axis of rotation and at the same time change the inclination of the orbit of the secondary. In addition, there is a more subtle effect altering the eccentricity of the orbit. Thus the orbital elements, eccentricity, inclination, and semimajor axis are altered by tidal interaction. The most important characteristic of the tidal interaction is its strong dependence on distance between primary and secondary. The r^{-6} dependence

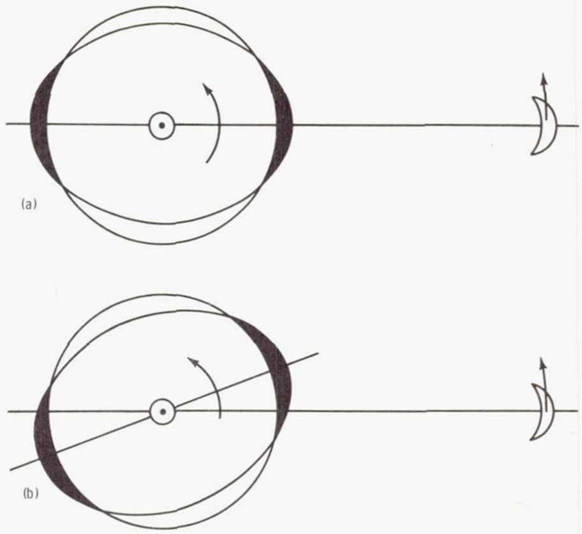

FIGURE 1.—*Earth-Moon tidal friction interaction. (a). The tidal bulge, if there is no friction, is symmetrical with respect to the line of centers between the Earth and Moon. (b). If there is friction, there is a delay in the time of high tide. The resulting distortion of the tidal bulge leads to a torque, diagrammatically illustrated. The torque decelerates the Earth's rotation and accelerates the Moon's orbital motion.*

implies a strong interaction when bodies are close and weak interaction at greater distances.

If one examines the stability of the planetary orbits to tidal friction, we find that all the orbits are stable for time scales of billions of years. Even the innermost planet, Mercury, undergoes only minute changes in its path because of tidal friction. We can thus reach the conclusion that the present arrangement of the planets is stable with respect to tidal interaction; the orbits have changed imperceptibly since the beginning due to effects of tidal friction. But we cannot yet state what is the stability with respect to the many-bodied interactions, nor can we trace the orbits back in time. This remains a major unsolved problem, whose answer requires the development of theory rather than space probes.

While the planets are stable with respect to tidal friction interaction, certain of the satellite systems have undergone major changes. At present, we know that the Moon is retreating from the Earth at a small but measurable rate. As the Moon retreats, the Earth slows down. While the rate of retreat is determined by astronomical observations made over the past 2½ centuries and geophysical observations of the last decade, there is evidence derived from artificial satellites that the Earth has been slowing down for at least 10 million years. Studies of Earth-orbiting satellites show that the Earth does not possess a shape appropriate for its rate of rotation. Indeed, the present figure corresponds to a time when the length of day was 3 minutes shorter, and the Moon was 150 kilometers nearer the Earth. If the present rate of tidal working has remained constant, this condition prevailed about 10 million years ago. A striking feature of the calculation is that the Earth-Moon system cannot be older than 1.7 billion years, a time short compared with the age of the Earth of 4.5 billion years (fig. 2).

This poses a major problem for both cosmology and geophysics. Has the Earth differed in its internal properties in such a way that friction is a more powerful retarding agent now than it was a few hundred million years ago, or is the present Earth-Moon system a more recent development? Extremely important data will be derived when man first returns samples from the Moon's surface. Are the lunar rocks very old? Or are they much younger than the 4.5 billion years usually assigned to them?

What of the other satellite systems; are they stable to tidal interaction? The complex satellite systems of Jupiter and Saturn with the presence of massive inner satellites demonstrate that the dissipative properties of the giant planets differ greatly from those of the Earth. In particular, these planets are much more nearly perfect bodies than is the Earth. They dissipate energy at a rate 100 to 1000 times less than does the Earth. But even with these low rates of dissipation, in certain of the satellites, particularly Neptune's Triton, has undergone tidally induced changes in its orbit.

ROTATION OF THE PLANETS

The tidal forces alter not only the orbital elements of the satellites but also the rotational characteristics of the planets. Despite the greatly differing masses and moments of inertia of the planets, there is a great regularity in their rotational characteristic, as is illustrated in table II. The obliquities are low

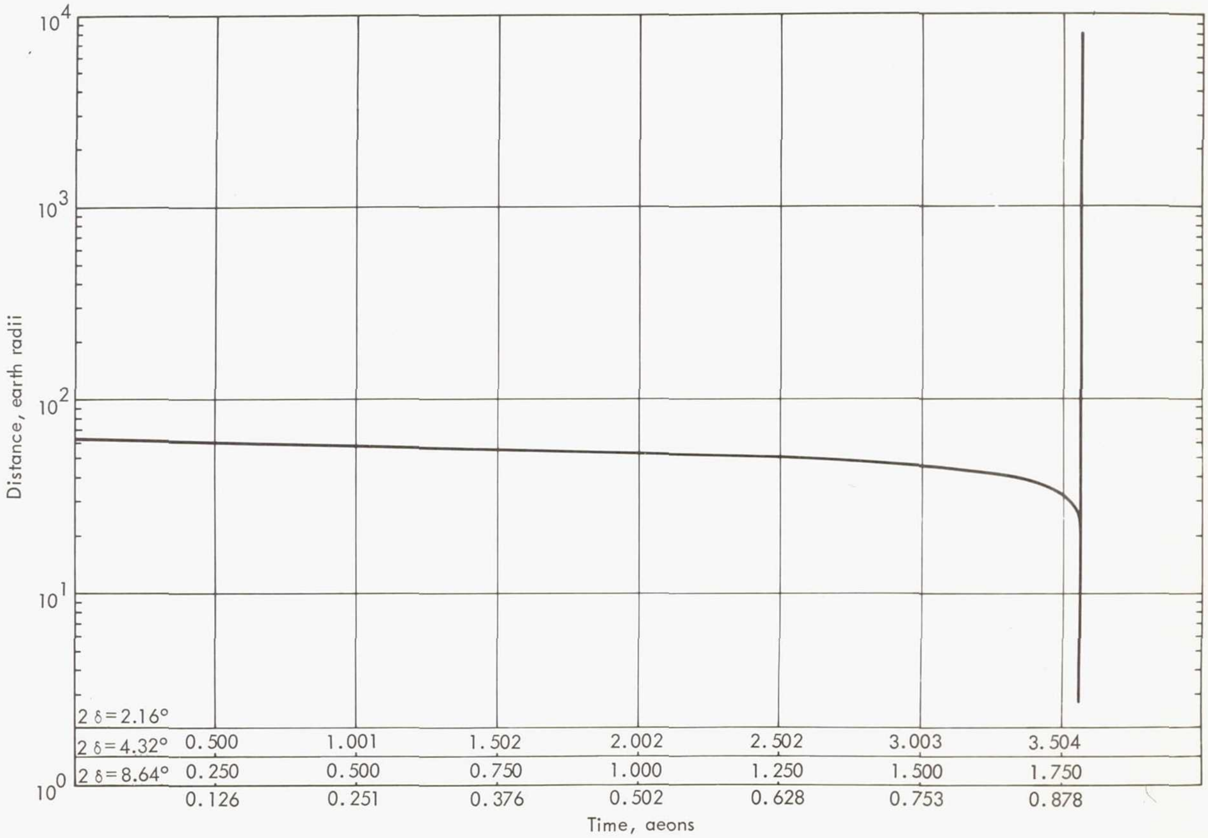

FIGURE 2.—*The past variation in the Earth-Moon distance. The Earth-Moon distance is measured in present Earth radii (1 Earth radius = 6371 km). The three time scales correspond to different assumptions regarding the phase lag of the tides raised by the Moon and Sun.*

except for Uranus, and except for Venus and Mercury the rotational periods are similar. Figure 3 further illustrates the regularity of rotational characteristics within the solar system; in figure 3 the dependence of angular momentum density on the mass of the planet is illustrated. Venus and Mercury show a large

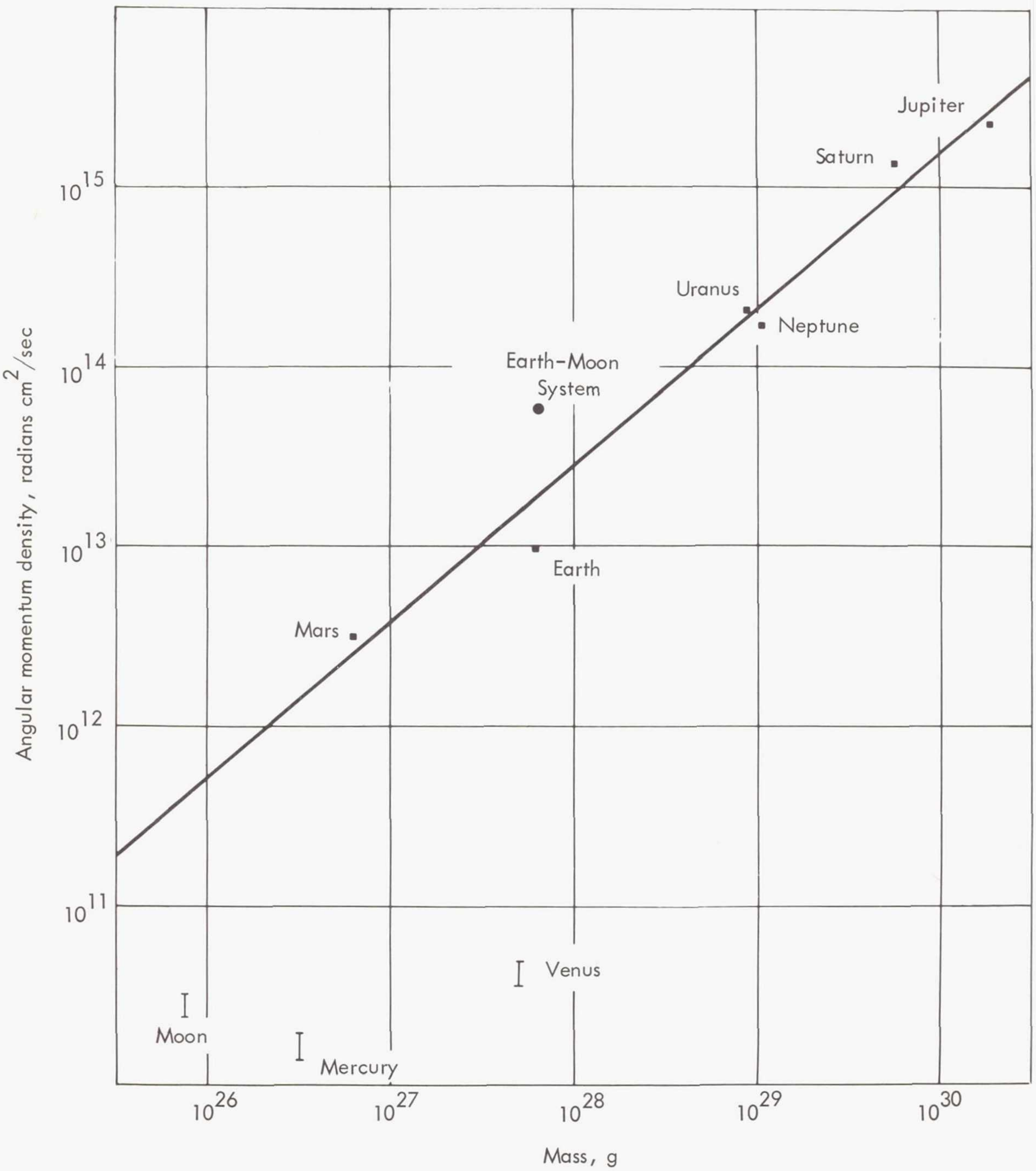

FIGURE 3.—*The angular-momentum density associated with the rotation of the planets. The short vertical bars reflect the uncertainties in the angular velocities and moments of inertia of the Moon, Venus, and Mercury. In determining the value for the present Earth-Moon system, the rotational momentum of the Earth and Moon and the orbital momentum of the Moon about the Earth were taken into account.*

Table II.—Rotational Parameters of Planets

Planet	Rotational Period		Obliquity, deg
	days	hours	
Mercury	59		~0.
Venus	250*		~0.
Earth		23.93	23.45
Mars		23.62	23.98
Jupiter		9.83	3.08
Saturn		10.23	26.73
Uranus		10.28	97.92
Neptune		15	28.80
Pluto	6.4		~0.

* Retrograde.

deficiency as compared to the outer planets and Mars. This deficiency can be explained on the basis of the tidal interaction of the planets with the Sun. The Earth shows a deficiency but less than that of either Venus or Mercury. If the Earth initially possessed the angular momentum density required by the observed relation, then it would have rotated once each 12 hours, and the Moon would have been at two-thirds its present distance.

While we understand certain features of planetary rotation, many mysteries remain. What is the origin of the observed regularity in rotational characteristics? Why does Venus possess a slight retrograde rotation? Is this due to atmospheric tides or because of thermally driven interior motion? Why is the axis of rotation of Uranus tipped at such a high angle? Tidal interactions cannot explain the anomalous rotation of Uranus.

PLANETARY INTERIORS

The rotation and indeed the orbits of the planets are dependent on their internal structure. Figure 4 shows this structure for the Earth. The principal features include a large metallic fluid core, a mantle in which chemical stratification is evident in the upper regions, and a crust rich in heat-producing radioactive elements, uranium, thorium and potassium. Are the other inner planets similarly stratified? We have only a few data from which to speculate.

Astronomical observations on the moon show that the Moon, like the Earth, has a bulge around the equator. Unlike the Earth, the Moon also protrudes along the direction between the center of the Earth and the center of the Moon. The magnitudes of these bulges are reasonably well known. They are much larger than those one would expect if the Moon were fluid or nearly so. The strength required to support the non-equilibrium bulges is on the order of 10 to 100 bars, comparable in magnitude to the strength of the Earth as deduced from the artificial satellite observations.

However, if we assign to the Moon the radioactive composition deduced for the Earth, and assume the radioactivity is uniformly distributed within the Moon, we are led to the conclusion that the Moon should be molten in its interior. This point is illustrated in figure 5. Thus the assumption of earth-like radioactivity and homogeneity is inconsistent with observed strength of the Moon.

There are two possible solutions. First, the Moon differs chemically from the Earth in a major way. Such a conclusion has, of course, major implications for theories of the origin of the Earth-Moon system. Second, the Moon is differentiated with radioactivity concentrated towards the surface. This second alternative implies that volcanic processes were once active on the Moon. My analysis of both terrestrial and Ranger photographs suggests that volcanic activity has played a very minor role in shaping the lunar surface, and thus I favor the first alternative. The solution of this problem will result from chemical analysis of samples returned from the lunar surface and from a determination of the distribution of mass with the Moon from observations of a lunar orbiter.

Mars has two small natural satellites, Phobos and Diemos. Observations of their motions yield data on the Martian interior. Figure 6 shows two models for Mars; in both of these models we are led to the conclusion that Mars, like the Earth, has a metallic core. This conclusion depends, however, on the value assigned to the equatorial radius of the planet. The range of values consistent with optical observations is so great that we cannot definitely conclude that Mars has a core. We can expect that ground-based radar observations in the next few years will lead to a much improved estimate of the radius and with it a greater confidence in conclusions as to the interior of Mars.

PLANETARY MAGNETIC FIELDS

In the case of the Earth, the magnetic field originates within the metallic, electrically conducting core. Mass motion in fluid core induces electric currents

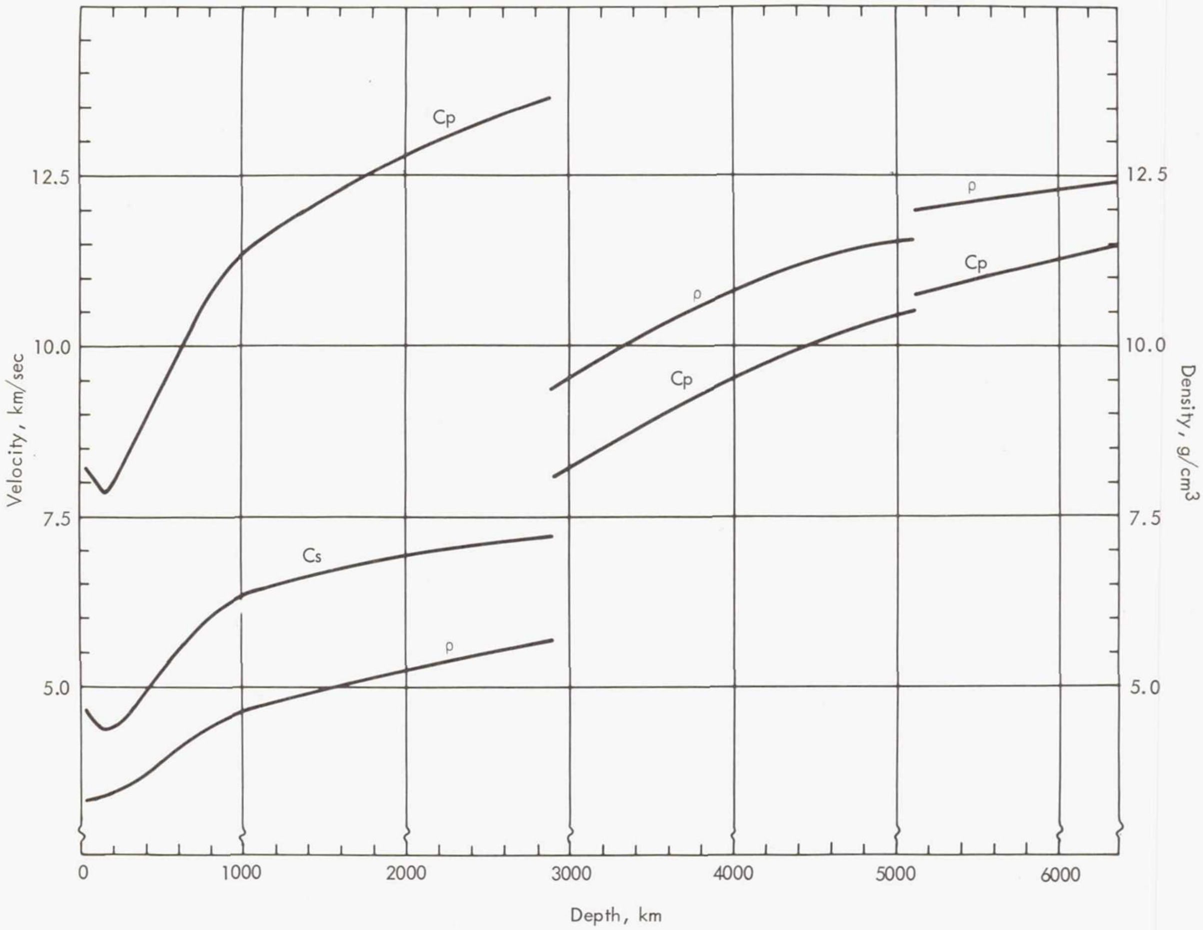

FIGURE 4.—*The variation of compressional* (Cp) *and shear* (Cs) *wave velocity and density within the Earth* (*Gutenberg, 1959*).

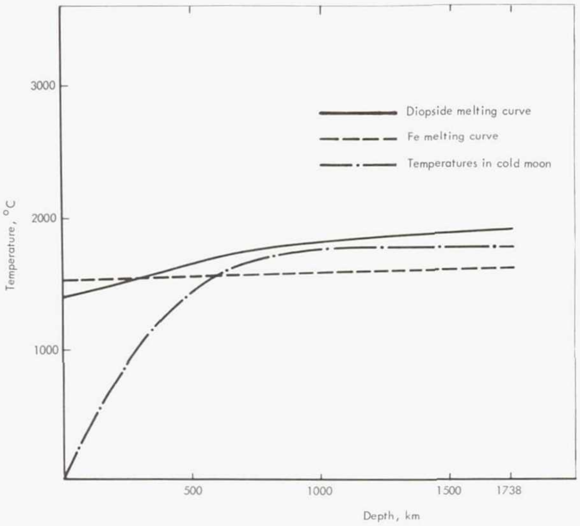

FIGURE 5.—*The variation of temperature in a Moon having chondritic radioactivity uniformly distributed. Initial temperature is 0°C. The diopside melting curve (Boyd and England, 1958) and the melting point of iron (Strong, 1959) are also shown.*

responsible for the magnetic field. The sources of energy for the motion are unknown; they could arise from thermal instabilities dependent on radioactivity deep within the Earth, or they could be tidally driven by the Moon.

We also know that neither the Moon nor Venus possesses a magnetic field comparable in intensity or geometry with that of the Earth. Lunik I measured the Moon's field, while Mariner II established the absence of a large field on Venus. Do these observations imply an absence of a metallic fluid inner core in these two bodies? This implication is particularly difficult to accept for Venus, since that planet is so similar in size and mass to the Earth. Or does the absence of a field on Venus mean that planetary rotation plays a critical role in the generation of a field? A partial answer to these questions will result from the Mariner IV determination of the Mars magnetic field. Mars is a rotating planet, probably containing a fluid core. If Mars does have a magnetic field, this will be strong evidence for a thermal origin of the Earth's field. My own guess is that Mars will not have a field. This speculation is based on the absence of nonthermal radio emission from the planet. The limits placed on the field by the absence of observable synchrotron emission are most uncertain, but I would suggest that Mars has a magnetic field at least 10 times weaker than the Earth's.

The observation of the magnetic field at Mars by a space probe coupled with a ground-based radar determination of the radius of Mars will provide information of great importance to understanding the Earth's magnetic field. This example well illustrates the theme of my early remarks. We can learn much about our Earth by studying the other members of the solar system. In these studies both ground-based and probe observations will be of importance. These comparative studies will provide the information required for a deeper appreciation of the problems of the origin and evolution of the solar system.

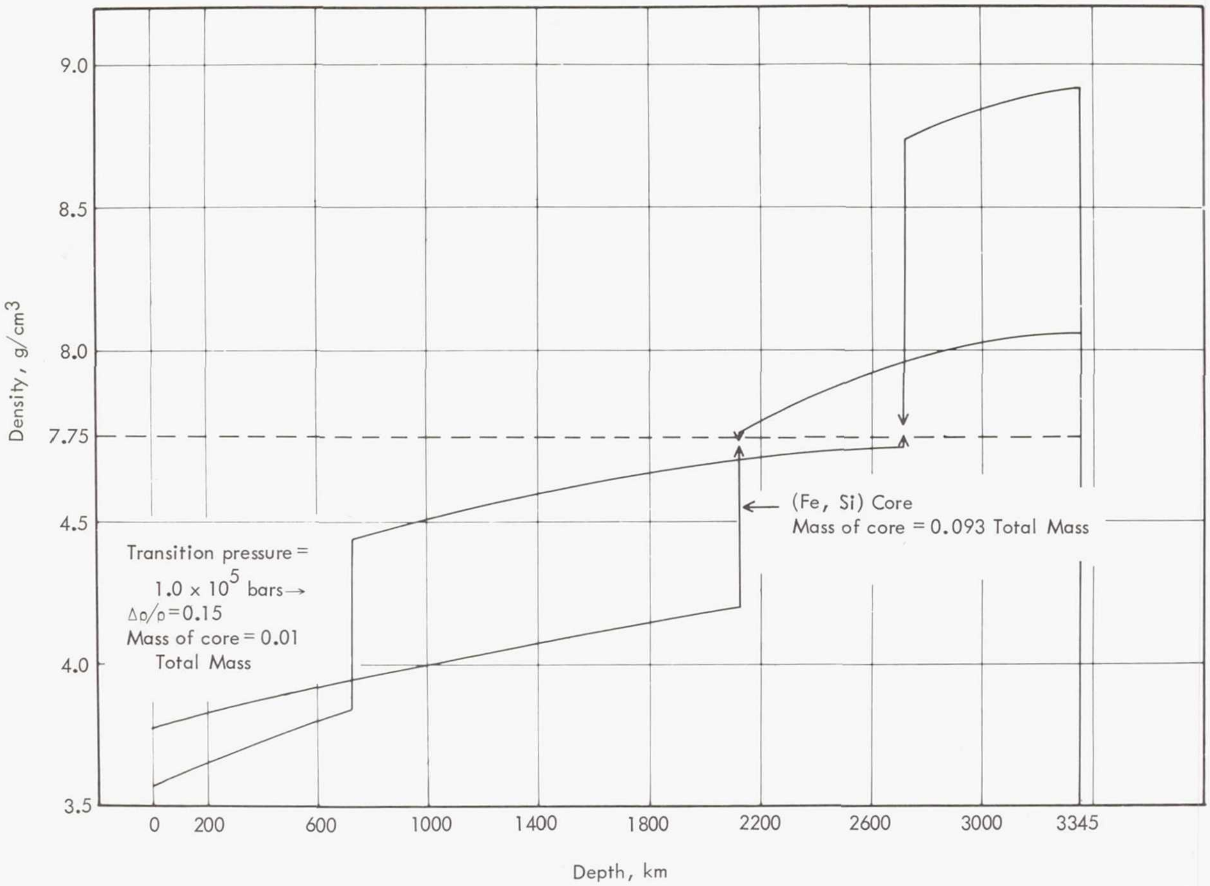

FIGURE 6.—*Variation of density with depth in Mars for two models. Radius = 3345 km, flattening = 5.0×10^{-3}. In one model, the phase transition takes place at 10^5 bars and there is a relative change of volume of 15 percent. In the other model no phase transition is assumed. The mass of the chemically distinct inner core is 0.01 total mass in the phase-transition model and 0.093 total mass in the model with no phase transition.*

THE PURPOSE OF SPACE RESEARCH

Thomas Gold
Director, Center of Radiophysics and Space Research
CORNELL UNIVERSITY

Space research is a great new adventure. I am quite sure it will not be very difficult here in St. Louis to gain sympathy for a point of view that a great communal adventure is a desirable thing. St. Louis was based on that. The exploration of the West was the purpose and excitement of the period when the city was founded, and it was the excitement of a new exploration, I believe, that was very largely responsible, not only for the driving spirit of this city but of the United States as a whole.

Each generation ought to have such excitement and something that really gives it a purpose. Trying artificially to devise the purpose is not usually successful. We have to hope that each generation discovers some particular field into which human effort and human intelligence can expand. I think we have this at the present time in science in general and in space research in particular.

Individual effort in exploration in science or technology is usually not possible any more, or, at any rate, the situation is not nearly as favorable for individual effort as it was perhaps a hundred years ago. Great efforts of team work with the support of the entire country are now the order of the day. More can be achieved in the modern situation by the great team efforts even if this is not quite as satisfying to some individuals as progress based on a few outstanding men.

But the great communal efforts have other advantages in addition to increasing knowledge. They tend to weld together a nation, to give it a purpose, and to divert it or its members from undesirable activities that they might otherwise get into in order to satisfy the instinct of adventure and to obtain the excitement that seems to be necessary for a full life.

Space research, I believe, is becoming this great new adventure at the present time, and it will give the next generation its purpose and its drive. I hope that your city will take its proper share in all this with its magnificent history in a closely related field. I hope very much that when the first man flies to Mars his spaceship will be named *The Spirit of St. Louis*.

For scientists engaged in space studies there are two ways of reacting to the popularity of space. One is to ridicule the popularity and the ignorant excitement—all that is quite easy because, of course, there is very much in it that is quite ridiculous—and to stress that the scientific purpose will not be advanced by all those science fiction types, or all the space cadets, or all the eager but ignorant and multitudinous hangers-on of space.

The other possible reaction of a scientist is to realise that all these people are members of the public who may well serve as the vanguard in the campaign to bring the interest and excitement to others. Space research is not like the physics or mathematics of the last century which required a small number of individuals of great insight to make progress, but, if only for purely economic reasons, it is a National pastime.

Of course, the scientifically ignorant people do not contribute to the good experiments and observations and to the essential scientific work, but they can communicate their interest to others and in that way make the exploration of space the great National or, indeed, human endeavor that I feel it ought to be.

We scientists should not belittle the ignorant enthusiasm or try to do away with it. Instead, we should try to educate so that in the course of time there will be as much or more enthusiasm, but less ignorance.

I dislike a high degree of specialization that results in a small fraction of the people being initiated into an activity that the rest of the Nation has to support but cannot understand. It is like the organization of high priests in ancient civilizations which dealt with mysteries the public could not know. How can the public tell when they are being swindled? How can they know whether the high priests are not merely shielding themselves behind an artificial curtain of mystery?

Much as I admire the great scientists of the past, there is no question but that their activities did have that mysterious appearance to the general public. In that case, of course, the scientists did not intend it, but they merely could not help it. The general public must have had the feeling that there was a significant branch of human activity that was permanently kept aside from them that they could not really enter into. On the other hand, they may not have worried very much then since only a very small number of people were directly affected, and they exercised no power nor did they consume much wealth. This is all changed now, and the public would have much more reason to be suspicious of supporting a large and powerful section of the community that was shielding itself with a curtain of mystery.

I would much prefer to look forward to a period of scientific progress in which the average boy or girl in high school is up to date on many lines of scientific exploration and feels the excitement which, in a previous era, must have gone with geographical explorations.

Let us compare what I am trying to envisage for the future with changes that have happened in the past. In the Middle Ages, for example, in many countries, ordinary arithmetic was regarded as something that was the prerogative of a few specialists, a few talented people with particular training, and quite beyond the average member of the public. Now we expect a child to master this subject by the age of 10.

I believe that science, at the present time, is in a very early phase and that it may undergo a similar change. The day will come, given good education, when it will be commonplace for people to understand quantum theory or the theory of relativity (or whatever the subjects may be then that will take their place). All this will come about not only because there will be better education, and people will learn more but also, I firmly believe, because the scientists will make the subjects very much simpler.

That would, of course, be an enormous change. Should one strive to bring about such a change or should one leave things alone and let them take their time? My view is that it is important for humanity to maintain circumstances that are changing all the time. Stagnation is bad for us. The real question is, what is the nature of the change we should work for. I would vote for this change to be, in fact, the expansion into the great new scientific age that I foresee, and I hope that that change will be worldwide and will encompass all of humanity. In the exploration of the universe around us and our place within it, space research and astronomy are the best subjects to lead the way into this new era.

I believe that people, in general, will learn a great deal more; the present education system does not even come close to exhausting the capabilities of the human brain. It is not so much that people will have to struggle a lot harder to learn—they will probably do that, too, and I feel sure that no harm will come to them from working a little harder than our children do now—but that is not the main effect. The patterns of thought, the language, the ways of teaching will all be improved enormously, and for the same effort very much more will be achieved.

In addition, of course, there will come the period, the great age of the symbiosis of man and the intellectual machine. In that age the power of high-speed electronics will be available to each of us for all those things that can be done better by electronics than by human brains: information storage and processing, arithmetic, rapid simple logical operations like algebra, statistical and probability calculations, and so forth. We will not waste our time or effort with our own brains when such jobs can be done more efficiently by electronic means, just as we are no longer too proud of our own physical strength to delegate digging to a bulldozer.

If we want to expedite this advance as scientists, we have the responsibility not only to advance subjects but to strive all the time to simplify them. Wherever possible we must find easier paths through the network of scientific understanding so that the material which perhaps took us 20 years to learn can be learnt by the next generation in 5. As individual scientists, we may be proud that we can work our way through a complex field; as a group, we should take pride in simplifying the field. Only then can we hope for a general widespread advance rather than a fragmentation into more and more specialized fields.

Every time a scientist is asked to explain an item, he ought to consider this. There are basically four different attitudes that scientists appear to take when explaining something difficult to nonscientists.

Some make it clear that the subject cannot be understood without superior training and perhaps even without a superior intellect. "Here it is," they say, "but you could not possibly follow that."

A second attitude is, "Never mind whether the other fellow really understands it, just so long as he thinks he does." That is the attitude which is often embraced by scientific popularizers, and the attitude that many reporters tend to force us scientists into, whether they like it or not. On the spur of the moment and with the limitations of their medium, they want one to say something quickly which, whether in detail it is true or false, at least has a correct ring about it to the uninitiated and sounds comprehensible to the general public. They feel that the phony simple story that has some of the points of the real one is surely better for their purposes than an incomprehensible true one.

The third attitude is to be very genuine and to go back to explain the entire logical path to the subject in question. This is a very sincere attitude and makes clear that there is no easy way: "You have just got to struggle the whole way along, and I am willing to bore you for 2 or 3 hours by giving you the entire story." Unfortunately, very often the world will go by and that story will not be heard.

The fourth attitude, and that is the one I favor, is for the scientist to shoulder more and more of the burden to find the simple logical path. Let him who is best qualified struggle to reduce the difficulty of the subject and make it much simpler than it was when he learned it.

I feel that there is an enormous amount of progress to be made in that line. It may imply a lot of effort, and often if one is asked some question as a scientist one is not ready with an answer. If one is not ready, it seems to me that one should go away and try very hard to find, in each case, a simple logical route so that in the course of time a wider and wider range of the public can become involved in the scientific conversation. Each time one is successful, it is a step toward the widespread dissemination of science and a step away from the attitude of the high priest.

The modern high school training courses in physics and in mathematics are endeavors that have, of course, that very point in mind. That is good but it is not enough. Let each one of us make this effort every time that we are asked so that we will help in bringing science closer to all of humanity so that they can all share in the excitement and the satisfaction when, nowadays in any case, they have to share in the expenses.

I would regard as the principal purposes of space research: to marshal human interest in science, to introduce great communal efforts for intellectual purposes, to use the spirit of adventure and exploration for noble ends, and thereby to channel it away from such harmful enterprises as war.

Let me give a few examples of the scientific discussion that is now taking place, items that interest me at the present time, and that will serve as examples of scientific endeavours which, at the moment, are not very generally understood, but which in a few years time will become commonplace knowledge even to the children at school. One subject in that category is the magnetic surrounding of the Earth, the "magnetosphere" as the region is now called. I am myself the author of that word and for better or for worse it is now firmly a part of the English language.

I recall very well the discussions at the international meetings of a few years ago where a great variety of complicated theories were proposed and where very few people saw much of what we now know to be the right story. Now all of a sudden, as a result of a few space vehicles and a few very well devised experiments, the basic story is clear.

Before the relevant experiments were done one was able to predict a number of things. Firstly, that there would be a region dominated by the Earth's magnetic field, a region which is now known to contain fluxes of energetic charged particles and the so-called radiation belts. It was known that this region dominated by the Earth's field would extend out to certain distances and then change over to the circumstances of the interplanetary plasma which, as had been known or surmised, is streaming out from the Sun. It was predicted that somewhere there must be a shockwave in front of the Earth like the shockwave in front of a bullet in the airflow. All this has now been seen very clearly. The memorable results of the Imp satellites and of Explorer 10 demonstrate the many points at which the changeover from the magnetosphere of the Earth to the interplanetary field was seen and the position in which the standing shock in front of the Earth was discovered. There is now a vast amount of detailed evidence to make quite clear that this interpretation was right. The somewhat insecure predictions that had been made before are now fully substantiated. We are, of course, all pleased with that success story.

More than that it has become clear in recent times, also from the Imp series of satellites, what the process is that delivers energy into the magnetosphere. Magnetic storms and the light of the aurora all demanded that energy initially resident in the stream of gas from the Sun be converted into energy of energetic particles deep in the interior of the magnetosphere or indeed coming right down to the atmosphere as in the case of the aurorae. What was the mechanism?

Most people had thought that the process would be taking place mainly on the side facing the Sun, on the side that is hit by the stream. There one had discussed all kinds of ways in which the energy of the stream might be converted into a form which could penetrate deeply into the magnetosphere, even though the stream itself could not. I think there was just one paper, that by Hines and Axford, which discussed that energy from the stream might be deposited not in the front but in the tail of the magnetosphere. Although the story is not quite the one which has now been accepted, it came close.

The amount of energy which is delivered by the interplanetary stream of gas to the Earth to make its appearance in the aurora is quite large. A substantial fraction of the entire energy in the stream hitting the surface of this magnetosphere must be delivered to produce the observable effects inside. A comparatively efficient mechanism is needed to bring energy from the outside of the magnetosphere to the auroral zone.

It was difficult to find such an efficient mechanism, for the simple view would just be that the big obstacle of the Earth with its magnetosphere in the solar wind would just make the stream cleave around and most of the energy that would be dissipated would be carried away as heat in the stream. But we needed to have this energy delivered to the interior of the magnetosphere instead. We now understand that each bit of the surface area of the magnetosphere of the Earth, as it is exposed to the solar stream, gets dragged out and its magnetic field, therefore, is stretched to make a very long tail behind the Earth. Work has to be done on the magnetic lines of force to stretch them out and this work reappears as an increase in the magnetic energy contained in the magnetosphere. As the Earth rotates, the front parts of the magnetosphere get exposed to form the exterior skin, and this means that new lines constantly present themselves to be stretched out by friction with the stream, and other lines previously stretched out get underneath and then have the opportunity to shrink back again to a much shorter length. Whenever that happens the magnetic energy so released must appear as particle energy of the particles of the gas that populate this region.

So we have here a very well devised kind of a paddle wheel which takes energy efficiently out of the solar stream. Energy continues to be delivered by the stream to fresh lines of force which are dragged out and then twisted under so that they can shrink again. This can be quite a steady process so far as the overall appearance is concerned showing merely a long tail of lines of force behind the Earth.

We scientists have to admit that, although there was much guesswork earlier, this particular story was not guessed by anyone. It really required space vehicles to survey the tail of the magnetosphere before these processes were understood.

There are other things that we have learned from those same space vehicles, as, for example, the normal condition of interplanetary space. We now understand that there is a fairly steady stream at a few hundred kilometers per second, mostly about 300 kilometers per second, from the Sun with a density of between 1 and 10 particles per cubic centimeter; and that during the time of magnetic disturbance both the velocity and the density of this stream are augmented. We are now looking forward to the period of enhanced solar activity which will soon commence in the normal rhythm of the solar cycle, during which we shall see, we hope with equal clarity, the circumstances in interplanetary space of large clouds of solar gas shooting out from the explosions on the Sun's surface.

Why do we want to know all these peculiar things connected with such very small amounts of gas and very weak magnetic fields out in space? You might say that there is hardly anything there at all, so why care about what little there is. It is the best vacuum that we have ever seen, and yet we concern ourselves with that little bit that is there and that distinguishes it from an absolutely perfect vacuum. Why?

The reason is that there is a whole branch of physics involved there which cannot be reproduced in the laboratory. We cannot do laboratory experiments to simulate these circumstances because the laws of scaling to a different size are against us. This is a branch of physics in which it is very difficult to gain detailed understanding except purely by theory or with the aid of some observations on a large scale. Some plasma physics can, of course, be done in the laboratory but there is much more that cannot. The solar system, on the other hand, can be used as our plasma physical laboratory, and we may hope to gain there an understanding of the events which may take place on the much greater astronomical scale of sizes. The structure of galaxies, the large scale architecture of the universe, may require for its understanding the development of a subject which is helped by the observations on the solar systems scale.

Having now a reasonably good understanding of the magnetosphere of the Earth, we may make inspired guesses about the magnetosphere of the Moon. There we think that no internal magnetic field is involved and that the Moon merely acts as an obstacle of a weakly conducting medium in the plasma stream from the Sun. In that case, the front face of the Moon, at any one time, must be magnetized with an intensity which can be estimated to be around 10^{-3} gauss. This is, of course, very weak compared to the Earth's magnetic field which is some 500 times stronger. This field is forced into the front face of the Moon by the interplanetary wind, and will be dragged out into a long magnetosphere tail behind the Moon. In front of all this one may expect to find again the standing shockwave.

This is the guess we can make now, but it will be very interesting when more is discovered and seen in detail by lunar satellites with plasma probes and magnetometers on board.

Another new subject that will soon be transformed into general knowledge is that of radar to the Moon and the planets. At our radio telescope in Puerto Rico, for example, we make detailed studies of the Moon by means of the reflection of radio waves by radar techniques. It is possible to obtain a resolution of as little as a few miles on the Moon, so that we can observe how individual regions on the lunar surface reflect radio waves and the radio reflection depends on structural properties of the ground, mainly on how solid it is and how rough it is. The optical information that we get from a telescope is more dependent on the reflectivity of a thin overlay whose presence would have no effect on the radar. Regions which optically look alike may look very different to the radar so that, for many purposes, we may be much more interested in the radar information. The radar probes deeper into the ground and is more related to those properties of the ground that we need to know for the purpose of exploration. The roughness information is concerned with a scale of unevenness of the order of 1 meter, which is even smaller than that obtained by the Ranger pictures and is approximately the scale that is most significant for technological purposes.

From such studies we have clearly seen that all the young looking craters on the Moon's surface are made of rough and hard material, while all the many older looking features seem to be made of a much more porous material and seem to be fairly smooth. The discussion had been that most of the craters were made by big explosions caused by the impact of large meteorites. Such an explosion would undoubtedly leave hard ground behind whatever form of rock was hit. Just the enormous intensity and the pressures that are implied would, of course, be enough to compact any material into hard rock. If this happened to each of the craters when they were formed, we must suppose that all the older craters have acquired a thick overlay of some substance which is not solid rock, which must be at least a few meters deep, and which is a much poorer radar reflector than rock. It might be a thick overlay of a porous sediment resulting from multiple meteoritic bombardment by smaller meteorites. It is very hard to think that any form of lava deposit could be responsible, for we would then need to suppose that this lava deposit covered not only the interiors of the older craters but every part right up to their rim, and that it did all this covering not when each crater was formed but much later.

The radar information has already helped us in unravelling the puzzle of the lunar surface, and, I am sure, it will help us much more. It is very important, of course, to do much of this investigation before the main round of lunar exploration is started since a lack of understanding then could mean very costly failures. The investigation of the Moon is expensive, so we must work very hard to be sure that in each round we ask the right questions and interpret the answers we get as fully and as carefully as possible.

The Ranger pictures showed a large number of features for which the explanation is not yet certain. One class of such features is of low-lying ground where there are holes, crevices, and sunken patches which could be explained most readily by some form of collapse into underlying hollows. Whatever this flat material is, it seems to be capable of some kind of collapse. In pictures we have seen only quite large-scale collapse features, and we do not yet know whether the same material is capable of collapse on a much smaller scale. The terrestrial ground is tested for firmness by the wind and the weather all the time which makes it unlikely that any randomly chosen patch will not be strong enough to carry the additional burden of a man or a vehicle. No such testing has taken place on the Moon, and we, therefore, have to worry. The action of meteorites over the millennia may have pounded the ground together; but, on the other hand, the evidence is that some hollow spaces had nevertheless developed. I think there is every cause for concern here and for much investigation before manned vehicles can be landed.

The Ranger IX pictures have clearly shown that the large interior plain of the crater Alphonsus possesses a curious and unexplained instability. There are many more small craters inside Alphonsus than outside, and it is clear that the majority of them must be of internal origin and not due to impacts. There are many rills and crevices which seem to end more or less abruptly at the edge of the crater floor. It seems that the interior of this crater has some shifting material in it, but that the movement of that material leaves the surrounding rock unaffected. This is suggestive that the region is composed of a material which is mechanically less strong and more pliable than the surrounding terrain. I, personally, have hazarded a guess that this material is ice under the surface at a depth of perhaps 100 or 200 feet.

On the Earth, water has been exhaled from the interior to make the ocean, and the amount made available would be enough to cover the entire Earth to a depth of 3 kilometers. If water were coming up from the interior of the Moon, even if it were only smaller quantities, the story would be quite different. Of course, if the water got to the surface it would readily evaporate and leave the Moon altogether, since the small gravitational field of the Moon is insufficient to hold a permanent atmosphere. From this it might be expected that any water on the Moon would have evaporated into space and disappeared. But that is not so. The Moon is much colder than the Earth, and everywhere, even on the equator, the temperature of the ground at a depth of more than a few inches is well below freezing. Even if the deep interior of the Moon had been heated by radioactivity, the permafrost layer would still be mostly kilometers deep. Any water that percolated upward as steam or liquid in the interstices of the rock would come to this permafrost layer and freeze there. As ice it could no longer escape through the cracks and crevices, and water and ice would thus be bottled up at some depth. It is an efficient arrangement like a self-sealing tank.

Even if the quantities of water on the Moon have been much smaller than those that have come from the Earth's interior, the effects would nevertheless be very marked. Cakes of ice under the Moon's surface would make sheets of low rigidity—no doubt, mostly in low-lying regions on the Moon—and any supply or removal of water would cause a movement of such a glacier. An overburden of rock rubble of 100 feet or so would be sufficient to reduce evaporation of ice into space to a rate which even on the geological timescale is not significant.

When we get to the Moon, the question of availability of water will certainly be one of great interest. Not only would a lunar water supply give us many technological advantages, such as a supply of hydrogen and oxygen, but also from the point of view of the investigation of the Moon's interior we would be greatly helped by having chemical samples from deep within the Moon for detailed investigation.

These were just examples of the discussion that is interesting us at the present time and I believe that in a few years time our excitement will be shared by a large fraction of humanity. Moreover, a little later some of these things that we now regard as far-fetched realms of scientific enquiry will have become common schoolboy knowledge.

SPACE RESEARCH INFLUENCES ON INDUSTRY AND THE ECONOMY

Chairman
Carroll A. Hochwalt
President
ST. LOUIS RESEARCH COUNCIL

INTRODUCTION

Carroll A. Hochwalt

As director of the St. Louis Research Council, it is my privilege—and my problem—to work daily with such questions on the influence of space research activity on industry and the economy, as we will be discussing in this session. We have three eminently qualified authorities on hand to discuss aspects of this subject today. They are: Dr. Seymour W. Herwald of Westinghouse Electric Corporation, Dr. Arthur M. Weimer of Indiana University, and Dr. Walter Isard of the University of Pennsylvania.

President Kennedy a few years ago referred to the challenge of space exploration as "the new ocean." It is, indeed, an ocean of ideas and concepts waiting to be plumbed by scientific inquiry. Its multitude of aspects challenges every one of the physical sciences at the most fundamental as well as the most practical levels. Consequently, the exploration of this new ocean of outer space is both the product and the leading edge of general advances in science and technology.

We also have come to know that scientific and technological advancements are the seeds from which spring the continuing industrial and economic growth of our communities and of our nation as a whole. Economists generally agree that technological advances have been responsible for 90 percent of the rise in productivity in the United States during this century. Such growth stems most vigorously from new ideas and new skills; from scientific and technological innovation. New products, new processes, new resources and new services are the fruits of such innovation. And they are a yield which is measured in terms of industrial and economic growth.

Just as the many skills and capabilities needed for space exploration draw from all of the various sciences, they feed back to those sciences and derivative technologies a wealth of new data. This feedback of new information becomes a rich substrate for new invention and technological innovation.

Space exploration can and should relate to advances of industrial technology in two ways. One way is in the direct transfer of specific developments to industrial use, with or without modification, as improvements over materials, devices or techniques currently in use. The second contribution is through the role that space exploration can play, when assimilated into industrial thinking, in widening the horizons for industrial inventiveness and creative innovation. In the first, new tools are provided for industry problems. In the second, new perspectives are provided for viewing industrial objectives.

It is important to recognize, however, that the extension of scientific and technological parameters by the achievements of space exploration does not automatically insure a "fall-out" of new industrial materials, products, processes and techniques. There is an inevitable time lag between scientific and technological advances in an area as esoteric as space exploration and the subsequent adaptation of these advances to inventions or innovations which have commercial utility. The knowledge must be not only assimilated but also integrated into a framework of thought which leads to invention or innovation.

In this latter respect I should like to emphasize especially the vital role of the entrepreneur. Scientific research and development do not, of themselves, generate inventions and innovations. A third and indispensable ingredient to the inventive process is the function which can best be described as entrepreneurship.

This is the quality in a practically oriented, risk-taking individual which enables him to sense the commercial potential of a new idea and to muster his organizational strength for its swift and profitable exploitation.

As I see it, it is the entrepreneur who provides the bridge of business imaginativeness and acumen which links the work of the scientist or technologist to the commercial success of a new product or service in the marketplace.

We know of the efforts that urban centers throughout the United States are making to weld that important linkage between science and technology and the economic growth of their communities. Our St. Louis Research Council is one such effort. Obviously, the space research program mounted by our Nation figures importantly in these plans. Just *how* importantly it figures in the entrepreneurial efforts of both our industries and our communities will be clear to us from this morning's program. The importance of such entrepreneurial efforts to our economic progress cannot possibly be ignored—or over-estimated.

TECHNOLOGY UTILIZATION—THE INDUSTRIAL OPPORTUNITY

S. W. Herwald
Group Vice President
WESTINGHOUSE ELECTRIC CORPORATION

When I agreed to discuss this particular subject, I sat down and tried to figure out what might be pertinent and what might make sense. I found I was either constrained to talk about things that are very prosaic that everybody knows or else about things so far out that I did not really believe them myself. It was at this time that I did a little reading on the subject of forecasting the future and retroactively looking at the results of forecasting. Then I found that people who make a study of this, particularly of the accuracy of future predictions made by individuals with technical training, conclude that the technically trained are not very good forecasters. They are overly optimistic on what they can do tomorrow. They are unduly pessimistic about the strides that can be made in the future.

I really think, in analyzing it, that there is probably a good reason for this forecasting inadequacy. All of us who have had technical training are taught that we must see our way from here to there, step by step, and that if we do not understand every step, we really do not know how to get there. I think this accounts for the optimism in current thinking because we, at least conceptually, see our way step by step. Also, it probably accounts for the pessimism in predicting the future because then we do not fully understand every step we are talking about. Incidentally, the people who show up best in this retroactive look are the financiers. They seem to be totally unburdened by knowing how to get from here to there. Instead they rely on their best theory. They just take a good calculated guess on the things that are going to be necessary and predict the need.

So, with that little background I ask for forbearance while I try to do some forecasting of what might be the effect of current space research on industry and the economy, based more or less on what might be desirable rather than on my understanding of how we get from here to there.

Let us start with a basic premise that I wholeheartedly believe—no industry nor any national economy prospers for very long unless it serves people. The point is that whatever we talk about doing, it must eventually be something in which people en masse participate, something useful for them. The approach I took, in trying to look at the future, was one of deciding what and where are the people's problems. Certainly, the first and foremost people problem, that takes little difficulty in forecasting and seems to be going on at a very, very hectic rate, is the one of the large number of people themselves. Figure 1 is just a restatement in numbers of what we probably all know intuitively—that the people problem is going to get much worse. It is really just an interpolation graph to focus attention on the fact that when we go back—prior to 1800 when the census count was worth anything—the numbers get exceedingly low. One of the things that amazes us, when we look at such a graph for the first time, is how few people were around in—let us say 0 A.D. But this population growth is one of the most fundamental problems facing us, and I thought it would be a good one to start with.

The people problem is going to be much greater—we have greatly increasing numbers of people, and these greatly increasing numbers of people will need the real fundamentals of food, water, shelter, and some room. They will need room to live in, room to transport in, and room to do all of the things that we can now visualize that take room as well as some in the future that we cannot foresee.

Let me share a statistic which floored me when I first looked at it. I still do not really believe it, but it seems to be fairly factual—in 1955, the arable land per person was about 1¼ acre (fig. 2). I think we get a distorted view of this when we go around the United States because we are way off base. We have way more arable land, even with all the contractions in the farming per person, than that 1¼ acre. And, by 2000 A.D. with population growth,

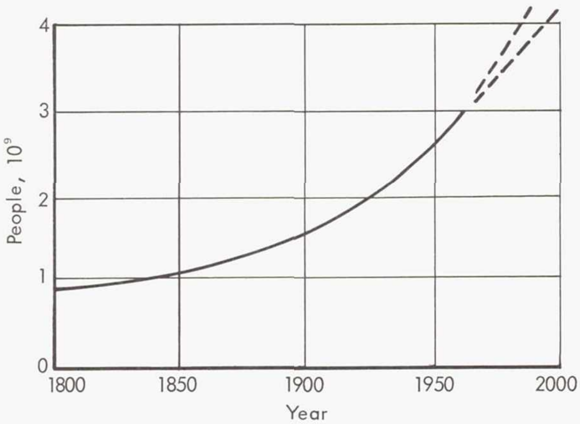

FIGURE 1.—*World population growth.*

it is estimated that this will decrease to a little more that ½ acre per person. So, in a very fundamental way, what we are really saying is that we will either have to get smart enough to grow more in that ratio, which is something better than two to one, or we will have to find new sources, or new places or new things with which to deal with the food problem.

There is a paper, "Man's Earth, Orbital Program and Earth Sensing" by Lowe, McDonald, Settinger, and Walter published in April 1965; it discusses the future use of observation from satellites. One of the things that this paper pointed out is the value of surveying and determining the optimal use of the arable land resources. Table I lists the kinds of observations that might be made from space. Because this is a little speculative, do not worry about what is feasible, probable, or questionable. There are a large number of things that we could sense fairly economically with satellites that we could not map in relatively small areas in a lifetime. Some do relate to problems of people—fire, flood, drought, and misuse of land. We could have worldwide forest fire detection and improved methods for predicting floods and droughts and detection of crop diseases. These are only immediately obvious areas of interest.

Let us talk about the economics in a very gross sense. Table II is a list of guesses as to the economics

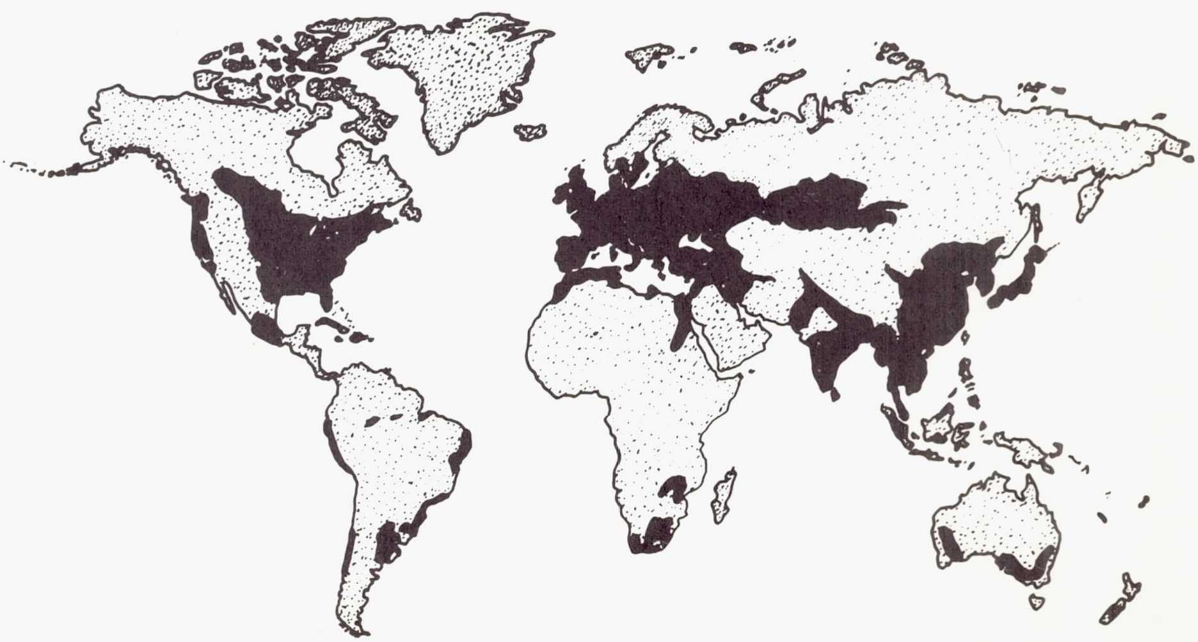

FIGURE 2.—*World crop farm lands (black areas).*

Table I.—Possibilities of Observing Agricultural Features from Space

Feasible	Probable	Questionable
Crop and species area	Crop and species type	Soil moisture
Soil temperature	Vegetation maturity	Frozen soil
Contour farming requirements	Plant disease	Unfrozen soil over permafrost
Terracing requirements	Soil type identification	Cause of damage
Snow area	Strip cropping requirements	Water vapor over vegetation
Water area	Flood and wind damage assessment	
	Snow depth	
	Water level in basins and rivers	

involved in doing a few of these, if we could take a look at the vegetation, the cultural features, the crops, the thermal map of the oceans relative to the currents—and again do not worry too much about whether you agree or disagree with the dollar value. The fact is there are significant dollars involved in considering an industry and an economy from the standpoint of its usefulness to people. I cannot predict exactly what kind of industry would then flourish, but I do know that any combination of industry and service to people has always, in the past, flourished. The value for doing such things as mapping world vegetation, the world map of natural and cultural features, agricultural crop surveys, land use studies, a film map of the ocean, worldwide ocean-sea data, water budget data, forest fire detection data, and weather data are estimated to have direct value somewhere in the nature of \$$\frac{1}{4}$–$\frac{1}{2}$ billion per year, conservatively. I think that, when we talk about realizing billions of dollars in other ways, \$$\frac{1}{4}$–$\frac{1}{2}$ billion is a realistic value. One of the President's speeches had an estimate of \$5.5 billion as the gross value of something as simple as a 5-day weather forecast on the economy.

Work on advanced surveillance cameras and radar would suggest that many of the things that I have listed here are indeed technically feasible and would, in fact, substantiate for the most part the claims made in the Lowell paper. Naturally, such surveys would be greatly enhanced by cooperation on an international basis, and this kind of cooperation is either becoming feasible—or necessary—and is well publicized. Look at what is relayed communicationwise now relative to our launchings. For example, at Cape Kennedy I learned that the Clay-Liston fight was relayed to Russia, and I cannot think of anything we should export less than that. But it is indicative of the fact that communications are good and getting

Table II.—Impact of Space Surveillance

Function	Applications	Coverage	Interval			Value, 10^6/yr
			yr	mo	wk	
World vegetation	Forest inventory	Global	5			50–75
	Energy budget	Global				175
Natural and cultural features	Geographic studies	Global	5			70–140
	Map revision					
	Land use planning					
	Oil and mineral location					
Crops survey	Food budget	Major crop distribution		1–3		Over 100
	Agricultural census					
	Wildlife reserves					
Thermal map of ocean	Marine life distribution	Ocean basins			2–4	
	Location of fisheries	Major inland waters				
	Marine biology studies					
Water budget data	Improved water regimen	Land areas			2–12	Potentially very high
	Crop yield prediction					
	Flood prediction					

better. In addition, with this kind of cooperation, voluntary or forced, in this kind of environment, we can contemplate the feasibility of worldwide geographical surveys that could be conducted to discover many of the resources that are currently critical to the economy such as oils, minerals, and water.

We have talked about the use of our current resources, the population explosion which will tax our agricultural capability, and how the arable land is not as much as we would like to have. Much more dramatic, however, is the use of the Earth's resources which could be arable—not the ones that are and could be used for crop production but those which are now considered too difficult to farm because of lack of water, inaccessibility, temperature extremes, or just because of an extremely hostile environment such as the floor of the ocean. Certainly, the experience being gained by exploration in extremely hostile environments, such as the Moon's surface, and the many studies that have been conducted on Moon basing and the automation of experiment and the delivery of habitable shelters and colonies should have a significant effect on our ability to overcome the problems associated with hostile environments right here on Earth. As a matter of fact, one example at Westinghouse is a current program on deep sea surveillance. We are using some of the people who have been working on lunar basing and whose methods, experience, and knowledge in deriving means to combat hostile environment will stand them in good stead. The effects of such a transfer of knowledge are very, very difficult to measure.

However, when one considers there are 126 billion acres on Earth and only 3.2 billion acres are considered suitable for agriculture at this time, there is enormous potential to increase the use of the Earth's resources through the proper understanding of how to work in hostile environments. If we consider the Arctic, we find that we can barely conduct expeditions in this region now. However, if we raised the temperature just slightly in these areas, it would certainly aid in capturing some of the mineral resources, providing additional water resources, and perhaps, developing additional agricultural bases.

Again, please remember that I am departing from my normal role, and it probably pains me as much as it does some of you, but let us consider the means for accomplishing this trick. The Sun is the primary energy source for all activities conducted on Earth. Our energy either comes directly from the Sun now or has been stored for generations in fossil fuel from the Sun. At the present time, the Earth subtends an angle, a solid angle which can absorb about 5×10^{-6} percent of the Sun's energy, as is illustrated in figure 3. If we could capture a little more of this energy and put it to good use, for example, raising the temperature in some of the polar regions, we would have a device with the capability of doing some weather control or at least making some of our hostile environment less hostile.

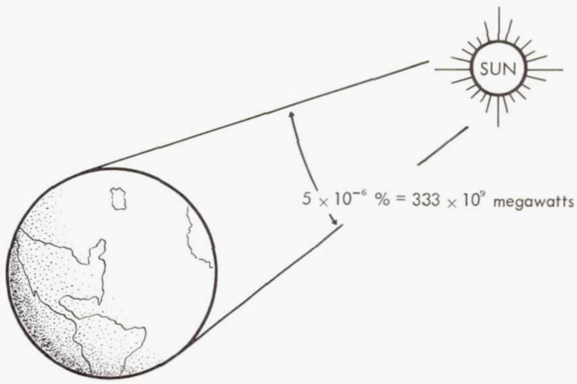

FIGURE 3.—*Energy from the Sun.*

Figure 3 schematically indicates why that 5×10^{-6} percent is such a small part. We really face a small section of the Sun; the rest of its energy is going out somewhere else. The Sun at 1 astronomical unit has about 2 kw/m^2 energy, and a reflector to concentrate this energy with 90% efficiency might weigh about 1 lb/100m^2. There is a lot of work being done on low-weight reflectors that could be boosted into space. Now, if we consider that today's booster costs are about $650/lb in orbit, we find that even with today's booster costs we are able to deliver 180 kw for about $650. If this equipment could be made to function for reasonably long lengths of time, so that the investment could be amortized, we might begin to have the basis of something useful. Now, with improvement in booster technology, these costs could go down, and, as a result of directed use of sunlight, we could conceive of controlling the hours of daylight in some limited areas, of inducing slightly increased temperatures in certain areas, of providing for increased temperature of clouds in mountainous regions and thereby delaying the rainfall until it gets further into the desert areas generally east of those mountains; this obviously would have enormous implications for our economy.

I do not know how we get from here to there, but at least, the pieces of the puzzle are ready for people to work on and contemplate. There are, of course, more direct and less speculative short-term applications of space technology which have a direct effect right now on our economic and industrial world. The subject of communications will be covered in depth in other papers of this conference, so I will just mention it in passing. The whole area of worldwide navigation and traffic control for ships is possible because of communications. Looking at the estimated traffic in the world, we find that a study by the Technology Audit Corporation of estimated world-wide traffic for 1970 predicted 750 000 ships involved and about 300,000 aircraft for a total of approximately 1 000 000 pieces of traffic. In the 1970's shipping traffic (fig. 4), it is estimated, will be increased by a factor of 20 to 25 percent, whereas aircraft traffic will almost double in that time.

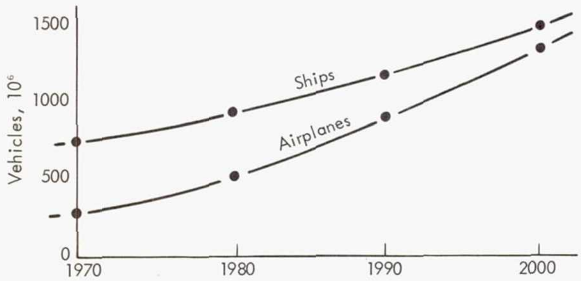

FIGURE 4.—*World traffic prediction.*

It is estimated that it will be possible by the early 70's to have an operational navigational satellite system which can provide navigation and traffic control information to the user's vehicle to one nautical mile of accuracy with user equipment costing in the neighborhood of $5–$10,000. Such a system would appreciably reduce the present volume of air space assigned to each aircraft. I said that we had people space problems facing us in the future; we obviously have people transport space problems also facing us in the future. A reduction of allotted air space by four or five would be possible through the use of such a system.

The space systems that have impact on agriculture, weather control, weather predictions, traffic control are really international in nature and are, in fact, the satellite communications that we are currently working on. This suggests that we are going toward international cooperation because we are being pushed together by technology and by the controls available to us. This, of course, would have enormous implications on how we do business in the future and, in fact, on whether or not we really will be able to derive benefits from space programs. Certainly international cooperation is required and necessary, and this implies closer political or economic ties. I do not need to paint the opposite picture for you of what might happen if we do not eventually learn to live together; the kind of society we have as an alternate has been painted rather well by others.

One could not look at the economic industrial impact of our space programs without considering the direct implications of this kind of program. Now, I am switching again by saying just forget about the future, forget about the ones that might even be near to the future, but let us talk about today. Right now, NASA has a budget of $5½ billion; NASA actually has created an industry. Looking toward experiment in space and the kinds of experiment we can do in space, we find new things to examine more thoroughly here on Earth. We see an immediate effect in the growth of an experimental industry in place of today's research industry, the so-called R&D organization, plus the limited hardware that is being built in attempting to uncover and exploit the information that we are gaining from our space experimentation. So I do not want to distort in looking toward the future nor take away from the fact that right here in place today is an industry engaged in what future generations will call a preliminary research of space.

I think it is interesting to speculate that what happens because of new technology or new areas of research is that effects usually show up in entirely unpredicted areas. It is amusing to look at the history of predictions and see who predicted what. I think Jay Gould was the only one who predicted that out of the Wright brothers' flight would come a transport system for moving people. So, out of space research, we can expect the unexpected. To review, I believe the implications and effects of space research on future industry and the economy are going to be large. They are going to be far greater than I can justify on a step-by-step technical basis. The greatest people-need problems such as food, livable space, power, and environmental control can all, at least speculatively, be positively influenced by space research. Industry and the economy will flourish in meeting these kinds of needs. Space research makes international cooperation desirable so that industry is bound to become more international in outlook. I think the implication of those three rather broad thoughts are far more fundamental than the details of whether or not I can see my way through the hardware.

INNOVATION, ORGANIZATION, AND TECHNOLOGY TRANSFER

Arthur M. Weimer
Special Assistant to the President
INDIANA UNIVERSITY

The influence of the space program on industry and the economy almost staggers the imagination. Both in terms of a direct impact through contracts and grants and through indirect effects, the space programs must be considered a major force in American life. Beyond all of these effects, we must recognize the significant influence that the programs have had on the overall attitudes of the American people, the lifting of their horizons and the expansion of their knowledge and hopes.

I intend to discuss some of the lessons we have learned about the processes of achieving successful technology transfers. I believe technology transfers have great potential for our economic growth.

The lawmakers who set up the National Aeronautics and Space Administration through the Act of 1958 recognized the potential that might exist in space exploration for nonspace industry and specified that the knowledge gained must be made available to nonspace industries, as well as to NASA contractors. (Much the same type of requirement is set up for the programs of the Atomic Energy Commission.)

The action of our lawmakers with respect to the space program was not a unique development. Throughout our history we have been concerned with scientific progress and its potential for economic growth. The record of the Constitutional Convention indicates that many of our early leaders including Washington, Madison, Franklin, and Jefferson held strong views about the importance of science, not only because of its intellectual challenges, but also as a means for advancing commerce through what was termed the "useful arts."

Dr. Richard L. Lesher of the National Aeronautics and Space Administration has selected several dates that have special significance for the early history of science, technology, and economic growth. These include the following: 1790, first patent law (also the first census); 1800, Library of Congress; 1802, Army Corps of Engineers; 1803, Lewis and Clark Expedition; 1807, Coastal Survey Act; 1829, death of James Smithson whose will provided for the establishment of the Smithsonian Institution "for the increase and diffusion of knowledge among men."

With the type of background suggested by these developments, it is small wonder that we are today devoting much time and effort to the exploration of space and that we should be concerned with the dissemination of space science and technology.

At Indiana University we have been engaged in an experiment in the dissemination and use of space science and technology since 1962, having entered into a contract with the National Aeronautics and Space Administration in the fall of that year. As a result of this contract, we set up the Aerospace Research Applications Center and have been undertaking to make maximum use of the results of the various research and development efforts carried on by NASA by developing methods to effect transfers to private business firms. The programs of the Center have been supported by the Indiana University Foundation and the University as well as by over 40 business firms.

In addition to working with the materials developed by NASA, during the past year the Atomic Energy Commission materials have been utilized; and through arrangements with the Department of Commerce, it has been possible to gain access to a substantial portion of the unclassified Defense Department materials. Various other sources are drawn upon as well.

Without going into the details of the programs of our Aerospace Research Applications Center, I should suggest that we have been undertaking to transfer to business firms ideas which NASA personnel and the personnel of contracting companies believe to have commercial applicability. We have developed both retrospective and current awareness computer search systems of NASA and other federal materials centered around high-priority interests of member companies. We have developed a highly competent group of people to work with these materials and to serve as liaison personnel between the member company personnel, including R&D and top management as well as a variety of scientific and technical personnel; NASA and other Government officials; faculty members of the University in the sciences and in management, marketing, and other areas of economics and business administration; and other professional people who may be helpful.

We are reasonably well pleased with the results of our efforts to date. Although many of the member companies prefer not to identify specific benefits that have been received, except in general terms, we do have some fairly specific evidence that the work of the Center has proved to be useful. In a number of instances it is understandable that secrecy would be maintained in regard to potential developments. In a general way we believe that we have helped a number of companies to improve their internal organization for utilizing technical materials as well as improving their communications systems.

In a number of cases we have made it easy for R&D personnel to receive the available Government R&D literature and often have saved them substantial time and effort. We know that in some cases we have been able to help companies avoid expensive R&D ventures because we have been able to bring them information of on-going activities which previously was not available to them. We have in a number of cases been able to bring company people into contact with NASA personnel in areas of development where reports have not as yet been published. In addition to these types of benefits, we have, of course, made it easy for member-company representatives to meet numerous officials of NASA, the Department of Defense, the Atomic Energy Commission, the Department of Commerce, and other Government agencies in connection with our semiannual meetings held on the campus in cooperation with the Indiana Executive Program and the Graduate School of Business. At these meetings there has been a substantial exchange of information between the representatives of the different companies as well as between company people, university faculty members, and Government officials.

We do have some specific evidences of assistance. In the case of one company we were able to find an improved method for joining thin metal by use of the tungsten inert-gas welding process.

A fairly simple but still valuable transfer was reported by one company which, because of its need for testing competitive products, found it necessary to remove lithography from cans. A NASA report described a paint remover previously unknown to this company, and it was found to be very useful for this purpose.

In another case, a company was able to reduce the turn-off time of a rectifier by means of information reported in one of the documents in the ARAC system. Still another company was able to locate a material capable of accommodating high-density magnetic fields for use as a core material in a pen-drive mechanism. In another case, joint efforts of company and ARAC personnel combined with careful literature searches made it possible to develop a new approach to a problem in the area of microencapsulation.

From these reports we are able to gain some concept of the potentialities that may exist. They suggest, indeed, that many companies are gaining substantial benefits from the work of the Center, and undoubtedly new developments will be forthcoming and will be in a reportable condition in the not too distant future.

What have we learned from this experience in terms of what it takes to bring about successful technology transfers?

First, I believe this is an area that offers great opportunity for a working partnership between industry, Government, and the university. The university can help to create a climate for innovation and can help to study objectively some of the processes that are involved, as well as serve as a means for disseminating information which is, in effect, an extension of the university's long-run teaching function. Through its Graduate School of Business, which has had a long period of successful working relationships with business firms, the university has helped to direct the interest of top management to the process of technology transfer and to the study potentials in the aerospace and space science industries. This has been facilitated by building on the Indiana Executive Program and by working with those who have come through the program in past years. Semiannual meetings of the Center in cooperation with the Business School Executive Program have served as a means for stimulating interest as well as for helping in the transmission of information. On April 8 and 9, for example, the semi-annual meeting was centered on the general theme of "Innovation: Organization Climate."

Second, of great importance is the interest of top management. When our Center was set up it was based on the idea which originated with James E. Webb, the Administrator of NASA, that a business school with long-term working relationships with top management might be able to make a significant contribution toward capturing and holding the interest of top management in technology transfer, and in particular to make the new knowledge generated by Government and the aerospace industry available to other sectors of the economy. This has, indeed, proved to be the case, and the Center has made the interests of top management one of its highest priorities. If top management is interested, all parts of the business firm will be interested and the attitudes of the entire organization are more likely to be favorable than not.

Third, those involved in the technology transfer process in Government, in the university, and in the companies must have a willingness to experiment, not only with matters relating to communications techniques but with organizational arrangements, in an effort to achieve the results desired. Such organizational arrangements must put key men in key places, men who have entrepreneurial minds and who make use of current information not as a means solely of solving problems directly, but as devices for suggesting other solutions to problems, of restating old problems, or of helping to identify significant new problems.

Fourth, another important lesson that we have learned from our experiences is the importance of abstracts and of presenting information in quick, easy-to-read form so that no one is overwhelmed with information at a given time. Thus, responses to retrospective searches or to current awareness searches are made in the form of abstracts, assembled in small packets so that they can be looked over in a few minutes; simple and easy-to-order forms are included which invite immediate followups on those items which appear to offer promise. Nothing defeats technology transfer so effectively as the overwhelming of busy people with voluminous reports. They are immediately relegated to the backlog and may never come back into the range of attention of the person involved, be he executive, scientist, engineer, marketing expert, or someone else in the company.

A fifth lesson is the potentially widespread applicability of the NASA and other Governmental materials. It is a mistake to limit access to the people interested in R&D and production only. We have found considerable value for management people, marketing people, and others in the organization structure, as well as for the more traditional outlets in manufacturing, engineering, product planning, and the like.

We have found it helpful to provide some point of central coordination between the company and the Center, but such centralization should not prevent the development of direct working relationships between people on our staff and those in the company. Close working relationships of this type help to stimulate ideas and help to keep the system dynamic.

Sixth, interest centers and profiles related to current awareness searches cannot be allowed to freeze into a given pattern, but must constantly be reviewed and adjusted to meet current high-priority needs. In short, *people are the key to successful technology transfer,* just as they are the keys to most other managerial, governmental, and educational problems. In these processes there is no substitute for brains, but beyond this, there is certainly no substitute for creativity, imagination, and innovative ability. We have not found very precise ways of identifying or developing people with these capabilities, but in a general way it has been possible for us to do this with respect to members of our own staff and to help some company managers do this.

Seventh, most of our failures in specific companies have resulted from the assignment of the wrong company personnel to this project. In some cases we have found it possible to correct these conditions. Sometimes we have had to go directly to top management in order to effect changes. In a few cases this has not been possible, and these represent our major failures to date.

Eighth, we have found it useful to present long-term projections as background for long-range managerial planning as a means of generating interest in technology transfers and R&D processes generally.

While we have learned some things, we need to learn a lot more. We have made some preliminary attempts to study internal company organization with a view to improving the technology utilization process. We need to do a good deal more along these lines. We have begun to learn how to use non-governmental literature more effectively for these purposes. A major case in point is the technical marketing service, which is only a few months old but which has already proved to be successful. This is essentially an abstracting and reporting service of carefully screened marketing literature. We are experimenting with some further efforts of this type in the fields of management, finance, and international operations at the present time.

The work of the Center has not been without its impact on the university itself in terms of stimulating interest in studies of R&D management and in communications systems and communication management, as well as in assisting scientists in their literature searches in various fields. Beyond this, the Center has stimulated interdisciplinary relationships that have not existed heretofore, notably between the Business School and the science departments, and it has become one of the main efforts in adapting to the new patterns of relationships that appear to be developing between the University and the region it serves, particularly with respect to economic growth programs.

THE IMPACT OF SPACE RESEARCH EXPENDITURES ON URBAN AND REGIONAL DEVELOPMENT[1]

Walter Isard and Stanislaw Czamanski
Department of Regional Science
UNIVERSITY OF PENNSYLVANIA

I have been asked to speak on *The Impact of Space Expenditures on Urban and Regional Development.* In a sense, this is a big topic. Of course, space expenditures, as you well know, are impinging on every aspect of our culture, our political, social, economic life, and I can talk for hours (I guess even years) on this subject. Graduate students, at least, have to hear me for three years.

Now we at the University of Pennsylvania, and others, have completed many studies analyzing the impact of major Government programs on heavy iron and steel industries, transportation equipment industries, etc. We have utilized all kinds of methods and techniques for these studies. Although there are several impact models and techniques, each with many variations, I shall confine my attention to these three basic, somewhat overlapping approaches:

1. economic base type analyses
2. simple econometric multiplier models
3. regional input-output techniques.

I shall present certain employment multipliers which are derived from a few variations of the standard economic base technique. Next I shall record employment multipliers implied by several types of simple econometric models. Then I shall set down the employment multipliers obtained from the utilization of input-output tables constructed for the several metropolitan regions. Finally, I shall systematically present the several employment multipliers contained in this paper, observe their similarities and differences, and comment upon how variations in industrial classifications and other statistical procedures and definitions may be said to account for some of these similarities and differences.

THE ECONOMIC BASE APPROACH

First, I would like to describe briefly the economic base model around which an extensive literature has grown. According to one pure theoretical form of this model, all economic activities within a city may be divided into two categories: those which produce goods and services for firms and individuals outside the area of study, and those which produce for firms and individuals within the confines of the city. The first category, covering those activities which bring new money into the community, is called basic or export; the second, which merely recirculates money already in the city, is called nonbasic, nonexport, or service.

Emphasis is placed on basic activities, since the community is considered to be organized around its export industries. As basic activities are considered "city building" activities, the inference is that an increase in basic activities will result in a growth of total economic activity and population, while a decrease in basic activities will result in a decrease of total economic activity and population. The model has been and, as a matter of fact, is still being extensively used throughout the world to forecast long-run urban and regional growth. There have been fewer applications to determine the impact upon the local economy of an important development such as the granting of a new government contract, a cutback in military expenditures, etc.

[1] Adapted from Techniques for Estimating Local and Regional Multiplier Effects of Changes in the Level of Major Governmental Programs (by the authors). Papers, Peace Research Society (International), vol. III, 1965.

In its simplest form the model is

$$E_t = E_b + E_s$$

where

E_t = total employment
E_b = employment in basic functions
E_s = employment in nonbasic, or service functions

Taking the ratio E_s/E_b as constant,

$$E_t = E_b + \frac{E_s}{E_b} \cdot E_b$$

or

$$E_t = \left(1 + \frac{E_s}{E_b}\right) \cdot E_b$$

The model may also be formulated in terms of increments of employment, that is:

$$\Delta E_t = \left(1 + \frac{E_s}{E_b}\right) \cdot \Delta E_b$$

Alternatively one could take either ratio

$$\frac{E_b}{E_s} = \frac{E_b}{E_b + E_s} \text{ or } \frac{E_b}{E_t} = \frac{E_b}{E_b + E_s}$$

as constant and, hence, obtain the multiplier.

A third variant of the economic base model, though slightly more complicated, is for some purposes more convenient. In this variant, the ratio of service employment to total employment is calculated and considered as constant:

$$r = \frac{E_s}{E_t}$$

According to this variant, an increase in basic employment increases total employment and consequently service employment, which is a fixed percentage of total. But the process does not stop here. The service employment represents an increase in total employment, and therefore generates new service employment, and so on. These round-by-round effects may be summarized as follows:

$$E_t = E_b \cdot \frac{1}{1 - r}$$

or

$$E_t = E_b \cdot \frac{1}{1 - \frac{E_s}{E_t}}$$

Many difficulties are inherent in the economic base approach. Among these are:

1. the classification of each activity as either wholly export or wholly service
2. alternatively, the division of any particular activity into that fraction which is either export or service
3. the practical application of the assumption that not only consumption patterns, but also production patterns, are identical when different areas or regions are compared
4. the failure to recognize and incorporate into the model imports as the counterpart of exports
5. the failure to incorporate interregional transfers of funds without a corresponding flow of goods
6. the dependence of the results upon the particular industrial breakdown used
7. use of the average or highly aggregated multiplier for measuring widely differing phenomena
8. the problems of differentiating the interindustry effects from other multiplier effects, such as the "human" multiplier.

Discussion of these and many other problems of application is contained in the relevant literature.

It may be interesting to consider several of the ratios which have been derived in standard economic base studies. These are listed in table I.

In order to facilitate comparison of the several approaches to multiplier analysis, I have constructed table II. The numbers in this table are derived from input-output or tables of a similar type. Each multiplier listed in the last column is a ratio of total employment in the region to employment directly engaged in producing those outputs classified as *exports* in the *final demand* sector for that region.

SIMPLE ECONOMETRIC MODELS

The many deficiencies of the economic base model have been detailed in the previous section and elsewhere. Its major shortcoming is failure to recognize that market considerations are not the most important, and certainly not the only factor which influences entrepreneurs in the choice of locations for new plants. There is a rationale for the development of a model based to a greater extent upon industrial location theory and to a lesser extent upon functional characteristics of cities.

A description of a model with these characteristics

Table I.—Ratios Derived in Economic Base Studies

Author	City	Date	Basic to service ratio	Multiplier $k = \frac{E_t}{E_b}$
New York Regional Plan Association	New York	1944	1:2.2	3.2
Matilla and Thompson *	Chicago	1950	1:1.99	2.99
	Detroit	1950	1:2.16	3.16
	Pittsburgh	1950	1:2.55	3.55
	New York	1950	1:2.91	3.91
	San Francisco	1950	1:2.93	3.93
	Cleveland	1950	1:2.97	3.97
	Boston	1950	1:3.16	4.16
	Los Angeles	1950	1:3.18	4.18
	Baltimore	1950	1:3.35	4.35
	St. Louis	1950	1:3.89	4.89
	Philadelphia	1950	1:4.47	5.47
Federal Reserve Bank of Kansas City	Wichita	1952	1:1.60	2.60
Denver Planning Office	Denver	1953	1:1.53	2.53
California Economic Development Agency	Los Angeles	1961	1:1.80	2.80
Greater Wilmington Development Council	Wilmington	1963	1:1.50	2.50

* Proportion of "surplus" to service workers, calculated by means of the location quotient, Matilla and Thompson: Measurement of the Economic Base of the Metropolitan Area, Land Economics, 31 (1955), 226, Table III.

Table II.—Comparison of Data for Different Approaches to Multiplier Analysis

Area *	E_b Direct export employment, 000 persons	E_t Total employment, 000 persons	Employment multiplier $\frac{E_t}{E_b}$
State of California	973.5	5 066.9	5.21
Los Angeles SMSA	693.5	2 371.2	3.42
San Francisco SMSA	252.5	920.5	3.65
St. Louis SMSA	184.4	673.1	3.65
Kalamazoo County	31.3	58.8	1.88

* SMSA = standard metropolitan statistical area.

has already been published.* This model was developed primarily to deal with long run "urban" growth. Originally it was not designed to measure short-run impact of Government programs, although it is now reformulated for that purpose. I will first mention a number of basic assumptions underlying this model.

The model builds upon the postulate that economic development and population change are interdependent, and hence ought to be statistically explained simultaneously. This approach is a departure from basic-service ratio technique. Its emphasis is on the long run. Now *long run,* both in macro- and in micro-economics, is defined as that period over which plant and capital equipment are in general fully utilized (depreciated); installations are sufficiently obsolete so that they are to be replaced. Under these conditions, growth of economic activity can take place only through new productive investments—or, loosely stated, through new job-creating investments. An increase in economic activity through either fuller use of existing equipment or greater productivity is not considered under this definition.

These new job-creating investments are initiated by individual decisions of entrepreneurs or business executives, whose main objective is assumed to be maximization of profits or returns on invested capital, and not considerations of harmonious development of urban functions. Location factors affecting each investment decision are numerous and heterogeneous. Labor costs, transportation costs on raw materials, and transportation cost on finished product to markets are factors considered important by location theories. But they are just three of many factors, and in a number of cases they are not the most decisive ones. Moreover, within any given type of economic activity, the units carrying out location decisions are dissimilar in

* Czamanski, Stanislaw: A Model of Urban Growth, Papers and Proceedings, the Regional Science Association, 13 (1963). In Press. Czamanski, Stanislaw: A Model of Urban Growth. Unpublished Ph.D. dissertation, University of Pennsylvania, 1963.

their locational sensitivities. The question therefore arises as to whether it is possible, given the complexity of location decisions, to aggregate types and units of economic activities in such a way that we are able to construct a simple urban growth model which yields meaningful results for impact and similar studies.

From a review of elements of industrial location theory, it appears that some factors affecting individual location are tied to the nature and extent of the resource base; that others are dependent upon the presence, size, and character of industrial agglomerations; and that still others are dependent primarily upon urban size and structure. Thus, it seems feasible to explore statistically the following classification of activities.

1. *Geographically oriented industries* (E_g), or industries who main locational factors are geographical. In this group fall extracting industries (resources-oriented), processing industries (industries in which a significant proportion of the labor force is employed in processes dependent directly on raw material inputs), industries depending on such resources as a large supply of good water, transportation centers (ports of entry of the country, railway junctions, main airports of the country, etc.), and large establishments (including Federal and other government facilities) employing more than say 10,000 workers on one site. By definition investments in this category of economic activity are taken to be independent of the size and character of urban development, and of industrial agglomeration.
2. *Complementary industries* (E_c), or industries for which the main locational factor is the presence of other industries. In this category fall all enterprises producing services or goods for a limited number of large industrial customers (E_g) located in the same urban area.
3. *Urban oriented industries* (E_u), or industries for which the existence of the city is the main locational factor. This category comprises services which cannot be transported, industries using female labor otherwise unemployed, the urban pool of skilled labor, and various other facilities. This classification includes many more industries than the limited number of market-oriented activities singled out by some other urban growth models.

To some extent these definitions cut across existing industrial classifications.

The following general model may be constructed:

$$P = a_1 + b_1 E \quad (1)$$

$$E = E_g + E_c + E_u \quad (2)$$

$$E_c = a_2 + b_2 E_g \quad (3)$$

$$E_u = a_3 + b_3 P \quad (4)$$

where

P = population of the region or city,
E = total employment in the region or city, and
E_g, E_c, and E_u = employment in geographically oriented, complementary, and urban oriented industries, respectively.

This model is highly aggregative. Both population and the various employment categories are really used as indexes. Population in particular is simply an index of city size and of the various services and facilities available. To the extent that a small city might provide some or all of the services required by an industry the model is not valid.

The model rests on the assumption that the larger or more populous a city is, the greater the variety and quantity of urban services it can offer. Characteristic differences between cities of the same size class are implicitly assumed to be negligible.

The validity of this model has been tested using data for 232 United States cities divided into four size categories. The following total population estimation equations (implying multipliers) were obtained.

1. Cities with 50 000–100 000 inhabitants,

$$P = 3\,960 + 4.3911 E_g$$

2. Cities with 100 000–300 000 inhabitants,

$$P = 24\,140 + 7.7928 E_g$$

3. Cities with 300 000–800 000 inhabitants,

$$P = 82\,378 + 11.2336 E_g$$

4. Cities with over 800 000 inhabitants,

$$P = 3\,814\,075 + 54.5703 E_g$$

5. All cities with 50 000–800 000 inhabitants,

$$P = -29\,750 + 13.3855 E_g$$

6. All cities examined,

$$P = -2\,467 + 20.5692 E_g$$

In this model employment and population are considered interdependent; both are determined simultaneously. It is also possible to examine separately the employment multiplier effects caused by a unit employment increase in the key industries. This effect can be further subdivided for analytical purposes into that part which is due to the growth of complementary industries alone, and the part which is due to other growth. The results are given in table III.

It should be noted that parameters for cities with populations of 800 000 and above were derived from a very small sample. Hence, this multiplier, as well as the one referring to all cities of more than 50 000 inhabitants must be used with care.

The question arises whether these coefficients are also meaningful on an incremental basis. Do these parameters represent a fair approximation to marginal employment and population multipliers?

A partial answer to this question is provided by another study.* In this study that above model has been reformulated on an incremental basis. The parameters were derived from data on 1947–58 changes in population and employment in a sample covering 49 SMSA's and 137 3-digit industrial categories. Where $E_{g(d)}$ represents employment in that part of the geographically oriented industries (E_g) which are tied closely to government defense and space expenditures, and $E_{g(nd)}$ represents the other part, the following results were obtained:

$$\Delta P = 109\,100 + 2.95658\Delta E$$
$$\Delta E_c = 2\,200 + 0.11726\Delta E_{g(d)} + 0.20613\Delta E_{g(nd)}$$
$$\Delta E_u = 10\,800 + 0.17109\Delta P$$

or in reduced form, after averaging between the research- and defense-oriented industries and geographically oriented industries,

$$\Delta P = 286\,000 + 6.85231\Delta E_g$$
$$\Delta E = 176\,900 + 2.31765\Delta E_g$$

The results are not quite comparable with those derived previously; a different industrial classification was employed, and SMSA's were used rather than cities. The two approaches produced some interesting differences.

The average multiplier due to the "inter-industry" effect (complementary industries) is 0.23119, while the marginal multiplier due to the same effect lies between 0.11726 and 0.20613. Excluding the largest cities (over 800 000) the average employment multiplier is 5.59886, while the marginal multiplier is 2.31765. Similarly, the *average* total population multiplier is 13.3855 while the *marginal* population multiplier is only 6.8523. It will be observed later that the marginal multiplier (via the econometric model) corresponds better than does the average multiplier to the multipliers derived from other types of approaches. Table IV presents some marginal multipliers based on the simple econometric model outlined.

INPUT-OUTPUT

Both the economic base and the simple econometric models already discussed are subject to major deficiencies. They fail to detect the interdependences of the many sectors of the economy, and they are unable to identify impacts upon each of the sectors individually. That is, (1) they disregard the variation in production and distribution characteristics of individual industries in different regions; and (2) they ignore the nature of the interrelationships within these industries and between these industries and

* Effects of Research and Development Expenditures upon Local and Regional Economies, a study carried out in 1963–64 by Stanislaw Czamanski under the direction of Walter Isard for the National Aeronautics and Space Administration.

Table III.—Effects of a Unit Increase in Employment In Geographically Oriented Industries

Size of cities, 000 inhabitants	Number of cities included in regression	Multiplier re: complementary industries alone $\frac{E_c}{E_g}$	Multiplier based on other growth $\frac{E-E_g-E_c}{E_g}$	Total employment multiplier $\frac{E}{E_g}$	Total population multiplier $\frac{P}{E_g}$
50–100	126	0.23119	1.32225	2.55344	4.3911
100–300	70	0.23119	2.20635	3.43754	7.7928
300–800	26	0.23119	3.76552	4.99671	11.2336
over 800	10	0.23119	11.51402	12.74521	54.5703
50–800	222	0.23119	4.36767	5.59886	13.3855
All cities over 50	232	0.23119	7.39663	8.62782	20.5692

Table IV.—Marginal Employment and Population Multipliers for Cities by Geographical Region and Percentage of Manufacturing Employment

	Employment multiplier	Population multiplier
All cities	2.31765	6.85231
Eastern megalopolis plus industrial belt	2.15701	6.32374
West coast region	2.26460	6.66519
Rest of the United States	2.23197	6.93523
Cities with less than 25% of employment in manufacturing	2.36292	6.43047
Cities with 25%–32% of employment in manufacturing	2.50861	7.47136
Cities with more than 32% of employment in manufacturing	2.29860	7.08316

other economic sectors. Hence, there is scope for another technique.

The approach which underscores the inter-industry relations and linkages, and incorporates them into a regional analytic tool is the input-output technique. A detailed description of this method and application to regional impact studies has been published elsewhere.

In order to compare this approach with the other techniques described in this study, I have selected several regional input-output and related models published recently. The five studies proven to be useful for purposes of comparison are listed in table V.

The five studies, prepared at various times for different purposes and for widely different regions, offer little basis for comparison in their original forms. The published tables cannot be compared with one another, and more important, they cannot be related to the other techniques available. Extensive computation was necessary to produce uniform tables for the five regions.

The first three studies—State of California, San Francisco, and Los Angeles—were cast in terms of employment. The latter two studies, St. Louis and Kalamazoo were in terms of dollars. The inverses were published only for the St. Louis and Kalamazoo studies. For a variety of reasons new inverses were prepared for all five studies.

The industrial classifications used in these studies differed in many ways. The California, Los Angeles, and San Francisco studies used 26 industrial categories and 7 sectors of final demand. The St. Louis study had 26 industrial categories and 3 sectors of final demand, while the Kalamazoo study had 34 industrial categories and 3 sectors of final demand. Since the tables for California, Los Angeles, and San Francisco were incorporated in one study, the industry groups utilized in these three tables were identical. These differed, however, from the sectors defined in the St. Louis and Kalamazoo tables.

As a first task, a classification of sectors was developed, such that all five input-output tables could be expressed and recalculated on a comparable basis. A comparison of the different sectors showed that nineteen industrial groups common to all five regions could be developed by aggregating the individual sectors. Each newly defined group was an aggregate of from one to four individual sectors of the five regional studies. In exceptional cases some sectors (particularly in the Kalamazoo study) were split among two or three new sectors.

Next it was necessary to express the St. Louis and Kalamazoo flow tables in terms of employment. For Kalamazoo this was a relatively simple procedure. Using the 1954 Census of Manufacturers data, a weighted employment to sales ratio for each of the 19 sectors was calculated. By multiplication of these ratios by the flow data expressed in dollars, a new flow table was obtained comparable in every important

Table V.—Selected Input-Output and Related Studies

Source	Prepared by	Period	Region
Markets for California Products, by State of California Economic Development Agency, 1961	W. Lee Hansen, R. Thayne Robson, and Charles M. Tiebout	1959	State of California Los Angeles-Long Beach SMSA San Francisco-Oakland SMSA
The Review of Economics and Statistics, Vol. 41, No. 4, Nov. 1959	Werner Z. Hirsch	1955	St. Louis SMSA
The Upjohn Institute for Employment Research, Kalamazoo, Mich., 1960	Harold T. Smith	1954	Kalamazoo

respect to the three adjusted tables for California, Los Angeles, and San Francisco.

Since a flow table was not available for St. Louis, it was necessary to convert the table of technical coefficients into a flow table. This was done by multiplying by total sales as given in the study. Employment to sales ratios were then computed, and these were multiplied by the respective flow data.

The five adjusted flow tables, expressed now in terms of employment, were next converted into tables of technical coefficients, and inverted on an electronic computer. The inverses, namely $(I-E)^{-1}$, were calculated from tables which did not include household consumption and primary inputs.

To facilitate comparisons with multipliers derived by other approaches, an "overall" or "average" multiplier is computed for each region (table VI). This overall or average multiplier is derived by weighting the multiplier of each industry by percentage share of total employment. Aggregating the multipliers of the different industrial categories detracts considerably from the value of an input-output study.

Table VI.—Average Employment Multiplier

(Sectors weighted by employment)

California	1.52036
Los Angeles	1.36579
San Francisco	1.33161
St. Louis	1.34032
Kalamazoo	1.08311

CONCLUSIONS

In bringing this paper to a close, I would like to make a crude comparison of multipliers derived by the several techniques discussed. For this purpose, I have prepared table VII. Column 1 of table VII presents the unadjusted economic base employment multipliers, as given in table II. Column 2 of table VII lists these multipliers after they are adjusted such that investment and government expenditures are treated like exports. Columns 3, 4, and 5 list average multipliers derived from the first multiple econometric model discussed in simple econometric models. The bottom parts of columns 6 and 7 list selected marginal multipliers derived from the same simple econometric

Table VII.—Comparison Between the Values of Various Multipliers

	Economic base *		Simple econometric multipliers					Input-output	
			Average			Marginal			
	Unadj. (1) **	Adj. for invest. & gov't expend. (2) **	Via urban oriented industry $\frac{E_u}{E_g}$ (3) ***	Via complementary industry $\frac{E_c}{E_g}$ (4) **	Total $\frac{E}{E_g}$ (5) **	Via complementary industry (6) ***	Total (7) **	Without household effect (8) **	With household effect (9) **
California	5.21	2.46	4.448	0.076	5.524	------	------	1.52	------
Los Angeles SMSA	3.42	2.14	4.021	0.101	5.123	------	------	1.37	------
San Francisco SMSA	3.65	2.01	5.446	0.105	6.552	------	------	1.33	------
St. Louis SMSA	3.65	2.81	3.814	0.067	4.882	------	------	1.34	2.743
Kalamazoo	1.88	1.33	1.845	0.154	2.999	------	------	1.08	(income multiplier)
New York-Philadelphia study: Isard-Schooler	------	------	------	------	------	------	------	------	2.032
232 Cities: Czamanski	------	------	------	0.23119	5.59886	For 47 SMSA's 0.11726 -- 0.20613	2.31765 --	East-Ind'l Belt West Coast Rest of U.S.	2.15701 2.26460 2.23197

* Isard and Czamanski calculations.
** Figures in these columns *do* include the original unit increase in employment in basic industry
*** Figures in these columns *do not* include the original unit increase in employment in basic industry.

model. Column 8 records the input-output employment multiplier. Column 9 lists multipliers from two input-output studies which incorporated the household income effect.

It now appears that (1) the economic base multiplier after adjustment for investment and government expenditures, (2) the input-output multiplier (inclusive of household-income effect) and (3) the marginal simple econometric multiplier are generally of the same order of magnitude. Except for Kalamazoo, the range of the multipliers is between 2 and 3.

The data for St. Louis in columns 8 and 9 of table VII suggest that inclusion of households within the structural matrix roughly doubles the multiplier effect. Accordingly the multipliers in column 2 (which take into account household income effects) become comparable with the multipliers in columns 8 and 9. Hence, columns 1, 2, 8 and 9 may be said to be roughly comparable. The marginal multipliers in columns 6 and 7 are the same order of magnitude as the input-output multipliers (columns 8 and 9), and so may be said to be comparable with the multipliers in columns 1 and 2 as well.

Finally, for the state of California the multipliers in columns 3, 4, and 5 may be considered comparable to the unadjusted multiplier in column 1. Both employ a more restricted definition of basic industry.

In one sense then, the multipliers on the whole are roughly comparable, certainly more so than appears initially. On the other hand, I must admit that I was not unbiased in my manipulations. As do most social scientists I seek to discover regularities and consistencies for a given theoretical framework. Thus, these numbers may reflect this search and not a real consistency. They are presented for what they are worth.

The second observation concerns the tendency for there to be an increase in the size of the multiplier with increase in size of the region studied. This is more or less true of all three types of multipliers. The effect is most pronounced and at the same time most difficult to explain in the economic base type multipliers. Why should a unit increase in basic employment cause an overall increase in employment of 1.88 in Kalamazoo and 5.21 in California? Or, rejecting Kalamazoo as too small, how can the difference of 1.79 between the Los Angeles SMSA and California be explained?

Clearly, these questions cannot be adequately answered without a thorough discussion of the theory underlying the definitions, models and specific procedures presented above. Such discussion is beyond the scope of this paper. These questions also remind me that all three models examined are essentially mathematical devices. The size of the multiplier effect derived and the justification for the use of one model as against another depends primarily upon the problem at hand, data available, and the time and the resources which the analyst can command.

DISCUSSION

S. W. Herwald
Arthur M. Weimer
Walter Isard

QUESTION: I have a question for Dr. Herwald. When you get the satellite up in the air circling the Earth and you collect the energy from the Sun, what is your means of transporting the energy to the Earth? Will it be by radiation, will it be direct, or will it be transposed into another form of energy?

HERWALD: I had not realized I said anything about a satellite, but if you want to call it a satellite, that is good. The scheme that we looked at is, either fortunately or unfortunately, the only one that we understand—to transmit a microwave link back. The economics of this look like an order of magnitude out right now. The other one was just rebeaming the energy, not trying to do the power conversion up there, but just capturing some more and deliberately putting the station in a place open most of the time. This does not look either immediately possible or unattractive, but if it can be rebeamed with a sufficiently large area, I think some of the conversion can be done on the ground where it might be easier.

QUESTION: M. G. Cooper, from Air University. First of all, Dr. Herwald, if you are going to raise the temperature level in the Antarctic, you are going to melt some water. If you melt water, New York, New Orleans, Mobile—particularly Mobile—are going to find water they were not wanting, and at a high level. I am sure you have an answer! And, secondly, when we speak of surveillance from space for agricultural purposes, such as forest count or areas of high vegetation, this sort of thing. Surveillance also means you're going to overfly property of someone who doesn't want to be overflown. Again, maybe your international cooperation is going to take care of this, but would you enlarge on those two very exciting areas?

HERWALD: Let me answer the first question because it is subject to engineering analysis, at least in gross form. In projecting the desalinization program that is required to get water for people—again it comes back to the people program—a big problem is that unless the water is, in effect, reprocessed and returned to where it was before, which we are not doing currently, the water levels will be lowered in a lot of areas. You went way further than I had contemplated, for the real truth is that we would be lucky if we could melt enough ice and snow to make up for the water that we are now diverting for other uses. The problem is to keep the levels from going down rather than to prevent their coming up to take out Mobile. I think that if we had such a process in effect and under control, the international implications would be tremendous. I noticed that you mentioned only the areas close to home—I am sure that the Dutch would be very unhappy—so it is really a tough problem. I used the Arctic as an example because it has so much water stored and visible. I think that far more important, if we really can direct some of this power, would be to try to get the temperature raised in some of the areas where there is an abundance of rainfall—for instance, on the western slope in Seattle and Oregon—to try to put it down in other areas that might then become agriculturally desirable. Now that has implications of the people in—never mind the international aspects—but the people in Washington and Oregon might not like that experiment.

Now the second question! I am sure that anything we talk about doing in space, sometime in the future, must have international cooperation or it will not occur, because sometime soon—maybe in the next ten years or less—if some government does not like a satellite that is overflying its territory it is going to take down that satellite. So anything I have said is premised on the fact that what is overflying a territory is there because people feel it is to their advantage to have it there.

QUESTION: John Conover, from the Air Force. We have talked a good deal about the several prognostications that have been made about the population growth to the year 2000. Have any prognostications been made as to the funds available for space research, exploration, and utilization, say in the year 2000? Will we be fund limited or will technology provide the region for growth to make these things possible?

HERWALD: In a gross sense, that one is strictly, again, a people question, because when we say fund limited, we are really talking about effort limited. It really means that Congress, the President, or some other authority decides how much of the Nation's energy is to be put into a particular project. Now, that is not limited except by people choice, so when we get it in terms of dollars—we sometimes lose sight of the fact that dollars can only pay for effort. The effort is not limited; it is the choice of the people in limiting how much is to be applied, and I surely would hate to have to tell whether or not we are going to be effort limited in that period.

ISARD: Well, I could make one or two comments. It seems to me that there is a wide range of possible levels of expenditures, space expenditures. Not only is there the range that is possible in terms of Federal Government sponsorship, but as new industries become creative and, in turn, become more research and development oriented, they, in turn, will allot more and more funds for research investment purposes. So it does not seem inconceivable that as much as 10 percent of our gross national product in the year 2000 might be devoted to space and allied research. What is our current GNP? Well, let us say it might be a trillion dollars, even more than a trillion. In other words, I could see that a hundred billion dollars might easily be expended by both Federal Government and industry in this area.

QUESTION: The title of your paper, Dr. Herwald, is "Industrial Opportunity." We were just talking about this $100 billion. From an industrial opportunity point of view, would you predict that the majority of this $100 billion might come from industry, or do you consider this more nearly a Government responsibility and, therefore, the major dollars might have to come from Government sources?

HERWALD: If any of the things that I speculated on really happen, they will happen because it is more economical to do things that way rather than doing them some other way. I think I agree with what was said here, that if space is really useful to the people—forget about the industry, but useful to the people—the economics is going to be such that there will be ordinary plowback of industrial R&D of the type that was mentioned, I think, in a far greater amount than if space has only limited surveillance usage or maybe transport use. I think that if it is strictly for reconnaissance as such, whether it is military or nonmilitary, the dollars will come mainly from the Government to make sure that we are pursuing it diligently enough, to make sure we are not missing a future bet. The thing I cannot tell you is the time scale of how many years it's going to take to where it's worth something. But once you get to that point, I think it's going to be more of a pay-as-you-go kind of thing in which the dollars are going to be plowed back because it's economic to do it and make it far more useful to people. Now, to guess whether the hundred billion in 2000, I wouldn't be surprised that a good guess is maybe 50-50.

QUESTION: On the split of the hundred billion that you—

ISARD: I think you see already Dean Weimer has told me my figures are really conservative. I gather that our estimated GNP in the year 2010 will be around $3 trillion. So that when we speak of a hundred billion at 3 percent, we are being much too conservative. Even if that were just the Federal share of it, I think one might think more in terms of $300 billion from the United States alone, keeping in mind that the Soviet economy is coming along very rapidly as are other economies in the Western Common Market area. In terms of the world, that could be easily doubled to something like $600 billion of today's GNP. Well, we need to be very imaginative!

QUESTION: Well, my main point was that I do not think any of us are really skilled in getting the feel of what is going to happen in the future.

ISARD: This points out the reason for these so-called long-run multipliers that I have been talking about. I am sure some of you must react to these as too large, but they should actually be larger than the ones I mentioned.

QUESTION: I am Henry Wells, with the Air Force. One thing that has intrigued me about space is the possibility of developing a phenomenon, a force, or a concept of some sort which would tend to negate the value of combat. Do you foresee any breakthrough in space technology beyond the nuclear warfare techniques which we now maintain for worldwide peace?

HERWALD: That is an interesting question because I do not consider it a technical question. It is a philosophical one of how to explain how one individual can persuade one group of people into thinking something is true while another individual can persuade another group of people to think that something almost 180 degrees from that is true. I am not sure that it makes any real difference whether we are discussing nuclear weapons, old-time bombs, or bows and arrows. The problem is strictly one of how far we have advanced in the nontechnical areas, in getting people to decide whether knocking each other out is the best way to settle their differences. Sure space can help! I believe that on an international scale we have the best automatic policing system, if we want to use it, that we have ever had. This would go far if people want a police system, but if they do not want one, what can we do about it?

As I have said, anything that is associated with really universal use of space must eventually rest on whether at least a high percentage of the people sitting on the world at that particular time decide it is more to their advantage to use it than not to use it. Any government that thinks that anything maneuverable is offensive is going to try to find a way of taking it out of the sky. If, on the other hand, it seems to be advantageous, the government concerned will try to keep it there, to make it better, and to have it serve more purposes.

WEIMER: This is a second-hand comment in a way. Professor Boulding at the University of Michigan groups such relationships between people or groups of people in three broad levels. One he calls the threat system which is, "You do something nice for me or I'll do something nasty to you." This is the essential level of international relations at the present time. The second area is the mutual benefit area which is essentially our trade, our enterprise system, and this is characterized by, "You do something nice for me, and I'll do something nice for you." The third, in part, is what he calls the integrative system which is not so easy to characterize, but which includes the broad range of historical development, customs, institutions, status relationships, ego relationships and the like, that grow very gradually. Probably our hopes are in the last two. We are making some real gains in the second one. The third one is slower, and I would, therefore, be a little less optimistic that this will be achieved soon, but I think we are making progress.

QUESTION: I am Vogel of the Austin Company. Dr. Herwald, your interesting projections into the future seemed to outline one other area—that we are going to be accumulating data at an ever increasing rate, making Dr. Isard's factor seem very small. Probably we will have the computers and the electronic equipment to analyze these data. How would you think humanity might, being limited as it is, find the means to interpret all of these data that will be collected?

HERWALD: That is a real good question, because we have it right now. There is great difficulty right now in the business world, for example, in absorbing the data that come out of these confounded machines that are supposed to help us. And there are a lot of people looking at the problem of how to do the screening of that which is significant. In other words, what most people looking at data really want to know is how these data differ from what was expected? The thing that overwhelms them is that they have to look through reams and reams and reams of data to find anything useful. There are a lot of people working today on programming what I would call the exception rule that everybody operates on. In other words, when one scans by eye or does anything else, he normally stops it on something that attracts his attention because it is what he is looking for. We will have to develop some kind of sequence of doing this, a sequence which automatically takes these reams and reams and reams of data and only flags our attention to that which it thinks is of interest to us. I think there will be a lot of progress in that area in the not-too-distant future, mainly because we are already in that state of affairs.

QUESTION: Dr. Herwald, granting the possibility, as you said, of reflecting excessive heat on polar regions, is the converse possible? Could we deflect heat? I am thinking particularly of the large arid, overheated areas in South America and, possibly, Africa, where deflecting heat might open up a large agricultural area. Also, would it be possible to move those cloud formations westward as well as eastward? I am also thinking of the large arid coastal lines of Peru and Chile.

HERWALD: I wish I were good enough to answer those questions because I had a lot of trouble putting myself in a position of even speculating that it could be done one way where I knew where the source was coming from. As an individual, I do not see how heat can be reflected back with any great ease. This does not mean it cannot be done, by a long shot. It is just that I do not happen to see it. I think that the areas of the clouds are the ones that have the most interesting long-term possibilities, if we can put small amounts of energy in them. My weather friends tell me that the energy balancing kind of things are subject to working on with relatively small amounts of differential energy. So I would really offer more hope in that area maybe, that you can do something, than the other. Again, developments are highly dependent on people. People have as an inalienable right established over generations that anybody who wants to change the laws of nature around them is subject to, as a bare minimum, civil suit.

QUESTION: My question is for Dr. Herwald. Could you please cite some figures on the water loss you mentioned throughout the world and, also, tell where the water is going.

HERWALD: It is not a loss. I hope I did not leave that impression. The gross amount of water inside the envelope stays the same, but in places like southern California, for example, just the amount that is being pumped out for irrigation is dropping the water table, and that is a redistribution of the water. As a matter of fact, the last survey I saw indicated that for quite a while in the U.S., which is one of the more fortunate countries, the amount of water that comes down is more than that which we use, but it is in the wrong place. We need the distribution water table change in localities. Certain specific areas have a problem in the distribution of water. The total envelope stays the same unless there is some escaping out of the Earth's atmosphere that I do not know about.

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SPACE COMMUNICATION
(Luncheon Meeting)

Chairman
James S. McDonnell
Chairman of the Board
MCDONNELL AIRCRAFT CORPORATION
MC DONNELL AIRCRAFT CORPORATION

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SPACE COMMUNICATION—ITS IMPLICATIONS FOR PEACE

Stuart Symington
Senator from Missouri
U.S. SENATE

From the standpoint of hardware production for exploring space—this new ocean—St. Louis is preeminent. Two hundred years ago Pierre Laclede Liguest, French fur trader, established his post here on the banks of the Mississippi. That action could be considered the free enterprise of space exploration of those early days.

Being traders, supported by missionaries, these good people then, too, were vitally interested in the promotion of peace. They knew also that it could determine their future. The space in question was the vast uncivilized areas west of the Mississippi, starting from this new trading post which became the City of St. Louis.

Canoes have been replaced by barges, railroads, airlines, and now the space capsule, which was made in our town, and of which we are all so proud. As Laclede stood under the stars waiting for the first of the fur-laden canoes to glide down the river, he could have known nothing of these planes or capsules, of an urban area of some 1 500 000 people, of the industry and commerce that would be involved therein.

But he did know that his trading post would bring others, that the land would be cleared, that a town would grow. He must have believed also that the great wilderness would eventually be conquered, and that peace, and a rule of law, would come to the land.

So we, too, today believe—indeed, we know—that our relatively simple beginnings in space will lead to developments vitally important to the future of mankind; and these developments will occur in much less than 200 years. As an example, the dean of the electronics industry in this country, David Sarnoff, with whom I served on the Board of the Radio Manufacturers Association nearly 40 years ago, recently stated:

> The time will also come when an individual carrying a vest-pocket transmitter-receiver will connect by radio to a nearby switchboard linked to communications satellites and be able to see and speak with any similarly equipped individual anywhere in the world. Each instrument will have a decoding unit, responsive to only one of a billion or more arrangements of pulses, similar to today's personal telephone number. In the higher frequencies of the radio spectrum, and in controlled light beams, the channels available for such personal communications will run into billions.

Because of the telescoping of time and space during the past 20 years it became clear that the full fruition of this communications revolution could be attained only through further concentration and centralization, in private business as well as in Government.

Accordingly, on February 7, 1962, President Kennedy sent a proposal to the Congress recommending the establishment of a privately owned communications satellite corporation. At that time the President stated,

> The actual operation of a communications system would provide a dramatic demonstration of our leadership in the area of space activity, as well as our intention to share the benefits of space for peaceful use, and the ability of our Nation and its economic and political system to keep pace with a changing and complex world.

Three years later, on May 2, 1965, television viewers in this country, Canada, Mexico, and many of the countries of Europe simultaneously saw in their own homes, the inaugural program of the Early Bird satellite. This latest satellite will soon be used for routine telephone calls across the Atlantic Ocean, this development, in turn, a result of the "Communications Satellite Act of 1962," an Act which authorized the first commercial use of space. This 1962 Act was in part possible because of the long history of private enterprise in the communications field.

Communications in one form or another is as old as the recorded history of mankind. The era of dynamic international communications, however, waited until August of 1858, when the first international telegraph cable went into service across the Atlantic. Queen Victoria sent her congratulations to President Buchanan, who cabled a greeting in return.

That first cable did not last long. Eight years later, however, one finally became successful, and the two continents were linked together in message communications.

On December 12, 1901, there arrived the first telegraph message by radio across the Atlantic. Before that, in 1892, the first long-distance telephone call was made, from New York to Chicago; and in 1956, service began over the first trans-Atlantic telephone cable.

One year later all the world was startled by the successful orbiting of the first Sputnik. That achievement changed forever many previously held tenets, including all known plans and programs for national defense, along with former concepts of communications development.

A year after Sputnik I, a talking Atlas missile brought the President's Christmas message. Four years later the Congress authorized a corporation to exploit communications satellites, and during that same year the Telstar satellite demonstrated the potential of satellites in international communication. Telstar was followed in rapid succession by the Relay and Syncom satellites.

Against this background of rapidly moving technology the established communications corporations had been considering a private venture in space communications. The Government desired, however, that this new technology be used not only for private progress and profits, but also as an instrument which would increase the chances for permanent world peace through better international understanding. The Government knew also that the Department of Defense was very anxious to develop a communications satellite system in recognition of its own changing needs.

In order to consider all these factors, the 87th Congress thereupon held extensive hearings related to a Satellite Act. I served with interest on the Committee that held the hearings.

We gave all interested parties an opportunity to present their comments; and the Act, as finally drafted, represented a unique charter designed to promote private enterprise in space. It declared that *the policy of the United States was to establish*, in cooperation with other countries, a commercial communications satellite system.

It is of great significance that, to date, the Satellite Corporation has closed agreements with 45 nations. Through joint ownership, and joint use, of this new technology there will be an unprecedented exchange of information and ideas among scores of nations. We would hope that some day this would be true of all nations.

Already there have been international satellite discussions carried on by recognized world figures. These leaders of many nations spoke directly into the homes of millions. Live telecasts of such discussions and of news events, sports, and cultural functions, will become an everyday occurrence.

Despite this tremendous step forward, however, we are still only pioneering in space, just a little beyond the "trading post" era of this vast new wilderness. But we hope that, in concert with our international partners, we will be able to look back to the fact that these communications satellites furnished a significant contribution to international understanding, and therefore were a major contribution to world peace.

It is all moving rapidly; in fact, by 1967, a fully global system will be available. Then the world will be linked together by means of a communications capability unprecedented in the history of mankind; and we have stated to all that it shall be our policy to make this new capability available for the benefit of all.

Our Country, and other nations who believe in freedom, are now engaged in a world-wide struggle for the minds and hearts of the people of all countries. This space communications system will be important to that end because, in the final analysis, peace among the nations of the world will depend on mutual interest and understanding. Better international communications are bound to contribute to that understanding.

Three hundred years ago, in 1665, John Milton stated our present hopes well when he said in his most famous poem:

> Good, the more communicated,
> the more abundant grows.

SPACE RESEARCH IMPACT ON SCIENCE AND EDUCATION

Chairman
George E. Pake
Provost
WASHINGTON UNIVERSITY

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TODAY'S RESEARCH SETS TOMORROW'S CAPABILITIES IN SPACE

Raymond L. Bisplinghoff
Associate Administrator for Advanced Research and Technology
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

In a conference on the peaceful uses of space, some portion of our time can be profitably devoted to reviewing the technical imponderables with which we will be faced in the future in exploring space. This is my assignment and the purpose of this paper.

I would commence by admitting that there are many perils in prophesying our future capabilities in space. Engineers and scientists have not often distinguished themselves as prophets. There is a general tendency on their part to overestimate the near term and grossly underestimate the long term. On the other hand, a good research director should be capable of reasonably accurate short-term predictions of new developments since today's research must be keyed to these developments.

Mankind has entered an era when science and technology can do a vast multitude of things, many of which society may not necessarily wish to do for social, economic, or political reasons. Scientists and engineers are, therefore, fitted only to prophesy options for the future. Other important judgments must be made as to which of the many technological options available will, in fact, be chosen.

A pattern for progress in space is one of providing options for future space exploration through advanced research and technology, on the one hand, and of later selecting and applying those which appear promising, on the other. Through such a pattern, rapid progress has been shown to be possible. Without such options, progress virtually stops. For example, the technology of hydrogen-oxygen propulsion was developed by the Lewis Laboratory of the NACA in the early 1950's and thus provided an option a decade later for cryogenic upper stages of launch vehicles in the Nation's space program.

My remarks, with respect to space technological options, are really nothing more than an extension of what we have known for many years about scientific knowledge. This was once succinctly stated by Dr. Lee A. DuBridge, President, California Institute of Technology, when he said, "We have never been able to predict in advance what the usefulness would be of new knowledge about the nature of the physical universe. All we know is that, by and large, new knowledge always has proved useful—and often it has proved useful in the most unexpected and unforeseeable ways."

Progress in space capability has been rapid. Our first satellite weighed 30.8 pounds. In the Saturn development program, the weight in orbit has already been increased over a thousand times or three orders of magnitude. The development of Saturn V will increase this another order of magnitude; and with the Apollo spacecraft, giving us the capability of placing 45 tons in lunar orbit, will permit space operations to the surface of the Moon. Today, an instrumented probe, Mariner IV, is on its way to Mars. Beyond these, we can imagine permanent orbiting laboratories, exploration of the Moon, manned voyages to the surface of near planets, stations or observatories out of the ecliptic plane, and probes to the Sun and deep space.

The technological innovations needed to achieve these ends are principally in the areas of very light structures and equipment; efficient conversion of solar, chemical, and nuclear energy for propulsion and electric power generation; accurate guidance, controls, and communications; and reliable operation for long periods of time in the space environment.

The drive for very light structures has led to intense work on new materials. Man's progress has always been linked closely with materials, but nowhere are materials more important than in space flight, where every pound added escalates into a large burden for the propulsion system. We seek lightweight materials that can withstand temperatures as low as —420° F, that must contain gases as hot as 10 000° F, and that will stand up under the stresses imposed by the rigors of flight.

Fundamental understanding of such properties as mechanical strength, ductility, and fracture are only now envolving. As we increase our knowledge of the forces bonding nuclei together and holding electrons in their allotted position, it will be possible to reassemble these basic units into new materials that are beyond our ability to imagine. Flight technology has required materials with greater resistance to heat. The step to the planets is exceptionally difficult because the high return entry speeds will heat materials beyond their working limit and, in some cases, beyond the melting temperature of our common alloys. What is more, these applications require materials that will retain their mechanical properties for thousands of hours, that will not burn or oxidize, that are compatible with new chemicals, and that are stable in the vacuum and radiation of space, and resistant to micrometeoroids.

You may be interested in a summary of our progress during the past year in improving the temperature capabilities of materials. Each of the bars shown by figure 1 represents the improvement that we have made through research during the year.

The lowest bar of the chart, for example, shows the improvement in the thermal stability of polymer films. Teflon is a familiar example of a polymer which is an organic compound with a very high molecular weight. We are interested in polymers for space applications such as lightweight flexible structures and electrical insulation. Thermal stability is an important property of polymers for there is a temperature limit beyond which they decompose. We have succeeded during the past year, at our Langley Research Center, in expanding the limit of their usefulness from 750° F to about 1100° F, as

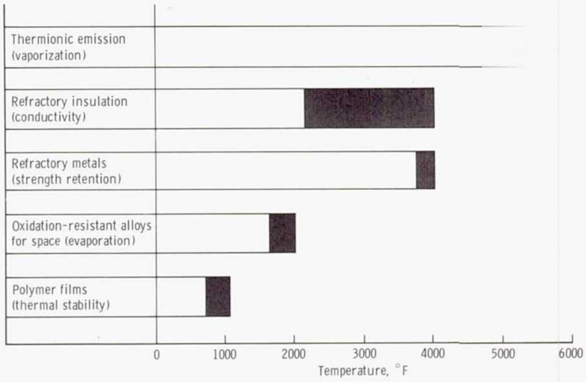

FIGURE 1.—*Improvement in temperature capabilities of materials. Shaded areas represent improvement made in year.*

illustrated by the shaded region of the lowest bar.

Oxidation-resistant alloys such as those of nickel or cobalt (for example, Inconel) are attractive for use on our spacecraft at moderately high temperatures. Progress in this area is illustrated by the second bar from the bottom of the chart. Through basic studies on the rate of loss by evaporation of certain strengthening components of the alloy, we have succeeded in substituting more effective elements. These new alloys do not vaporize as readily but provide equal strength, thus allowing us to increase the upper temperature limit at which they may be used from 1700° F to 2050° F.

The remaining three bars illustrate corresponding improvements in other high-temperature properties of refractory materials.

A key area of technology in space flight is that of entry into the Earth's atmosphere, and landing at a desired location. The successful accomplishment of this phase of flight stretches the boundaries of our knowledge in aerodynamics, gas dynamics, heat transfer, and materials. The speed, angle of entry, and shape of the reentry vehicle are critical factors. If the entry angle is too low and speed very high, the spacecraft is not slowed sufficiently by frictional drag of the atmosphere and it will continue on past the Earth into space. If the entry angle is too high and the speed high, the spacecraft penetrates the atmosphere too rapidly and the friction and heat generated will melt the spacecraft. The problem is to slow down without excessive heating. Entry speeds from Earth orbit are on the order of 25 000 feet per second; from lunar missions, about 35 000 feet per second; and from planetary missions, 40 000 to 70 000 feet per second.

Figure 2 portrays the three principal areas of reentry research that we are engaged in today at the Ames, Langley, and Flight Research Centers; namely, configuration studies, heat transfer, and structures and materials.

In configuration studies, the blunt body used for the Mercury, Gemini, and Apollo spacecraft was first postulated by Allen and Eggers of the Ames Research Center on the basis of work done by universities and Government laboratories. Our work has progressed to the other shapes shown, including "lifting bodies" that can land in the manner of an airplane once safe reentry is accomplished. Figure 3 shows the landing area or "footprint" as a function of hypersonic lift-drag ratio (L/D) of a lifting reentry vehicle. If L/D is 1 or more, the landing area is considerable. A light plywood lifting reentry vehicle was built for landing tests. It is towed aloft and the pilot glides back for a landing at about 60 to 80 knots. Numerous tests have proven the landing feasibility of this configuration.

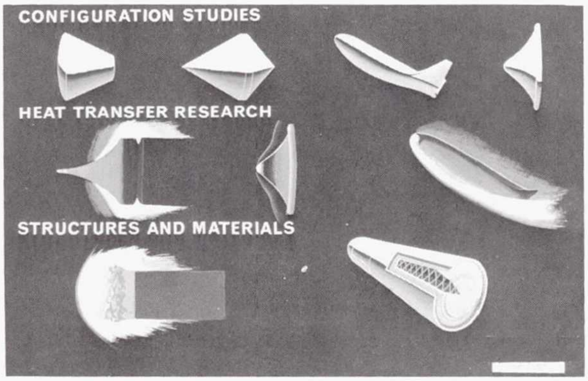

FIGURE 2.—*NASA reentry research.*

As shown in figure 2, the heat transfer of reentry bodies involves shape and velocity of the body, density and composition of the atmosphere, and the transport and other properties of the gases at high temperatures. The figure shows two shapes as they would appear under test in hypersonic wind tunnels.

Materials and structures for reentry must provide strength, resist the intense heat, and insulate the interior of the structure from the heat. The figure

FIGURE 3.—*Range capability in relation to hypersonic lift-drag ratio.*

illustrates an ablative material that chars on heating for the forward section and a typical reentry structure.

There is a strong interplay between aerodynamics that produce heat and the properties of the material of which the reentry vehicle is made. Some materials become so hot that radiation will greatly augment the convective transport heating. For example, ablating material made of polycarbonate will cause heating several times as great as will material made of polyethyline.

Because of the importance of radiative heating at reentry speeds greater than 25 000 feet per second, there is now a strong suggestion that slender-nosed bodies rather than blunt-nosed configurations may be the proper design for reentry at these excessive speeds.

For some time there have existed strong Government-university-industry teams in the program on reentry technology led by the Ames, Langley, and Flight Research Centers. At the present time, 8 different companies and 11 universities are involved. This work is providing the technology needed for our next step in manned space flight capability.

The state of technology in every age has depended on man's ability to convert and to control energy. The intensive development in chemical propulsion in the last 10 years has given us the power needed to carry useful payloads into space. Chemical propulsion will continue to play a large role in the missions of the future. We visualize it as the best method for lifting payloads into Earth orbit and for landing and departing from extraterrestrial surfaces.

Last year a complete rocket engine using hydrogen and fluorine was successfully tested for the first time by the Pratt & Whitney Aircraft Division of the United Aircraft Corporation. This work marks the culmination of over 15 years of experimentation by universities, Government laboratories, and industry using fluorine as the oxidizer. Hydrogen and fluorine offer considerable promise as a high-energy propellant combination for missions requiring very high velocities such as solar probes.

The tests were made using the modified RL-10 engine designed for hydrogen and oxygen, shown in figure 4. This use of existing hardware represented a substantial savings over the cost required if special test equipment were built. In all, 13 tests totaling 600 sec were made with two engines over a range of test conditions.

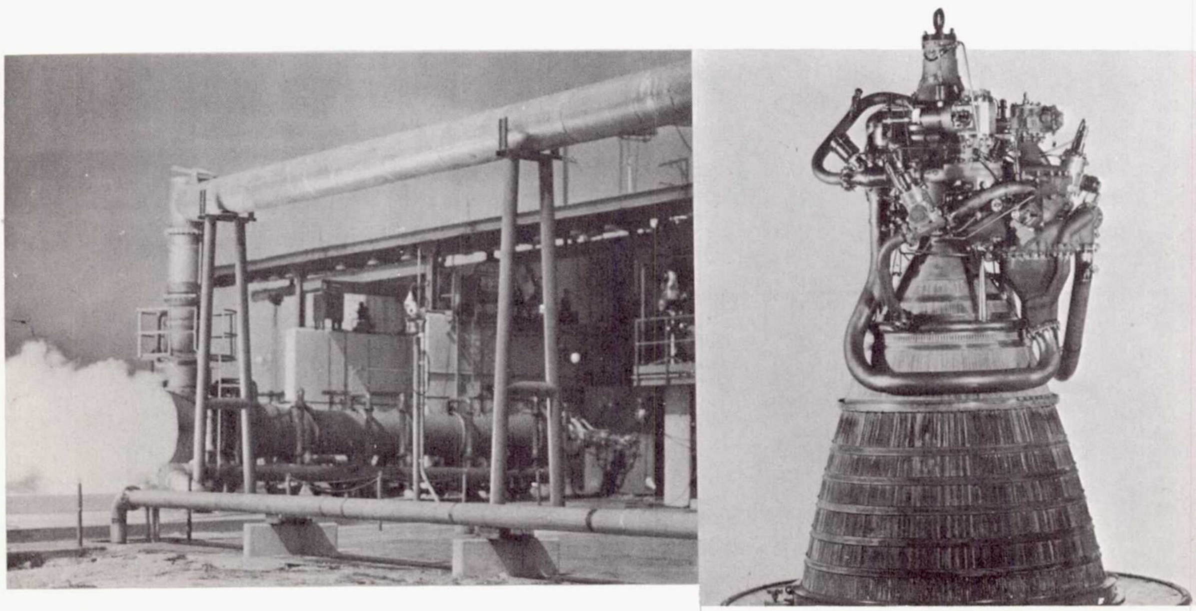

FIGURE 4.—*Hydrogen-fluorine engine tests.*

a. Engine firing. 13 tests on two engines. 600-sec operation. 92–96% theoretical performance.

b. Engine after 227-sec operation. Thrust: 15 000–20 000 lb. Pressure: 300–400 psia. Mixture ratio: 4–12.

In addition to our interest in more energetic chemical propellants, we are studying a whole new class of propellants that are more storable in space than oxygen and hydrogen. These propellants will allow us to operate chemical propellants after months of space voyaging such as a landing or takeoff from Mars. Oxygen-fluorine mixtures used with light hydrocarbons or diborane are examples of propellants in this class.

We foresee the need for much larger launch vehicles than the Saturn V if we are some day to mount a manned expedition to Mars. We have technical work under way on advanced high-pressure chemical engines for this purpose. We are also working on new combustion-chamber shapes and new nozzle concepts to develop the technology needed for launch vehicles with thrusts of 20 million pounds or more.

We believe that chemical propulsion has reached maturity as a propulsion system. The additional work needed is in the nature of increasing efficiency; reducing weight and size; increasing operating versatility, reliability, and life; and reducing cost.

The next step increase in rocket performance will come about through the use of nuclear energy. It has been only 23 years since Fermi and his group of scientists and engineers produced the first self-sustained chain reaction in a nuclear reactor. Today we see the beneficial effects of this energy source in the fields of medicine, agriculture, electric power generation, and underwater propulsion.

We are hard at work harnessing nuclear energy for propulsion and electric power generation in space in cooperation with the Atomic Energy Commission. Nuclear propulsion, employing a solid core reactor, is twice as energetic as the best chemical propulsion. In advanced forms employing solid or gaseous core reactors, nuclear rockets are three to five times as energetic as the best chemical propulsion.

Nuclear rockets are potentially useful for flight beyond the Earth's atmosphere including advanced lunar missions, manned planetary missions, and unmanned probes to the far planets or close proximity to the Sun. As previously mentioned, we look to nuclear propulsion as the most feasible means for manned landing on Mars if and when this becomes a national goal.

Last year there were successful tests at high power and temperature of three reactors in the nuclear rocket program. These were accomplished by the joint efforts of the Los Alamos Scientific Laboratory, the Aerojet-General Corporation, and the Westinghouse Electric Corporation. They developed a thrust as high as 57 000 pounds and a specific impulse as high as 765 seconds. These tests constitute a major milestone in nuclear technology in that they demonstrated for the first time that nuclear rockets can deliver the high performance that has been predicted for them. Figure 5 shows one of these reactors that was successfully tested.

The reactor tests were made at the 1000 megawatt level. Our mission studies indicate that a 5000 megawatt reactor size would be very useful as a propulsion module for future missions. Preliminary designs of this larger reactor have been completed. We will approach this reactor development in two steps: first by testing for increased performance with 1000-megawatt-size hardware, and then by testing with the larger reactor at 5000 megawatts.

Parallel to reactor development is work at the Lewis Research Center on critical nonnuclear components such as the nozzle, turbopump, and controls, and the integration of these components into a working rocket system. The nozzle design for cooling, for example, must cope with temperatures in the range of 4000° to 5000° F while the liquid hydrogen entering the cooling passages will be 400° below zero.

In addition to graphite core reactors, work is under

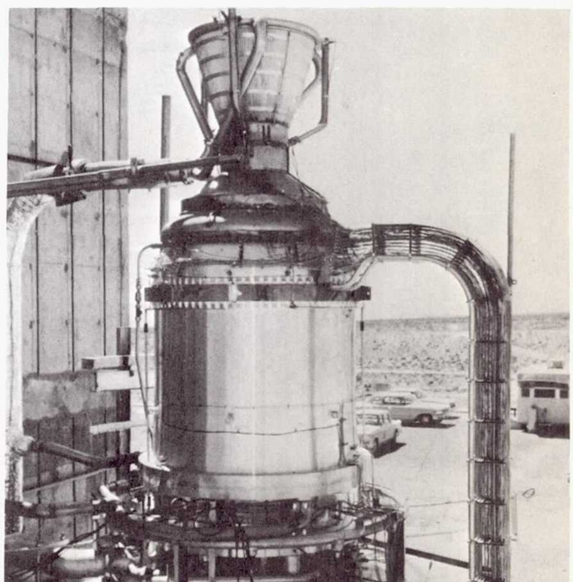

FIGURE 5.—*KIWI-B4E reactor test at Test Cell C.*

way, at a modest level, on a reactor where tungsten is used as a uranium-bearing material. A tungsten reactor has advantages of flexibility of reuse, long operating life, and light weight.

Beyond solid core reactors on the energy scale are reactors that use such ideas as dust beds, liquid core reactors, and gaseous core reactors. These seek to get around material limitations and use higher temperatures to produce more thrust per pound of propellant consumed. The gas core reactor, for example, maintains the fissionable material in gaseous form so the hydrogen working gas can be heated by it to temperatures above the melting point of solid materials. This concept has many problems, however. We must learn how to sustain a chain reaction with the nuclear fuel vapor, transfer heat from the nuclear fuel vapor to the hydrogen, and exhaust the hydrogen without losing the nuclear fuel. These are very formidable problems but our scientists and engineers thrive on challenges such as these.

There is another group of advanced propulsion systems that are of interest in specialized applications. These are the electric types where the electrical power comes from either solar energy (for small systems) or nuclear electric power (for large systems). Three types of thrustors—electrothermal, electrostatic, and electromagnetic—have promise and are being studied. These propulsion units are characterized by small thrusts—as low as a few millionths of a pound to as high as perhaps 100 pounds. They are extremely efficient and energetic—from 3 to 30 times as efficient as the best chemical systems. They are relatively heavy, however, so acceleration is very low. They appear ideal for attitude- and station-keeping functions where small thrusts for long periods are needed. They also appear very attractive with and without nuclear rockets for solar and deep-space probes and planetary missions where time is not at a premium and where very low acceleration for long periods is acceptable.

In our electric propulsion program, 1964 saw the resolution of a basic uncertainty over the feasibility of ion propulsion for space applications. In the SERT I (Space Electric Rocket Test) flight launched from Wallops Island on July 20, 1964, the United States conducted the first successful flight test of an ion engine. Figure 6 illustrates the SERT I spacecraft.

During this flight, an ion engine was operated with and without electrons injected into the exhaust stream to determine whether or not the electrical charge

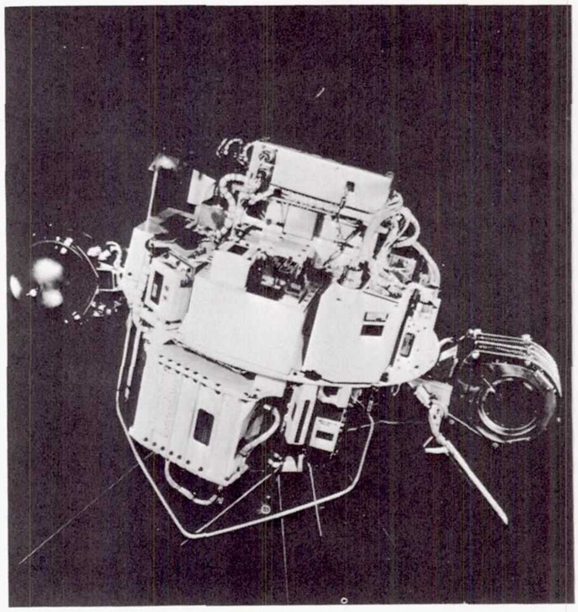

FIGURE 6.—*SERT I spacecraft in free-flight configuration.*

in the exhaust could be neutralized. This question could not be resolved by ground tests because of the unknown influence of the test chamber walls on the results. The flight conclusively demonstrated that neutralization can be achieved in space and further demonstrated that the performance of an electric engine in space can be closely correlated with the data obtained from ground tests.

All space vehicles require electrical power for the operation of communications, guidance and controls, measurements and data processing, and life-support systems. I have already mentioned the need for electrical power for the electric propulsion systems. We are working on electric power generation using chemical, solar, and nuclear energy sources. Each has application in our program. Chemical sources such as batteries and fuel cells are used for energy storage and power for relatively short use periods. Solar power, as exemplified by the familiar solar cell, is best in the Venus-Earth-Mars environment.

When one travels closer to the Sun, from the Earth to beyond Venus, the power energy decreases because of the low performance of solar cells as the temperature increases. Such materials as gallium arsenide and gallium phosphide are being investigated for use in advanced solar cells to withstand higher temperatures.

Going away from the Sun beyond Mars, the solar energy is drastically diminished and one naturally turns to nuclear devices for power sources at these extreme distances. In nuclear systems, for example, we have succeeded in demonstrating by tests in 1964 the ability of the SNAP-8 system to deliver its predicted performance. The SNAP-8 project has been aimed both at establishing the development technology for high-power nuclear-electric systems such as ion propulsion and at providing a specific device capable of delivering 35 kilowatts of auxiliary electrical power for thousands of hours in space. During the past year, various components in this complex electric system were built and tested. These components ran together in a loop for approximately 100 hours before the test was halted to permit inspection of parts.

Along with materials and structures and energy conversion, the art of measuring or sensing and then using the data obtained to control the flow of energy has evolved as a key technology area for space exploration. Precise pointing and attitude requirements are fundamental to improved capabilities in space. For example, the gain-bandwidth efficiency of a synchronous communications satellite is directly affected by the accuracy with which the antenna can be pointed. Although vernier-controlled small propulsion devices are essential to high pointing accuracy, the most critical element is the sensing device itself which provides the attitude reference.

The accuracy required of these devices must be about an order of magnitude greater than that of the overall stabilized system. Sensors for pointing accuracies from 1 to 0.1 degree are within our grasp. However, solar observatory requirements will require 10^{-3} degree and laser communications and long-range astronomical requirements will approach 10^{-5} degree. Although star and solar sensors can be used to obtain very precise pointing information, horizon sensing is a more simple and direct method of attitude reference for orbiting spacecraft. The accuracy of infrared horizon sensors has been in the neighborhood of 1 to 2 degrees. The use of physical phenomena other than infrared may be required to obtain the accuracies up to 10^{-3} degree which will be ultimately required for mapping and scientific data gathering and to minimize communication power. Visible airglow, ultraviolet radiation, and radiofrequency radiation are all possible phenomena for achieving this end.

Fundamental to all of man's undertakings is his ability to communicate rapidly with precision. One measure of our ability to communicate is the number of bits of information that can be transmitted per unit time. Today we recognize that about 5000 bits per second must be transmitted for intelligible voice communication and some 10 to 100 million bits per second for high-quality television. Such rates are achievable with today's technology between points on the Earth's surface and near space.

However, at the heart of the difficulty of extending this capability to deep space lies the fact that the data rate capability for a given system varies inversely with the square of the distance between transmitter and antenna. For example, the capability of the Mariner system transmitting from Mars is only of the order of 1 bit each 5 seconds. The data rate of microwave systems may be increased by increasing operating frequency, antenna aperture, and power and by decreasing inherent noise in receiving systems. Improvements of this kind, including the use of 2300 Mc frequencies and 210-foot antennas, may permit the Mars-to-Earth capability of the Mariner system to be raised to some 2000 to 5000 bits per second in the early 1970's. This is, however, short of that needed for real-time television transmission. It is questionable whether conventional microwave techniques can be stretched to the extent of providing real-time television from Mars, in which case the use of optical communication systems must be developed.

Although much remains to be done, we believe laser tracking and communication offers much promise for the future. Calculations indicate that better than a tenfold improvement in tracking accuracy is possible over the best tracking techniques in use today. This possibility, together with the promise of improved communications, particularly over very long distances, has prompted us to increase our efforts in laser technology.

The Goddard Space Flight Center conducted the first flight experiments during the past year aimed at the use of laser technology for communication and tracking. The Explorer XXII satellite, shown in figure 7, is equipped with an array of small corner reflectors designed to reflect a laser beam transmitted from the ground. Explorer XXII was launched October 10, 1964, by a Scout booster from the Western Test Range.

The laser transmitter and receiver, located at the Goddard Space Flight Center in Greenbelt, Maryland are shown in figure 8. Tracking is accomplished through a computer which alines the laser beam with the predicted satellite position. The laser pulse starts a counter that is stopped when the deflected pulse is

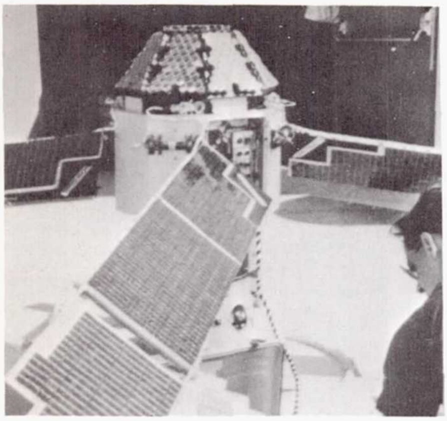

FIGURE 7.—*Explorer XIII.*

received. The oscillograph trace shown in figure 9 was taken during a tracking experiment. The reflected pulse is shown at the extreme left edge of the trace.

Finally, I wish to mention the role of the human in space and the equipment needed to sustain and to protect him. We do not know man's capacity to withstand or adapt to the rigorous demands of space flight. We know the environment is the most hostile

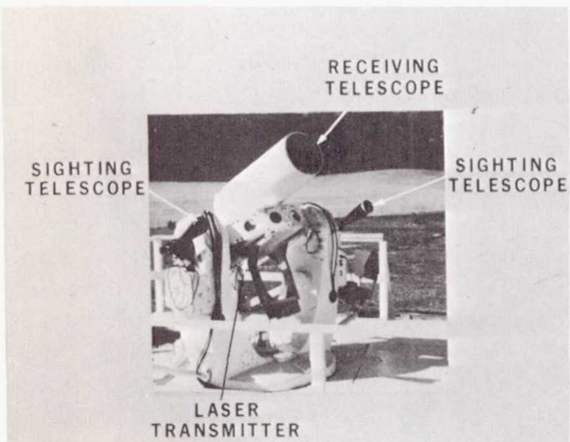

FIGURE 8.—*Laser transmitter and receiver at Goddard Space Flight Center.*

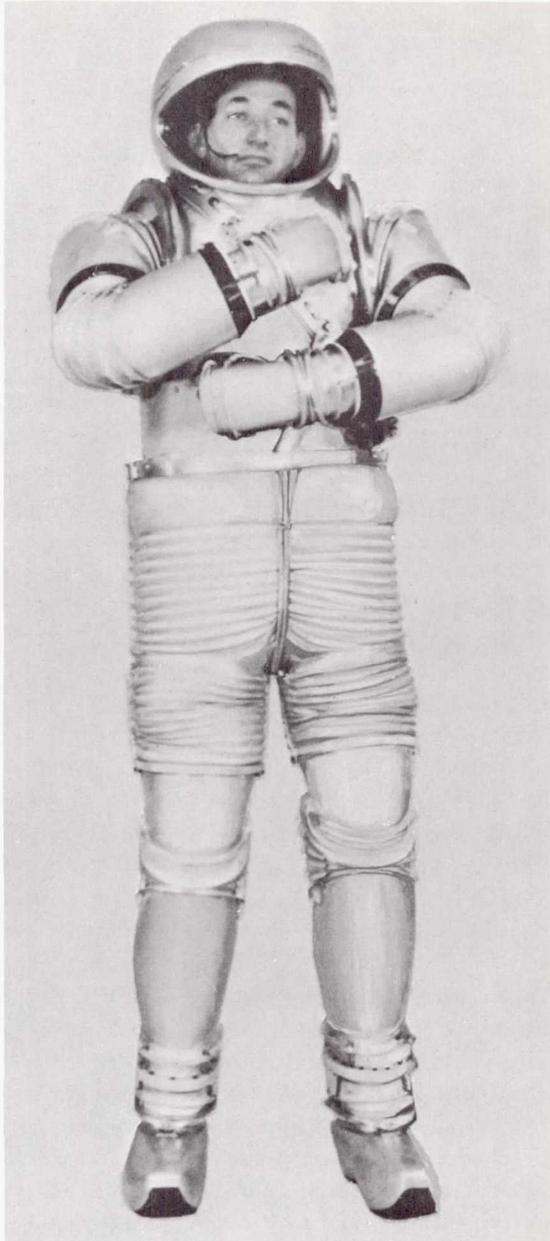

FIGURE 10.—*Metal space suit.*

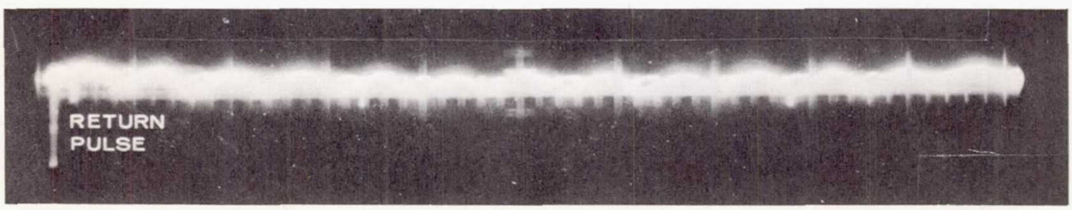

FIGURE 9.—*Oscillograph trace made during Explorer XIII flight.*

one man has yet encountered—vacuum, extreme temperatures, zero gravity, radiation, and meteoroids. He will be in confined spaces for long periods of time. The manned Mars voyage, for example, will take on the order of $1\frac{1}{2}$ years and perhaps longer. We need to obtain data on man's tolerances to this new environment as well as to determine more accurately the characteristics of the environment and its effect on man.

We have research under way to measure man's tolerance to the space environment. We are developing advanced life support and protective systems such as space suits. An example of our work on space suits is shown in figure 10. This space suit is designed to provide protection and mobility for astronauts when they leave the shelter of their spacecraft. The contract work, with Litton Industries, managed by the Manned Spacecraft Center, incorporates new principles in suit design which allow man to manipulate freely with less expenditure of energy than is now possible. This suit, fabricated principally from 0.030-inch aluminum, provides a greater degree of meteorite protection than do the more conventional flexible suits. A constant-volume design concept permits the use of rolling convolute joints which result in lower resistance to movement in the pressurized state. Tests over a range of internal gas pressures with different gases have demonstrated the flexibility of the joints as well as an unusually low leakage rate.

In assessing our growth in space capability in terms of three steps from Earth to Earth orbit, from Earth orbit to Moon, and from Moon to planets, it is important to recognize that the first two steps rest on essentially the same technologies. These are technologies which have evolved for decades and which are familiar: Chemical energy conversion, relatively common engineering materials, measurement and control systems generally consistent with aircraft and ground technology, and microwave communications. However, the third step will demand performance and efficiency well beyond the first two. An entirely new level of technology is needed: nuclear energy conversion, new refractory materials, accuracy of sensors—improved by orders of magnitude—and laser communications. There are the underlying requirements of higher reliability and longer lifetimes than have yet been demonstrated, together with low specific weight.

The requirement for improvement in this spectrum of space-related technologies will drive them well beyond their present level. The presence of difficult goals can have a profound influence on Earth-bound consumer products through the advancement of common fields of technology in addition to opening the gateway to deep space. The NASA program of advanced research and technology embraces most of these elements at least in their fundamental forms. Without this research the space program would soon wither and die. With it, by the year 2000, an enormous influence can be exerted on national prestige and strength.

SCIENCE IN AND FOR SPACE EXPLORATION

Richard W. Porter
Consultant, Aerospace and Defense Group
GENERAL ELECTRIC COMPANY

In this session we are trying to think together for a little while about the "impact" of space exploration on science. "Impact" is a harsh word which perhaps explains the extent to which it has become fashionable in these harsh times. I have not consulted my dictionary because, having driven an automobile in heavy traffic for many years, I have direct physical experience with the word. I know what it means. In fact, all of us who have followed the accounts of the embryonic stages of lunar exploration in the form of the Ranger series obviously know what the commentator meant when he triumphantly shouted, "Impact," after an exciting sequence of pictures closer and closer to the surface of the Moon.

In a way, I think this is an appropriate word to describe the relationship of space exploration to science, because I do not believe the ability of man to send his instruments into space or to go there himself will change the fundamental character of the development of science any more than Rangers VII, VIII and IX have changed the surface of the Moon.

"Science," to quote Albert Einstein, "is the attempt to make the chaotic diversity of our sense-experience correspond to a logically uniform system of thought. In this system single experiences must be correlated with the theoretic structure in such a way that the resulting coordination is unique and convincing. . . . The sense-experiences are the given subject matter, but the theory that shall interpret them is man made—hypothetical, never completely final, always subject to question and doubt."

The earthy old editor of the *Baltimore Evening Sun,* H. L. Mencken, seems to have understood the true nature of science better than many of our modern journalists, as is evidenced by this terse editorial of April 6, 1931:

> In the sciences hypothesis always precedes law, which is to say, there is always a lot of tall guessing before a new fact is established. The guessers are often quite as important as the factfinders; in truth, it would not be difficult to argue that they are more important. New facts are seldom plucked from the clear sky; they have to be approached and smelled out by a process of trial and error, in which bold and shrewd guessing is an integral part. The Greeks were adepts at such guessing, and the scientists of the world have been following the leads they opened for more than two thousand years. Unluckily, the supply of Greek guesses is now running out, and so science begins to show a lack of imagination. What is needed is a new supply of guessers. Mathematical physics has produced a pretty good one in the person of Dr. Einstein, but some of the other sciences seem to have none, and suffer badly from that lack—for example, physiology. It has been piling up facts for more than a century past, but the meaning of most of them remains occult. If it could develop a Class A guesser he would soon be one of its magnificoes, and of a rank comparable to that of Du Bois-Reymond, Johannes, Müller, Lavoisier, Malphighi or Harvey.

Science is not big rockets or manned space capsules or automated telemetric cameras crashing into the face of the Moon, fascinating as these things may be, any more than it is giant atom smashers, electron microscopes, or telescopes. To state it even more simply, chemistry is not test tubes. But science can use these instruments and conveyances to extend the range of Dr. Einstein's sense-experience, thus doubtless adding to its chaotic diversity. This is my first main thought for the day. Second, the technological problems of building such instruments and conveyances frequently provide an incentive for scientific work which otherwise might not receive prompt attention. These two rather obvious points are the burden of my contribution to this discussion. I shall try to elaborate them briefly.

In general, the tools of experimental science are the instruments used to extend the senses of the scientist thus enabling him to observe phenomena more acutely, and also the devices and systems which he uses to control or systematically modify the physical environments in which the phenomena are observed. In this latter category should be included, I believe, the means which are sometimes used to transport the scientist or his instruments to a place from which observations can be made more advantageously. Under some conditions, therefore, I suppose one would have to classify the jeep as a "tool of experimental science." I doubt if many experimental geophysicists would dare to disagree! It is essentially in this lowly category with the jeep that space vehicles belong, when related broadly to science. Why then do scientists consider them so important?

In order to answer this question, I would like to refer to an analogy which I happen to like. In this analogy, science is compared to a gigantic crossword puzzle, extending perhaps to infinity in all directions. What we can see, hear, feel, smell, and taste here on the surface of the Earth shows us only a few squares of this puzzle and, although we can begin to fill these in with words that seem reasonable, we begin to be in trouble whenever we approach the boundary of this little region. The whole structure will be somewhat in doubt so long as any of the squares remain blank, although, of course, this doubt continues to decrease as word after word seems to fit in correctly. The microscope and the telescope have opened up large, new areas of this puzzle; electrical, magnetic and thermal measurements still more. Particularly challenging parts of the puzzle were brought into view by the spectroscope, the ionization gauge and the Wilson cloud chamber. Although our newly acquired ability to send instruments and people into space differs in many ways from these earlier examples, some of us believe that the ability to make observations and measurements from space vehicles will extend our view of the puzzle at least as much as any other technological advance in the history of the world.

We have not yet reached the tenth anniversary of the first artificial Earth satellite, yet already some scientific progress has been made, and the outlines of still more to come can be dimly foreseen. For example, we now have closeup photographs of several selected areas on the Moon from the Ranger vehicles—photographs showing up to one thousand times more detail than those taken previously with the best Earth-based telescopes. These pictures have not answered very many questions, but they have certainly raised a lot of new ones that we had not been aware of before.

For example, the Moon appears to be a very neat, orderly sort of place with remarkably little rubble strewn about. If, as we have been prone to believe, many of the craters were formed by the impact of objects from space on a stony surface, one would expect to find quite a number of boulders and rocks of various sizes scattered here and there. One does not see many objects of this kind in the photographs. Why? Scientists are beginning to guess. Additional information from the Surveyor vehicles—perhaps from the first workable Soviet lunar landing vehicles—may help to show whose guesses are right, but they will probably raise other questions which will require still more data, and so on. This is scientific progress. I rather doubt that the results of lunar exploration will change our ideas about the fundamental nature of space and time or matter and energy, but one can never tell. The Moon should be a history book full of information going back billions of years. If we can learn to read it correctly, it may have much to tell us.

If all goes well, a similar beginning will be made in the closeup study of the planet Mars during next July. We should expect that the Martian photographs, if obtained, will again raise questions rather than answer them. But eventually we hope to land our instruments there, also, and as time goes on the new areas of the puzzle will be filled in. There is one peculiarly important question in this part of the puzzle and that is whether anything that could be called a living organism exists or has ever existed on the surface or in the atmosphere of Mars. This planet seems capable of supporting some of the simpler forms of life that have developed on Earth, and it is tempting to suppose that perhaps similar evolutionary processes have led to similar but not necessarily identical results on Mars. One of the obstacles to be overcome in trying to answer this question is the difficulty of avoiding the contamination of Mars with terrestrial microorganisms in the early phases of exploration. It is a difficult question, but the answer, especially if it should be positive, will be extremely valuable to the science of biology.

Even more puzzling than either Moon or Mars is the planet Venus. To scientists it has become not the goddess of love, but a real "bag of worms." Using the tools of radio and radar astronomy, we have learned that its surface is very hot—hotter than the melting point of lead—and that it rotates very slowly in the wrong direction. It has a much thicker atmosphere than Earth, although we are not sure what gases it contains—only that there seems to be a lot of carbon dioxide and not much oxygen—and it is perpetually swathed in heavy clouds of what we are not yet sure. No single hypothesis yet advanced explains all the so-called facts we already know, or think we know, so the obvious requirement is for more facts. It is like a guessing game. When enough clues are given we hope to be able to find an answer that fits them all. Incidentally, it is the confidence that there exists a consistent answer that will fit all the facts that makes this game called science possible at all.

The atomic furnace that supplies power for our solar system is the Sun. Once held in awe as an object of religious adoration, it is still perhaps the most important object of non-terrestrial scientific research. Since it is obvious that spacecraft, manned or unmanned, are not ever likely to approach much closer than the outermost fringes of its corona, we shall have to be content with what we can learn by studying the electromagnetic energy which it radiates and the particles of matter which are driven away from it in a sort of solar wind. Since only a small part of the solar spectrum can penetrate our atmosphere—essentially, only that part we call visible light plus some of the shorter radio wavelengths—and since much of the important scientific evidence is to be found in other parts of the spectrum, such as X-rays, ultraviolet, and the longer radio wavelengths, it is clear that we must use rockets and satellites to carry our instruments above the atmosphere.

In order to achieve any degree of completeness in the scientific picture of the solar wind and its occasional storms, we shall need not one but several spacecraft continually probing the plasma flow and magnetic fields in different regions of the solar system. Of course, until we began to launch scientific rockets and spacecraft, only the most courageous of scientific guessers had any idea that there was such a thing as solar wind, and we had only the vaguest of notions about the origin of terrestrial magnetic storms and ionospheric disturbances. Thus, in this area space research has begun to expand our view of the puzzle and to help us fill in some of the blanks closer to home.

The scientists who first began to use rockets and satellites to observe solar ultraviolet and X-rays, being full of curiosity like all good scientists, were obviously tempted to look at other parts of the sky, especially in regions where astrophysical hypothesis indicated that these highly energetic radiations should be strongest. As a result, a *new* branch of astronomy, our oldest science, is emerging. Because it deals with the high-energy end of the spectrum, the scientific information which will be obtained is likely to be extremely useful in answering fundamental questions about galactic and intergalactic phenomena. Again, however, the results of the first crude experiments seem to be raising more questions than they answer.

As one last example, I would like to mention the scientific study of the Earth's atmosphere. Application of the results of this area of science are well known in the practice of weather forecasting. Observations from rockets and satellites are adding to our store of meteorological information in two ways. First, the use of many small, inexpensive rocket sondes for measuring wind, temperature and pressure or density in the upper atmosphere, that is, above the normal limits of balloon sondes, is beginning to give a coherent picture of the major features of the circulation in this hitherto relatively unstudied region of the atmosphere where some of our weather apparently begins. Second, the use of artificial Earth satellites to photograph clouds and to measure the energy radiated outward from the Earth in different spectral regions is providing a means to fill in the large geographical gaps where conventional weather stations are not available and is giving us, for the first time, something that approaches global coverage of the tropospheric circulation.

An additional contribution from space research to meteorological science that now seems certain to come in the near future is the use of satellites in data-gathering systems involving free-flying, constant-altitude balloon sondes and free-floating instrumented buoys in the oceans. By this means, it appears possible to obtain detailed three-dimensional data about the tropospheric circulation on an almost continuous global basis. Anticipation of the availability of some such data-collection system is already providing the incentive to develop fantastically extensive mathematical models of the lower atmosphere, covering at least an entire hemisphere and also super, high-speed computers capable of handling such models.

There are many other examples of this kind. Studies of the size, shape and internal mass distribution of the Earth by means of the motion of satellites in its gravitational field, and exploration of the geomagnetic cavity produced by the interaction of the Earth's magnetic field with the solar wind are but two. However, rather than to spend more time elaborating this half of my subject, "Science *in* Space," I should like to turn now to the other half—"Science *for* Space." By this I mean scientific work stimulated by the demands of new or improved technology required for space explanation.

There is no absolute division between the nature of the work involved in these two categories; however the ultimate objective is clearly different. The astrophysicist wants to observe and to try to understand the Sun because it is our nearest star and because it is a complex of physical phenomena that fascinate him intellectually. The spacecraft engineer, on the other hand, is interested in knowing the intensity and energy spectrum of the different kinds of radiation from the Sun under various conditions in order to design appropriate shielding. The mission analyst and operations control officer need to know all they can about the statistical probability of solar flares and ability to predict them, in order to plan and control space flights correctly. Their point of view is not incompatible with that of science. In order to give the engineers and analysts all the information they need, the physicist must learn what he wants to know anyway. And, of course, the spacecraft which the engineer is trying to design will be useful in making observations for the physicists, which cannot be made in any other way.

The same relationship holds for many kinds of space environmental data, such as the micrometeorite environment, magnetically trapped radiation, the characteristics of planetary surfaces and atmospheres, astronomical constants and so on. The capability to explore space not only gives us an opportunity to learn more about such things, but also demands that we learn enough about them to make correct and meaningful evaluations and predictions.

On the other hand, there are some kinds of scientific work which are strongly stimulated by the needs of space technology, but which would not otherwise result from the exploration of space. These have to do principally with the physics and chemistry of materials; with combustion and high-temperature high-pressure plasmas, and with certain biological, physiological, and psychological phenomena. One would not normally find it either necessary or desirable to go out into space to study photosynthesis, for example; however, the technological interest in photosynthesis for use in a closed ecological system for space exploration has led to considerable laboratory work on this subject which might not have been done at all, or at least not so soon. I shall try to give a few more examples of this kind of scientific work.

Lubrication, for instance, is a rather old area of technology. Oils and greases have been used for a long time to reduce bearing friction. However, these common lubricants tend to evaporate in the vacuum of space, and to be polymerized or changed chemically by the radiation levels encountered during some space missions. Lamellar solid lubricants, that is, crystalline materials having a layer lattice structure, seem to be one answer to this problem. To find the best material for this purpose and to apply it correctly requires a detailed understanding of the internal forces in such crystals and the role of occluded gas molecules, both of which involve rather fundamental scientific research, despite the fact that the work has a definite technological objective.

In a similar way the demand for lightweight materials that are strong, stiff, and able to retain their strength up to very high temperatures has led to a re-examination of the theoretical strength of small, perfect crystals of alumina and boron, and to the phenomena of adhesion between such crystals in the form of long, thin fibres and metallic or plastic matrix materials. The re-examination has stimulated some basic work in solid state physics which might not have been done on the same time scale without the pressing requirements of space technology.

The problem of micrometeorite penetration of spacecraft structures and the need to minimize the probability of damage through optimum design and selection of materials has led to careful experimental and analytical studies of the phenomena involved in hyper-velocity impact. This, in turn, has required extension of the equations of state for various materials far beyond the regions that were previously of concern to engineers. The need for lightweight, high-temperature energy conversion devices has inspired new scientific interest in the characteristics of thermionic emitting surfaces and space charge phenomena, on the one hand, and in non-equilibrium ionization phenomena for MHD generators on the other.

As a last example of the demands on science by space technology, I should like to mention the solid electrolyte ion-exchange fuel cell. Conceived in 1954 by General Electric scientists, this type of fuel cell seemed ideally suited for space applications because of its inherent promise of light weight, low volume, long life, ability to work in a zero-gravity environment and to produce potable drinking water along with electric power. However, it was discovered early in the course of development that the ion-exchange membranes, which were produced by incorporating polystyrene sulfonic acid into a fluorinated hydrocarbon matrix, were subject to rapid degradation and subsequent leaching out of the active material under some operating conditions. This caused early failure of the cells and impaired the potability of the water produced. Basic chemical research was urgently needed to develop an understanding of the oxidative degradation of styrene polymers so that appropriate steps could be taken to eliminate or at least to minimize this source of trouble. I am happy to state that the research was done and that corrective steps have been successfully taken.

None of these examples has yet led to any major scientific discovery, that is, one that would fundamentally change our ideas about mass, energy, space, or time. None of them has brought a Nobel prize to any of the scientists involved. But each in its own way represents a striving after truth—an expanding of the part of the crossword puzzle we are privileged to see. "It is open to every man," Einstein says, "to choose the direction of his striving" and "the search for truth is more precious than its possession."

THE SPACE PROGRAM AND HIGHER EDUCATION

James R. Killian, Jr.
Chairman of the Corporation
MASSACHUSETTS INSTITUTE
OF TECHNOLOGY

As a visitor a long way from home—not from outer space but from New England—let me begin, in the spirit of your Bicentennial, by expressing my admiration for the great and distinguished National resources here in St. Louis, both in education and in business and industry, and for the vital part they are playing in concert to advance education, to support our National leadership in science and technology, and to insure the success of our space program. We in New England and, more specifically, we in "Greater Cambridge" are in a good position to be aware of your vigor and your contributions.

Since space exploration involves so many frontier problems and skills, it is not surprising that it touches practically every discipline represented on the university campus—most heavily, to be sure, those in the physical and biological sciences and in engineering but reaching into the schools of management and law, the social and behavioral sciences, and the humanities. As I shall indicate, we see this reflected in the many different kinds of space-related programs now to be found in our institutions of higher learning. Dr. Hugh Dryden, some few years ago, spoke of the exploration of space as a social force which the university cannot ignore. If nothing else, our universities are our only net producers of new professional men and women with the exceptional qualities and training demanded to solve problems on the space frontier. And to that extent at least, there is hardly a university in the country with the resources to do so that is not now caught up in Dr. Dryden's social force.

In describing and applauding this widespread university involvement in the space program, especially in St. Louis and the Middle West, let me pause to reaffirm my conviction about the central role of our educational institutions and the bearing this has on their relations with the Federal Government. They must serve our society in many and widening ways, as, for example, by assisting our National space program, but in doing so, they must adhere unswervingly to their central responsibilities to teach, to nurture new talent, to search for new knowledge, and to perpetuate and disseminate knowledge. These missions require an environment benign to independent scholarship, to contemplation and creativity, to disinterested curiosity, and to ideal aims and long-term goals. The more successful our universities are in pursuing these goals and in maintaining these characteristics—in other words, sticking to their time-honored functions—the more successful they will be in serving needs of the economy and the Government. In discussing their relation to the space program or any other program of national service, I therefore emphasize that our educational institutions must be places "of light, of liberty, and of learning," where all policies and all programs are shaped to insure a lively interaction of questing young minds, fresh and eager in outlook, with older minds full of wisdom and learning. Universities can and do contribute to utilitarian ends, but they must serve a higher purpose than utility.

Sponsored research which universities undertake for Government and industry and which so far has greatly strengthened them, should be handled by both sponsors and the universities in a manner that undergirds and does not erode this central role and essential spirit of the university.

There must be a constant renewal of effort to protect and sustain the universities in their role as educational institutions. The universities themselves must be unremittingly vigilant and unswerving in adhering to their academic ideals. The Nation has a right to insist on this. Since it has come to be, as the principal source of university research funds, such a potent trustee in relation to the university system, the Government must refrain from policies and procedures, especially in the terms of its contracts and grants, which are onerous to the spirit and life of the university.

Today there is widespread fear in universities that, perhaps unwittingly, the Government, after a period of skillfully handled relationships, is now beginning to insist on more and more red tape, cost accounting, supervision, and reporting, that is designed more for hardware procurement than it is for university research. The very qualities that make universities our most effective centers for basic research—relative simplicity of management, stress on the freedom of the individual scholar and avoidance of regimentation—could be eroded by too many controls and overzealous bookkeeping. The universities must, of course, be meticulously responsible in handling public funds, but they cannot let themselves be treated as factories without grave damage.

I hasten to emphasize that NASA and most other government agencies working closely with educational institutions have been sensitive to the special nature of educational institutions and have sought to protect and strengthen them. I am not directing my remarks to NASA or any other specific agency. The fact that there is a current tendency, taking the Government as a whole, to impose difficult restrictions and controls arises not from any specific agency design but as a kind of Parkinson's law. In part, too, it is a response, an over-reaction, to a new and perfectly legitimate examination by Congress of the Government's very large research and development program. This quite necessary examination sometimes is translated into more detailed bookkeeping and supervision.

On this occasion and before this audience, I make a special plea that the Government and the university community be vigilant and diligent in together seeking sound solutions for the management of their partnership. This management today, I must report, is attended by growing difficulties, and there is a disturbing increase in restrictions and controls that can damage the universities.

With these observations off my chest, let me now turn to a report of how NASA is working with the universities. My basic data, I hasten to acknowledge, comes from NASA, but my interpretation and ordering of it is my responsibility. In presenting this material, I try to give special emphasis to NASA's impact on the Middle West.

In the short span of seven years, the National Aeronautics and Space Administration has grown to where it now accounts for almost about one-third of the Federal Government's total annual expenditures for research and development and more than 40 percent of the Federal funds allotted for basic research. NASA expenditures at universities are currently on the order of about $130 million per year, with about one-third of this obligated under its sustaining university program and the other two-thirds in specific project grants for basic and applied research and development.

University scientists and engineers have been involved in the space program since its inception, proposing and preparing equipment for many of the experiments carried in our scientific satellites and space probes or undertaking supporting research in the laboratories on such matters as novel energy-conversion problems or developing new heat- and radiation-resistant materials or inertial guidance systems. These experiments and research projects are carried out under grants assigned to individual investigators, who usually in turn involve other professional colleagues and their students in the projects. At the present time, it is estimated that approximately 3500 university faculty members and graduate students (5800 if supporting personnel are counted—technicians, clerical, and so on) located on some 165 university campuses are participating in NASA-sponsored research.

NASA's sustaining university program was begun in 1962, and NASA officials are to be commended for their exceptionally far-sighted conception of this program, for essentially it is aimed at some rather important long-range National goals. Foremost among these is the need to replenish and augment the Nation's supply of highly trained scientific and technical manpower by encouraging more of our able students to complete their work for the Ph.D.—a goal that was set forth in the Gilliland report of the President's Science Advisory Committee in 1962 as meaning we should try to at least double our annual output of new Ph.D.'s in the sciences and engineering by the end of this decade. NASA, through its graduate training-grant program, as I understand it, hopes to encourage and support at least one-fourth of the desired increase in doctorates in these fields. Specifically, the program makes available to the individual graduate student an annual stipend of between $2400 and $3400 for a period of three years, in the hope that this will enable him to spend full time on his graduate study and complete his doctorate within a minimum time. The grants include an allowance with which the university can strengthen its graduate program in space-related sciences and engineering. Each university has full discretion in awarding predoctoral fellowships within its grant, it being felt that the university itself is in the best position to evaluate a candidate's interests, qualifications, and need. In the coming academic year, there will be over 3000 predoctoral candidates at 142 universities receiving support under NASA's training-grant program. NASA is budgeting $25 million annually for support of this program, adding about 1300 new trainees each year to have something over 4000 students in the "pipeline" in order to yield about 1000 new Ph.D.'s each year.

I think it is especially gratifying to note that of the 52 students that so far have completed their Ph.D.'s with NASA support, 29 are currently engaged in research and teaching at universities and 10 more are continuing their studies as postdoctoral fellows—in other words, 60 percent of them chose to remain and work within university environments. The high caliber of the students selected by the universities to receive NASA predoctoral support is reflected in the fact that of the first 886 students to enter the program, over 80 percent have either received their degrees or are still in training and in good standing, about 16 percent have dropped out or deferred their training for personal or other reasons, and only 1.4 percent have been dropped because of poor academic performance.

There are two other important phases of NASA's sustaining university program. One is that it provides funds for construction of laboratory facilities at universities where needed for NASA-supported research. To date, 27 universities have received facilities grants totalling over $29 million to provide one million square feet of new research laboratory space.

The third phase of the program is designed to stimulate wider participation in interdisciplinary research in all the sciences and engineering that may have a bearing on the success of our space effort. And most significantly, the bulk of the interdisciplinary research funds granted so far have gone to strong universities which have shown a potential capacity of developing into major new centers of strength in research and graduate education—as for example, Washington University. At present there are 31 universities located in 22 states participating in NASA's interdisciplinary grant program; each grant is tailored to the particular capability of the university; on an annual basis they range in size from $50 000 to $1 million and in total now amount to 7\frac{1}{4}$ million annually. To be sure, they include Caltech, the University of California at Berkeley and Los Angeles, and M.I.T., but they also include the University of Denver, Montana State, the University of West Virginia, the University of Louisville, Southern Methodist in Texas, and Adelphi in New York. Six of them are located in the Middle West: Purdue, Kansas State and the University of Kansas, the University of Missouri and Washington University, and the University of Wisconsin.

It has been rather widely assumed that New England attracts and receives rather a good share (but by no means the largest!) of Federal research and development funds and that the Middle West is something of a "have-not" region in this respect. But in preparation for this talk, I have had occasion to study the facts of the matter a little more closely and found that, insofar as university participation in the space program is concerned, the universities in my home state of Massachusetts, with the exception of Harvard and M.I.T., make a relatively poor showing in comparison with those in most of the Middle Western states—both in numbers of Ph.D. candidates receiving training, and in number, size and importance of space research projects undertaken. For instance, in Massachusetts we currently have 108 students receiving NASA Ph.D. training-grant support (or will have during the coming academic year), and these are spread among 9 universities, while 4 universities in Illinois between them are able to provide training for 156, and likewise, 4 universities in Missouri, a total of 103. In the Middle West as a whole, there are now 30 universities participating in NASA's predoctoral program and providing grants for 809 students; this represents about one-quarter of the total program for the coming academic year.

Grants for construction of new laboratory space totalling nearly $8 million have been made at 8 Middle West universities: University of Chicago, University of Illinois, Purdue, State University of Iowa, University of Michigan, University of Minnesota, Washington University, and the University of Wisconsin. These include additions to the Jet Propulsion Research Center at Purdue, new facilities for research in theoretical chemistry at Wisconsin, construction of a Space Research Center on the newly developing North Campus of the University of Michigan, and added space for research in physics and astronomy for Dr. Van Allen's group at the State University of Iowa.

Beginning with Dr. Van Allen's extremely important discoveries, I think the Middle West universities can be justly proud of their contribution to the fundamental purpose of this Nation's space program, which is to enlarge our understanding of our own Earth, its solar system, and the universe.

Scientists located at several Middle West universities have designed experiments for the series of Explorer satellites that have helped define the structure of the Earth's magnetosphere. Others are preparing equipment for the geophysical observatory to be placed in a circular polar orbit some time this year to yield more sophisticated information about the earth's inner radiation belts and upper atmosphere, and several more (at the University of Kansas, University of Minnesota, and Michigan State) are developing experiments for possible inclusion in NASA's first major (1000-pound) biosatellite, which is designed to test the effects of extended space flight on various life forms and, thus, yield information that may be helpful in designing long manned-flight missions. In addition, a group at the University of Michigan is developing instrumentation remotely to detect and to analyze possible life forms on a planet such as Mars or Venus.

There is also a large program under way at the University of Michigan to develop radio astronomy equipment that can be carried up and function in a satellite. Scientists at the University of Chicago, the University of Illinois and the University of Minnesota have made extensive use of high-altitude balloons and sounding rockets for experiments to refine our knowledge of the ionosphere. There is a very large NASA-supported program of fundamental research in molecular chemistry at the University of Wisconsin and a similar, though much more modest, one in polymer chemistry at Notre Dame. There are substantial research programs in molecular biology at the University of Chicago and in celestial mechanics at the University of Cincinnati. A group at Ohio State is investigating advanced devices for communicating at millimeter and submillimeter wavelengths. Fundamental studies of the dynamics of plasmas, some of them related to spacecraft reentry problems, are being undertaken in several universities.

NASA has supported, or is currently supporting, a number of studies aimed at promoting more rapid and more widespread industrial applications of new knowledge developed in the space program. Two historians at the University of Minnesota (Short and Rosholt) have had a grant to prepare an administrative history of the National Aeronautics and Space Administration. The economist, H. J. Barnett, now at Washington University, has recently received a grant to develop methods of analyzing the impact of space-program activities both on the national economy and on regional economic growth.

I could cite many more examples for, in all, there are currently about 175 active NASA-sponsored research projects spread among 28 Middle West universities, but perhaps I have given enough to impress you with the remarkable range and depth of competence of Middle Western universities to participate in research in space-related sciences and engineering.

Clearly the universities have a major role in the national space program and clearly the Government is looking to them for assistance and for the advancement of their educational and research effectiveness. If we can solve the problems of contracting, cost accounting, supervision, and control, the Government and the universities together, great additional academic strength can grow out of the Government's space research and development program.

DISCUSSION

Chairman: George E. Pake
Raymond L. Bisplinghoff
Richard W. Porter
James R. Killian

QUESTION: Dr. Killian, I noticed in your paper that you mentioned NASA's aid to students for their doctoral program. I wonder if you think that, in general, facilities of today's high schools and universities, especially on the graduate level, are adequate for today's research. Do you think that a lot of the facilities today are outdated and that the money could be spent more wisely for increasing and bettering these facilities?

KILLIAN: I am not sure that I have the gist of the question. Would you repeat it please?

PAKE: I believe that the question is expressing concern for the quality of facilities in the educational system. He mentioned both high schools and colleges. I think he is suggesting that perhaps an alternative use for some of these funds that are used for fellowships might be to put the money into facilities.

KILLIAN: I am not sure that the way to better these facilities of the precollege level is through programs such as NASA's, although I am sure that it is going to have an effect in the long run. I do think that the Facilities Act, that the aspects of the new education bill that has been passed by Congress, and that other programs such as the Vocational Program will make possible a substantial improvement in teaching facilities in precollege schools—not only an improvement in facilities but also in opportunity to the proposed new National Research Educational Laboratories on the educational process. They make a very major contribution to the improvement of education in high schools and other precollege schools.

QUESTION: I would like to ask Dr. Killian if, in the study of the universe, scientists believe it would be well to stress more the spiritual nature of the universe—the spiritual and mental nature of it. Sir James Jeans expressed the idea that most conclusions originate in our own minds and that matter is not such a hard, fast, and tangible thing which most of us believe. As I understand it, the idea that matter is made up of electrically charged particles and varies according to the kind of particles and the number of them; the latest idea, I understand, is that all matter is a matter of ways. Those are rather nebulous things, and it seems to me we have pushed the matter into a corner where it has been reduced to more or less a mental opposition. Would it be good for physical scientists to bring that forward to the public to let them begin to think more of themselves, possibly, as being mental. We need healing, and we are accused of being a materialistic people. If physical scientists can advance the idea of the spiritual nature of the universe and man, perhaps we can have healing such as we had in the days of Christ.

KILLIAN: I think the questioner has, in a way, answered his own question by the observations he has made. But let me take a somewhat general try at this one. It seems to me that one of the great things that is happening today is the advances of science. The more science develops and grows, the more it becomes possible and also necessary for all of the other fields—philosophy, the humanities—to grow, too. It would be my observation that we are moving into a great age for the humanities, philosophy, and for all these related areas that I think you are talking about as a result of our having a great age for science, too. All of the stimulation and all of the challenges that we find in the space program will contribute to the enrichment of this other part of our intellectual life; this other mode of thinking.

QUESTION: Dr. Killian, it is risky, I know, to talk about specialists and generalists, but we all see the need for and the emphasis on the creation or the educational processes in creating a greater supply of specialists and I wonder if there is any attempt within the university to consider the other problem, that of the generalists? I'm from General Dynamics and we have many design specialists and I like to think occasionally that we need more design generalists who can apply some of these ideas that the specialists—assist in generating and making programs out of them rather than scientific thoughts. Is that too general a question? I sometimes look to the university to bring to us graduates, both at the bachelor's degree level and higher level, who are more experienced in—or at least have had better education—the application of these ideas than grouping them into larger concepts.

KILLIAN: That is a difficult one to answer in any brief span, too, but I think my colleagues here would agree with me that we have been witnessing in the last several decades in our universities—particularly in the scientific branches of our universities and our schools of engineering—a very great broadening of the educational base; that the preoccupation with the wholeness of learning, if you will, has become one of the dominant factors, developments in our educational processes today, and that we see increasing emphasis on the behavioral sciences and on the social sciences. We see increased developments in the impact of science on government, for example, and the impact of science on society being examined in our universities. There are a whole host of things that are developing that bear upon the objective that you are expressing.

QUESTION: I would like to direct a question to Dr. Bisplinghoff. He spoke of the development of these new approaches to rocket engines and so on. I wonder if he could tell us what the possibilities are for reducing the ever-increasing cost of these ever-larger rockets—possibilities like, for example, reusable equipment that might make it possible to actually carry out such a broadly based and varied program as he was speaking of.

BISPLINGHOFF: We are very much interested in the use of reusable boosters in spacecraft and the space agency. At the present time, it is not economically feasible to redirect our space programs in this direction, simply because of the large investment that we have already made in boosters, such as the Saturn boosters and others, and the relatively small number of missions that will be flown. However, if one projects into the future a large number of space missions, a large number of trips to orbit, and a large number of returns from orbit, it appears desirable to have a so-called recoverable booster system and recoverable spacecraft system that will allow us to use these devices over and over. It is simply a problem of economics, and I assure you that if the economics dictates it, the technology will be available to do it. We are making modest investments at the present time in recoverable booster technology and recoverable spacecraft technologies. I mentioned some of them very briefly in my talk, and at such time as the economics dictates, we can speed up these research and development activities to develop devices which can be used over and over again.

QUESTION: To Dr. Bisplinghoff. Are the recent cutbacks or elimination of such programs as SNAP-8 of the 260-inch and the M-1 program going to leave a gap in the post-Saturn era in the development of large boosters to get these loads to space, or are we reaching the point where some of these other systems of propulsion may obsolete or replace these systems before they develop any further?

BISPLINGHOFF: I think we must say that dropping the large solid motor and the M-1 and SNAP-8 programs will delay our ability to move into systems beyond the Saturn system. These are obviously systems or technologies that we have envisioned for use in the post-Saturn era. Their purpose was to develop the technology so that we would have them available if we wished to use them during this era. If we stop this work, these options will obviously not be available to us. Of course, stopping these programs was, I think, a necessary thing to do in light of the total space budget and the demands which are made on this budget by the present programs. Our decision had to be made in light of these facts, and it was made. Hopefully, we can at a later date reinstate similar programs which will then allow us to move into advanced systems beyond the Saturn systems.

QUESTION: My question is for Dr. Porter. In your comments on space or science in space, during your extensive travels around the world, particularly your contacts with the Soviet Union, would you care to comment on the Soviet attitude to the approach of science in space and science for space the degree which parallels your own philosophy?

PORTER: As you must certainly know, everything that goes on in the Soviet Union is done behind a semi-transparent curtain, a curtain which passes some kinds of information and not others. So we have only the most selectively filtered or distorted view of what goes on in the Soviet. I do not pretend to know very much more than any of the rest of you here know from reading your newspapers.

But to try to answer your question a little bit, I think that to a large extent this view is a universal view. Without any question, the Soviet program, like our own, began with a military booster capability—a military rocket capability that resulted from development work on military rockets beginning shortly after World War II. Exactly what the motivation for that program was in the Soviet Union, I do not know. There are two different opinions among people in the United States who consider themselves expert on Soviet motives. Recently, in talking with Dr. Katz of Rand, I discovered that both of us have a rather strong suspicion that the Soviet program was not originally expected to be anything like the size and scope that it now turns out to be. We think that the Soviets might have been impressed with the loud talking that was being done in the United States about a satellite program for the IGY and decided, since they had the booster capability to a larger extent than we did at that point, that they might as well go ahead and launch a satellite, which they did as you know, before we got ours up. I think that they were astonished at the resulting public reaction all around the world, and, of course, we helped matters along a great deal in this country by the things that we said and did. I think that perhaps the political—the governmental—people who manage the budget in the Soviet Union seeing this effect decided that this was worth supporting for reasons of national prestige in the Soviet Union, and it has proved to be well worth supporting from their point of view from that angle alone.

If you look at world trade figures before and after Sputnik and a few things of this sort, you can see some very interesting facts. I think, however, that the scientists of the Soviet Union were very quick to try to make use of this capability to do science in space. Of course, the demands of the program have required that additional scientific work be done for the technology of their space program. So as things have developed, I do not think there is anything greatly different between their program and ours. They seem to have more quickly caught the interest in the man-in-space program. They seem to have started a little earlier with some of the physiological and biological work than we did. On the other hand, they seem to be a little slower to catch what we consider to be the very great scientific and philosophical implications of the problem of life on other planets and have not, apparently, done so much work in that direction. So you can detect some little differences in emphasis, but on the whole the programs are not greatly different.

PAKE: I would like to interject a comment there somewhat relevant in my own experience. I happen at the moment to be also serving on a committee of the National Academy of Sciences which is making a 5- to 10-year plan for the future support of basic physics in the United States. This is quite an ambitious study involving some 20 members of my committee plus about 40 other members of the physics community in the United States making a careful survey of the needs and requirements. It is, of course, going to recommend that the programs which the United States should follow will cost more money. We are not quite sure what kind of reception this will get in the Congress of the United States. One member of my committee who spent two weeks in Russia at a scientific meeting came back saying that the Russians—the Russian physicists—are eagerly waiting to see what kind of growth rate we project for American physics so that they can run to the Soviet counterpart that provides the budget there to say, "Look what the Americans are going to do; we've got to do at least this well." I am sort of worried now that our Congress will not respond as well as somebody on that corner of the globe will.

QUESTION: Building on your comments, Dr. Pake, and on Dr. Porter's most recent answer and then arcing back to the comments concerning the necessity for broadening—not a lessening—of specialization, but at least a broadening of the cultural base and the philosophical outlook of the specialists there, would any of the panel care to enter further into the realm of speculation as to whether this sort of thing might be a vehicle for leading the Soviets over to a less provincial and militaristic outlook in their government and a greater philosophical outlook toward good will towards mankind in the world in general.

PORTER: Well we all hope, of course! One of the stated—at least privately if not publicly—elements of our national policy with respect to the Eastern bloc in other countries is to bring the Soviet Union especially into the present century, into the 20th century, politically as well as otherwise. Certainly the advances which they are making in science, the people who are being exposed to that kind of thing, and through that to international relations with other scientists, all of these things help. But I do not think that we ought to be very sanguine about how fast the Soviets are going to change their fundamental political philosophy. I do not think it is going to change very soon or very completely. I think all you can say is that we keep on pegging away at it through one channel or another. Cultural exchanges of all kinds are very helpful in this respect, and we should try to continue them wherever they do not explicitly act against our national interests. At the same time, we must remember that we are dealing with the Soviet Union and, even more so, with the Communist Chinese who are a group of people who at their highest philosophical level are devoted to the demise of our system and our way of life. So we have to play this game with our eyes wide open and not be trapped into any stupid moves on our own part while, at the same time, continuing to do all we can to increase the brotherhood of man with man and cross this boundary.

PAKE: Dr. Bisplinghoff, would you care to add anything to this?

BISPLINGHOFF: Nothing, except, perhaps, to add a word to Dr. Porter's last remark, that science does provide a wonderful common denominator to build friendships in the Soviet Union and other countries. We find our scientific interchange—our people going to the Soviet Union, their people coming here, and few students exchanged—a very effective avenue of cooperation and friendship. I think this alone is quite significant in our relations with the Soviet Union.

QUESTION: Dr. Killian emphasized in his discussion how much of a contribution this NASA research was doing for educational institutions, particularly, for example, in this part of the United States and all over the United States. I recently came back from a space medicine meeting on the west coast in which the president of a college opened the meeting with remarks about the expensive cost of this space program. To say that his remarks were acid is putting it mildly—they had a pH of about 1. He was quite bitter about the whole space expense, although probably you could have told him that we have a few hundred million dollars lying in India for sending wheat over there which we will not get back either. Perhaps you would answer this, Dr. Bisplinghoff, if whether NASA should expand its program of selling the contribution that the space effort is making in the United States in scientific institutions, as well as colleges, more than it is doing. Maybe it is not doing a good job of selling its worth.

BISPLINGHOFF: This may very well be. All I can say is that we try, and I am sure that we, with such a large program, will never be able to eliminate all of our critics. We hope to eliminate as many of them as we can, and we attempt to sell the program in every possible way. I acknowledge that we can do a better job in some areas, and it is our intention to try to do so whenever we can.

PORTER: Could I say a word or two to that point? I have done a lot of thinking and made several speeches on this general subject of whether we can afford space research and exploration. Aside from the strictly military missile program, the present level of expenditure on space in this country which I take it is the part of the program to which this man was addressing himself, represents about 1 percent, a little less than 1 percent, of our gross national product. This means it is about 1, a little less than 1 weekend per year for each member of our working force. I have asked a lot of people on the working force if they think it is worth to them 1 day out of 300 to have a national space program like this. They say, "Well, yes! Put on that basis it seems to be quite realistic."

When we start talking about $5 billion to a man who has been having a little trouble balancing his own departmental budget this year, it sounds like a terrible thing, but the question is would he find it any easier to balance his budget if we did not have this sort of program. It would simply mean that we would find ourselves even more overequipped, as far as overall effort in the country is concerned, to do what we need to do than we are now.

We, in this country, are a very affluent society at this particular point. We are no longer at the stage where we have to sweat and strain as hard as we know how to clothe, feed, and protect ourselves. We have reached the point where we can do these and still have a good deal of time and effort left over. The question really is going to be what shall we spend that time and effort for. Shall it be for amusement? Shall it be for many other sorts of things we can think of? I think that in many cases the space program with its incentives, with its challenges, with its inspiration is probably a very good candidate for using this extra time and extra effort. So, I do not believe eliminating the space program would make it any easier for other kinds of research to be done. I do not believe that, in general, the kinds of science which I mentioned as being extremely important would go on anymore rapidly if there were not a space program. I think that if we did not have the space program, there would be, perhaps, an even greater unemployment problem than we now have. We would have to solve our unemployment problem in other ways, and I doubt that we are imaginative enough to solve it very quickly by some of these other ways.

This is just a shorthand answer. I would like to make a whole speech on the subject. I think we really do need a space program to inspire imagination and to soak up the excess energy which we and our people have. I would remind you that, for example, the budget of the National Science Foundation for basic research, not specifically related to space in any way, has gone up enormously after the beginning of the IGY with its satellite program. It did not go down any. The money for the space program has not been taken away from NIH, from NSF, or from any of the institutions that support basic research in this country. In fact, all those organizations have had a budgetary increase probably larger than they would have had without the space program. I think we would have to say, if we look at the overall picture, that the space program has been an incentive and a supporter of all of these kinds of research.

PAKE: If I could add only one brief remark to that, I would say that it is true, of course, that the distribution of funds from any of the particular Federal agencies that involve themselves in aiding the university or college program is found to be somewhat variable. I think that if Dr. Killian had not had to leave, he would reiterate his point that the NASA program has, in fact, involved a wider distribution among educational institutions than probably any other Federal program that comes to mind. He would say that the real concern and difficulty here is quite often that people will say, for instance, that the budget for NASA is $5 billion a year and then they will cite some other program or other problem area which they feel should have more support saying that if we were not doing that, we might have the money for this other purpose. I think, as Dr. Porter has emphasized, that this is just not logical thinking. There is no assurance at all that if the $5 billion were not appropriated for NASA it would be available for other purposes. I have heard many spirited discussions of this kind pro and con about the space program and its aspects. It seems to me that many of the critics of the space program will tend to assume, for example, that because NASA spends money on science—although not a terribly large fraction of it is a purely science budget, as Dr. Porter emphasized—the whole basis of the program is science. I think we must realize that the space effort is a large effort involving elements of national defense. Although there is specifically a military budget, I would point out that the capabilities we have in defense are enhanced by many developments in the space program. There are also elements of national prestige on which it is very hard to put any kind of a dollar figure value. There are elements of science, to be sure.

I think, finally, that another way of phrasing what Dr. Porter is saying is that it is hard to imagine what he called the most affluent society, but also in many ways the most advanced society in the world, suddenly, deliberately deciding not to embark on this really very exciting adventure. It is not fair, therefore, for anyone to view the space program as entirely a science effort or as entirely a defense effort because it has many functions, and, therefore, it is not simple to categorize it.

I think that Dr. Bisplinghoff may have a good point. Whenever a budget gets big enough for people to see it, there will be some people who will be a little bit envious about it and have other ways—other thoughts in mind—as to how they might like to spend that much money.

QUESTION: Dr. Bisplinghoff, you mentioned the ion propulsion system and you said that when in space the engine *might* reach—might gain—a static charge but you did not say whether it actually did.

BISPLINGHOFF: Well, this was the question we could not answer fully in the laboratory, and we sought an answer to this question by flight test. The concept involved is to inject a stream of electrons into the ion stream to neutralize the ion stream. This concept was tried in the laboratory. We felt that it provided a solution to prevent the spacecraft from gaining a charge, but we were not sure. We found, as a result of the flight test, that it did provide an excellent solution and that the performance of the ion motor was very close to what we predicted from the laboratory experiments.

QUESTION: Gentlemen, we have heard today tributes to NASA's influence on the universities and that is rightly so. I would like to ask a question of all three of you if you would kindly take a whack at it. Our space program, as we know it, got started almost as a reaction in a great way after Sputnik, but the Marshall team and the men that we know have built this industry are not really a product of the NASA educational spillover. Would you gentlemen comment—and I would particularly like Dr. Bisplinghoff to comment rather in his advanced research area—on whether you are getting as many ideas from industry now as you were. Or do you find that your advanced research improvements, your step forward, is coming from the university level? In other words, are we advancing in our technology and pushing our frontier of technology forward? Are you noticing now that space technology is creating ideas for you from the university level rather than industry or is industry still carrying the brunt of the burden?

BISPLINGHOFF: I do not think you can really distinguish—really select—one of these and say that the ideas are coming from it alone. I think that, in this country, we have to look upon a large effort, such as this, as a cooperative venture involving three entities: the Federal Government, the universities, and industry. I do not think we can do these kinds of things unless we have these three elements in the effort. On the Government side, since we are spending large amounts of Federal funds, it is incumbent on the executive branch of the Government to manage these funds in an efficient way. They must, therefore, create agencies such as NASA and staff them with competent people. On the other hand, the work itself must be done by the other two entities, mainly the universities and the industry. We find that the universities make very great contributions; the biggest contribution of the university is in giving us trained people, educated people. However, at the same time, in this process of education, they do a great deal of very good fundamental research; the large majority of the really important fundamental research contributions come from the universities. On the other hand, the technologies themselves, as well as the development of the hardware and all the ideas surrounding this development, must be supplied by industry. So, I do not believe that we can say that one contributes more than the other. I think we are all working together in a complementary way.

PAKE: Do you care to say anything about that, Dr. Porter?

PORTER: I certainly agree wholeheartedly with everything that Dr. Bisplinghoff has said. There has to be a three-dimensional—or even greater—cooperation than that because still other organizations are in place. You mentioned the origin of NASA. This, of course, is very interesting to me because I was, to some extent, involved in that. I acted as the chairman of the old IGY Satellite Panel before there was a NASA. At that time, the National Academy, working with the National Science Foundation, tried to keep that little program planning and execution going on a red-hot basis. At the time NASA was set up, I think that there was some very wise and careful thinking done about what the program should be in the United States. There was by no means unanimous agreement on the part of everybody concerned that this was exactly the right way to do it, but, once it was decided, I think we had a very good closing in of the ranks behind the concept, and agreement among everybody concerned that this was the way it was going to go.

So, we had a large number of people from the old Naval Research Laboratory group who came into NASA. Many of those are now in positions of very great responsibility in NASA. We had the nucleus of the NACA which was, of course, a very highly respected organization, and then we had this group of people that you mentioned were then working under the Army Ordnance—von Braun and his people whom I personally helped to bring out of Germany. We got the nucleus of the organization from the Jet Propulsion Laboratory at California Institute of Technology and a lot of other people who came in because they were attracted to the program. So, I think it has been amazing how people have come into the picture, in-house in NASA and through NASA contractors, both university contractors and grantees and industrial contractors. I think this is a tribute in many ways to the people who have managed and run NASA, because they have welcomed these people, have given them the opportunity to do the work they wanted to do, and have given them inspiring leadership to do it. Only under such circumstances could we have had the kind of program that we have today.

BISPLINGHOFF: Fortunately, the advanced research and technology part of the NASA program has its roots in the old NACA which, as Dr. Porter mentioned, was a very effective research organization. It dealt, in its earlier years of course, entirely with aircraft, and it still does devote some part of its effort to aircraft research and technology since the first "A" in NASA, of course, is aeronautics and we still have a very heavy responsibility in aeronautics. However, many of the concepts and technologies which were later employed in the Mercury Program and are being employed in the Gemini and Apollo Programs were pioneered by the NACA in the 1940's and 1950's long before we thought about a space program. I refer to such things as the blunt body and the hydrogen and oxygen technology which with this basis of the NACA is really what gives the strength to the Government side of the advanced research and technology program; this strength, of course, is complemented by universities and industry.

PORTER: We have not had a good debate on this program yet, so I am going to pick you up on one point. You said, "1940's and 1950's—long before we thought about a space program." I think that I could quote page and verse that in the late '40s, just before 1950, the feasibility of an artificial Earth satellite had been very well proven from an engineering point of view by a Rand report and also by a Martin Aircraft Boeing-Navy report. In fact, this was attested to by a five-man committee of the old Research and Development Board, the RDB, of which I was a member and which, I think, made the flat statement that, at this point in time, the feasibility of launching an Earth satellite has definitely been proven. I think we were engaged in a space program of sorts, only not very many people realized it, in the firing of the V-2's and then later the Viking research rockets of our own design. We were firing altitude vehicles outside the Earth's atmosphere for scientific purposes on a pretty regular basis back in 1947—'46, '47, and '48.

The first two-stage rocket was launched in the early 50's from Patrick, and I think most of us who were involved in that program at that time very clearly had in mind the space program that was to follow. It is not at all unfortunate that not everybody climbed on the bandwagon so soon, because it was still in preliminary stages at that time. I think the program has come along in very good timing at a very good pace. We were beginning to be ready with the concepts at the time the public was ready to grasp the importance and the incentive of the program.

BISPLINGHOFF: Yes, I think your statements are correct. I remember a paper in the late 40's that illustrated we had, at least in view, the technology that would be needed to take us to the Moon. On the other hand, in NACA in those days the budget was something in the order of $60 to $70 million and very little of that money could be invested in space activities because the NACA was simply dedicated to aeronautics. It had not turned the corner, and it really did not turn that corner until the mid 50's when the people within the NACA realized it had to go into the space activity. Although there were many people who had faith in the future of space activities, it was very hard to get money to devote to space research.

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POLITICAL IMPLICATIONS OF SPACE EXPLORATION

(*Dinner Meeting*)

Chairman
Thomas H. Eliot
Chancellor
WASHINGTON UNIVERSITY

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THE POLITICS OF OUTER SPACE

Harlan Cleveland [1]
Assistant Secretary of State for International Organization Affairs
U.S. DEPARTMENT OF STATE

There are plenty of good reasons for getting excited about the age of voyage and discovery in outer space.

But we all have to look at so immense a subject through our own professional keyholes. So, as a political scientist, my good eye is glued to the politics of outer space—because the politics of outer space may have a lot to do with those rather abstract goals of ours called "peace" and "world order."

As one of the junior vice presidents in charge of worrying about world order, I was privileged to be much involved in the staff work that led the United States to launch the Charter of the United Nations beyond the gravity pull of our own planet.

It was already Year 5 in the Space Age when we proposed, the Soviets cosponsored, and the United Nations General Assembly unanimously voted a landmark resolution on the law of outer space placing space and celestial bodies beyond the claim of nations.

(We do not yet know whether those principles will commend themselves to whatever intelligence we may meet Out There. But the Preamble and the first two Articles of the Charter are a good summary of what we have learned from several thousand years of feuding and fighting among men who are brothers and brothers who are different from each other. So if we do meet anybody Out There, and he or she is intelligent, maybe the logic of this concentrated wisdom will turn out to have a wider appeal.)

Sometimes, in my unscientific dreams, I wonder what one of our astronauts, a first envoy of the human race, would have to say if he met a being from another planet. Suppose the Martian or Venusian said, "Tell me, in a few words, what's the essence of what you on Earth have learned from your brief half-million years experience with life." Would our man try to explain to Mars and Venus the issues in the Cold War? Or would he talk about what we have learned, with much stalling and much grinding of our political gears, about how groups of men can cooperate with each other?

I think our astronaut would be more likely than most Americans to talk about international cooperation. For he operates under an act of Congress which enjoins NASA to conduct its space program in cooperation with other nations. He knows that every shot from Cape Kennedy requires a web of interlocking agreements with other lands. And he would know, I suppose, that we are even now negotiating an international agreement in which the nations that experiment in outer space assume the liability for accidents they cause, and every nation would agree to return to his land of origin any astronaut or his vehicle which fell to Earth within its boundaries.

From where I sit, it is clear that so far, the exploration of outer space has drawn men and nations together more than it has spread them apart.

The same is true, by the way, in the exploration of Antarctica, that empty windy land populated by penguins who know how to picket but who do not carry signs. Maybe the lesson of this analogy is that it is easier to cooperate where there are no people.

But a more relevant lesson is surely this: Where nations perceive a common interest, they can readily come to clear and enforceable agreements.

The law of outer space is like the law of your own community: Your freedom and my freedom to do damage to others is restrained in the interest of my freedom and your freedom to walk unmolested

[1] Now United States Ambassador to the North Atlantic Treaty Organization, Paris.

the streets we share. There is no other basis for freedom or civil order, whether in Missouri or on the Moon.

Our experience tells us that three conditions must be fulfilled before nations can agree to work together—even if they continue to argue vigorously about *why* they are working together.

First, the technology to make cooperation necessary must be there.

The airplane made international air safety regulations both possible and necessary. When scientists found that mosquitoes carried malaria and mosquitoes could be killed with DDT, it became possible to eradicate malaria from the face of the Earth—and ridiculous not to do so forthwith. Once space began to fill up with castoff hardware and other technological garbage, we had to start moving toward the registration of launchings—which the UN now does—and toward an international agreement about liability for accidents.

But technology does not speak for itself. So, *second,* national leaders who understand its promise and its peril must come to feel the need to cooperate, to channel and contain the inventions of the scientists and the innovations of the engineers. We see again and again that a nation can perceive its own interest in cooperating with others about one subject, while carrying on political quarrels on other subjects. In dealing with other men, it is hard for us to trust them in compartments—to sign an agreement on one subject and fight with them or haul them into court on another subject. Yet that is just what nations do, because technology makes it imperative.

It is not enough for technology to require and a nation's leaders to perceive the need for a breakthrough in international cooperation. There must, *third,* be international institutions to reflect the common interests—to put the technology in the service of felt needs.

Let us now bring these abstractions down to Earth—if that is a permissible manner of speaking at a symposium on space. Let us at least bring it down as far as the atmosphere that envelops the Earth. For that cliché of Mark Twain's is obsolescent—somebody *is* doing something about the weather these days.

What is happening to weather reporting and forecasting is both clear and exciting. And beyond that, what man might do to modify the weather makes a political scientist blink at the political fallout of the atmospheric science.

Men have always known that their livelihood, and often their lives, depended upon the weather; but until very recently that is about all they knew of it. That is why they endowed the elements with the attributes of gods. You may have seen the lovely Tower of the Winds built in Athens in the first or second century B.C., or the sculptures of the fierce rain god of the Maya civilization in Mexico, or the Pueblo Indian dance to appease the sun god. In any event, the chances are that in the past 24 hours you have uttered or heard some superstition that comes to us out of the rich mythology about weather which is still deep in our culture and our conscience.

Until recently the best a sailor could do about the weather was to wet his finger, watch the sky, and repeat the inherited folk-wisdom—"Red sky in the morning, sailor take warning; red sky at night, sailor delight." Some farmers who lived close to the earth acquired—as a function of their joints if not of their reason—mysterious and often misleading hunches about the weather. The hunches did not help very much: the rain still fell before the hay was in, and the ground was still parched and dustblown when the sun shone too hot for too long.

What *did* help were the first steps in the transition from mythology to technology. I will not review the long and stirring history of that technology. In the middle of the seventeenth century one of Galileo's graduate assistants developed a primitive barometer—and in the early eighteenth century Fahrenheit, in Holland, invented the mercury thermometer—and as such tools were invented, the cussed curiosity of men led to the beginnings of a systematic science of the atmosphere.

For a while there were some rudimentary tools but no theory to work with. Then in the eighteenth century a brilliant theoretical physicist named Helmholtz worked out the basic theoretical equations of hydrodynamics. Now nobody knew how to apply the theory to the way the atmosphere actually worked, so for much of the two centuries that followed, theory ran ahead of the tools in the newly emerging science called meteorology.

Then suddenly new inventions came along rapidly. The electric telegraph made it possible to collect enough data fast enough to make the first stab at forecasting the weather without depending on old wives' tales or plying the gods with questions.

Then came the radio—and the airplane—and photo transmission by wireless. And the Second World War came, too—with its suddenly expanded and urgent requirements for greatly extended upper air observations—and especially with the new electronic computer.

Soon the science of meteorology was coming of age due to the convergence of three major developments.

One was a refinement and simplification of Helmholtz's theories of hydrodynamics and their application to the atmosphere. Meteorologists came to understand much more about the physical processes occurring in the upper air. They could begin building more complex models of the Earth's atmosphere as a basis for long-term weather forecasting.

Then the electronic computer opened the prospect of processing enough data fast enough to make longer-term forecasting mechanically possible before the weather had come and gone.

And when observation and communication satellites came along, they offered the potential for collecting enough data for processing and then for distributing it in time to do the receivers some good.

The marriage of these technologies for the first time made it possible to think seriously about the atmosphere of the Earth as the single, self-contained physical system it is now considered to be—in other words, to view world weather as the Lord has presumably viewed it right along.

With the technology as well as the theory in sight, the weathermen got excited; and since everybody is interested in the weather, it was not long before the second condition of progress was manifest—a felt need for international cooperation.

There remained the need for an international institution to put available technology to work in the common interest. This would complete the preconditions for agreement on the things that draw nations together.

In 1951—just 14 years ago and only 6 years before the first Sputnik—an "ancient" professional society called the International Meteorological Organization had become an inter-Governmental agency with executive capacity called the World Meteorological Organization (WMO), affiliated with the United Nations as a specialized agency.

Just 4 years ago—which was 4 years after Sputnik I—President Kennedy laid down a challenge to the United Nations: to design a global weather reporting and forecasting system for the benefit of every nation in the world—a World Weather Watch, as it came to be called. With such a system it may be possible to provide daily weather forecasts for periods of up to 2 weeks ahead, compared to 3 days at the best today.

The implications are simply breathtaking—for agriculture, for flood control, for navigation, for tourism, for sports and recreation—for every nation with airplanes to fly, for every firm with work to be done outdoors, for every family planning a weekend outing or a wedding reception on the lawn.

This will not be ready tomorrow, but the planning is moving ahead at the WMO and in the national weather bureaus, especially our own. There is plenty of engineering ahead—political and social engineering as well as the other kind. But we are on our way, and there is every reason to expect a functioning World Weather Watch by early in the decade of the '70s.

And the story will not end there. Somewhat further in the future lies the exciting prospect of purposeful modification of the weather by man—of minimizing the incidence and the severity of hurricanes, tornados and other violent storms—of influencing the level of precipitation, and, perhaps, of modifying temperatures.

This will depend upon basic research which is not yet done, but which is getting underway. There is no sound basis at this time for predicting when we may acquire the awesome power to alter the climate upon which human and all organic life depends. But when the time comes—as almost surely it will—it is a power that cannot rest in the hands of any one nation.

President Johnson said it when he sent to Congress earlier this week a National Science Foundation report on weather modification: ". . . it is clear that large-scale weather or climate-control schemes cannot be contained within national boundaries."

We do not want other nations modifying *our* weather, and so we will certainly have to accept some restraints on our freedom to modify theirs.

The agreements that will make a world system of the world's weather envelope are just an illustration—but a good one—of the proposition that international politics is not a "zero-sum game" in which an inch gained by our player must mean an inch lost by another.

The reality is that international agreements *can* be reached—and international organizations *can* be formed—and international common law *can* be elaborated—on subjects which draw nations together even as they continue to quarrel about the frontiers and friends and ideological frenzies which keep them apart.

So let's look for a moment at the political merits of functional organizations—the kind that work at peace through meteorology, or health, or food, or education and training, or communications, or culture, or postal service, or children, or money, or economic growth—or the exploration of outer space—organizations, that is, for the pursuit of some specific and definable task beyond the frontiers of one nation—a task for which the technology is already conceived or conceivable, for which a common interest is mutually recognized, for which institutions can—and therefore must—be designed.

• Organizations like these begin by taking the world as it is. No fundamental political reforms are needed; no value systems have to be altered; no ideologies have to be seriously compromised.

• These organizations start from where we are, and then take the next step. And that, as the ancient Chinese guessed long ago, is the only way to get from here to there.

• These organizations tackle jobs that can be managed through imperfect institutions by fallible men and women. Omniscience is not a prerequisite; the peace of the world does not stand or fall on the success of any one organization; mistakes need not be fatal.

• These limited-purpose organizations bypass the obstacle of sovereignty. National independence is not infringed when a nation voluntarily accepts in its own interest the restraints imposed by cooperation with others. Nobody has to play who doesn't want to play. But for those who do play, there are door prizes for all.

• These organizations built around an agreed task can readily achieve a reasonable balance between power and representation in the control of the organization. In the General Assembly of the United Nations the principle of one vote for each nation is sacrosanct. But in a functional organization it is possible to work out ways in which those who contribute most of the resources can take a larger responsibility for decisions as to how those resources will be used. In the International Labor Organization, the industrial nations have a special position; in the International Maritime Consultative Organization, the big shipping nations, including Norway, have a special voice. In the UN Outer Space Committee, there is an unwritten rule that the nations actually engaged in exploring space will act by consensus rather than fail to act by taking votes. And in the UN Security Council, of course, the special right of veto is reserved to the Great Powers, by the Charter itself.

• Finally, these task-oriented organizations can readily grow with the need and adapt to the new tasks made possible by new technologies. Healthy institutions, like healthy cells, grow organically, by evolution.

None of these advantages of the functional approach to world integration are theoretical. The International Postal Union survived two world wars that left the wreckage of political agreements scattered all over Europe. The League of Nations fell apart but its functional organizations—such as those for weights and measures standards, narcotics control, and labor standards—all survived and are going stronger today than when Stalin, Hitler, Mussolini, and the Japanese walked out of the League. At the height of each Berlin crisis, the United States and the Soviet Union persist in cooperating to regulate the hunting of seals in the Bering Sea—as they have done for several decades.

Two examples from the front pages of our newspapers are more than enough to clinch the point. The General Assembly of the United Nations was out of business for a year over a political-constitutional point which so far has prove insoluble—while the Specialized Agencies and affiliated organs working at functional tasks proceeded apace. And in the midst of the military, political, and diplomatic turmoil of Southeast Asia, the organization charged with the regional development of the Lower Mekong Basin has continued to work in routine and astonishing harmony.

International technological agencies, then, can guide peaceful enterprise and weave the nations together with functional strands despite their political conflicts. Yet they obviously cannot by themselves keep the peace of the world. International peacekeeping machinery is needed for that.

But is not peacekeeping *also* a specialized, functional task?

And if so, can we learn something about peacekeeping by remembering what is needed for successful cooperative work at other functional tasks, like world-weather forecasting? The analogy is not exact, of course, but perhaps it is instructive.

We can dismiss at once the first test—that of adequate technology for peacekeeping. If there is anything that is surplus in this world, it is the physical tools for the enforcement of order.

The next requirement is the felt need—the perception of a common interest. And in a crude sense, I think it can be said that it is precisely a recognition of common interest in survival which has led to the partial ban of nuclear weapons tests, to the installation of the hot line, to the banning of weapons in outer space, to the cutback in production of fissionable materials, and to mutual steps toward some reduction in armaments expenditures by the Soviet Union and the United States. There is, in short, recognition of a common interest in the prevention of a nuclear war.

And I think this extends to conventional wars as well—because conventional war could lead to nuclear war. It was 15 years ago that an invading army was last marched against an opposing force across a boundary line fixed by international agreement. And I think that Korea proved that there is no more nourishment for anybody in old-fashioned aggression—that there is a common interest in the prevention of conventional as well as nuclear war.

But when we get to the modern doctrine of militant violence—to what the Communists call "wars of national liberation" and what we call "clandestine aggression"—we meet the greatest threat to world security today. For on this subject there is no felt need for international cooperation, no recognition yet of a common interest; indeed, there is total disagreement over where the interests of the nations lie.

And it is here that the third precondition for cooperative action—the institutional machinery to use available technology to serve common interests—is sadly lacking.

We are hopeful that out of the Dominican experience will come a recognition of a common interest in the Western Hemisphere in providing our hemispheric institutions with adequate peacekeeping machinery.

The framers of the Charter of the United Nations, like the founding fathers of the Organization of American States, did not foresee the emergence of a doctrine of hidden aggression. The UN's peacekeeping machinery was conceived for the purpose of coping with traditional conflict. It is not yet fully adequate to deal even with more familiar threats to the peace. But it has not found the handle to deal, so far, with recent aggression, masquerading as wars of national liberation, in Africa and Southeast Asia.

The most hopeful thing that can be said about this state of affairs is that the institutional gap for dealing with contemporary threats to the peace has been made glaringly evident—which is usually the precondition for institutional invention.

Clearly we need functional organizations both to keep the peace and to foster a progressive international community—the first needed to sustain enough order in the world while the second proceeds to integrate the world along functionally useful lines.

Obviously the two interact. If we cannot contain the so-called "wars of national liberation" by international action, political temperatures may rise to the point where nations become unwilling to cooperate even where it is obviously in their common interest to do so.

On the other hand, whenever organizations of a functional world community succeed, then political quarrels may seem so damaging to shared national interests that the quarrels have to be resolved or submerged.

And this is why—as a political scientist working at the nuts and bolts of peace on Earth—I am excited about the politics of outer space.

Space is not a new subject or function—or academic discipline, for that matter. It is rather, a new place in which all the old familiar arguments and uncertainties are born again. But in this newly accessible place called space, the new uncertainties are so massive that even the largest temporal powers, feeling even smaller in an expanding universe, are drawn together in the search for God knows what.

So far, at least, the environment of outer space is favorable for international cooperation—not only in weather but in communications, in medicine, and in law. Two presidents have even suggested that we go to the Moon as envoys, not of nations but of mankind at large.

Whatever cooperation you can achieve with other nations in preparing, launching, and tracking and using the scientific satellites of man's intelligence, will be part of the contagion of peace—that mysterious process by which nations become so accustomed to working with each other for mutual benefit that the emotional rivalries of the past are pushed aside, not to be settled but, better, to be forgotten.

Thus when we meet to deliberate on the peaceful uses of outer space, we are dealing with the prospects of peace on Earth.

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IMPACT ON COMMUNICATIONS

Chairman
Robert J. Henle, S.J.
Vice President
ST. LOUIS UNIVERSITY

INTRODUCTION

Robert J. Henle, S.J.

This session of our Symposium will deal with the impact of the Space Age on communications. If communications had been developed to the extent that we are predicting, Father Reinert would be presiding here this morning, but since he is in Rome and our communications have not yet developed to that point, he was unable to be present.

It seems to me a very appropriate thing that the Jesuit institution should participate in a symposium of this sort. When I think back over the history of my own order and the exploration of the early Jesuits, not only here in the Midwest by the famous Father de Smet, but throughout the Americas and also penetration into China, I remember the words of the historian Bancroft about the colonization of Canada, that not a cape was turned, not a bay entered, but the Jesuits led the way. And reflecting on all these things, it is a source of personal regret that the first astronaut was not a Jesuit. However, there is, I understand, a young Jesuit in training to be an astronaut, and he, perhaps, will found the first Christian mission on Mars. Though at the present moment, it is not very theologically clear as to exactly what he would be doing there.

THE COMING ERA OF SATELLITE COMMUNICATIONS

Joseph V. Charyk
President
COMMUNICATIONS SATELLITE CORPORATION

Speaking in Washington, Frank Stanton, president of the Columbia Broadcasting System, said, "The mountains have been leveled and the oceans dried up by an 85-pound piece of scientific jewelry transmitting a 6-watt signal." These are among the more colorful words that have been used to describe our Early Bird satellite. It has been called many other things and probably will be called many more, but I think most people agree that it does herald the dawning of a new era in long-distance commercial communications. The full implications cannot as yet be adequately assessed, but Mr. Stanton is surely right when he adds that a new potential for all mankind has begun. Thus, it is especially appropriate, I believe, on an occasion such as this to review where we stand in our efforts to exploit possible areas of impact of this new technology.

The charter for our unusual Corporation was prepared in 1962 through the passage of the Communications Satellite Act. After much study and debate it had been decided that the new capability for communications which had been born with the space age and the potential that it held should be exploited through a unique private corporation imbued with a strong sense of public responsibility and subject to close Government scrutiny and regulation. And today, almost three years later, there is little about our Corporation and the problems we daily face that is not unprecedented. We thus live in an unusual environment that carries with it the excitement, the uncertainty, and the challenge that perhaps befits the momentous responsibility which has been assigned to us.

This assignment was summarized by the Act of 1962 as follows: ". . . to establish in conjunction and in cooperation with other countries, as expeditiously as practicable, a commercial communications satellite system as part of an improved global communications network which will be responsive to public needs and national objectives, which will serve the communication needs of the United States and other countries and which will contribute to world peace and understanding." With such a charter, the Corporation formally came into existence in early 1963, with no staff, no program and no funds.

Today, just a little over two years later, we are still unusual. We have capital resources of close to 200 million dollars, or interestingly enough, about one million dollars per employee. We have organized and are members of an international consortium comprising telecommunications entities from 43 other countries and Vatican City State. We are the manager for the implementation of the space system on behalf of all of these participants.

The stock in our corporation is held by 164 communications carriers and more than 140 000 stockholders distributed throughout the United States and abroad.

In accordance with the provisions of the Communications Satellite Act, we have a most able 15-man Board of Directors with 6 members elected by the public stockholders, 6 members elected by the communications carriers stockholders, and 3 members appointed by the President with the advice and consent of the Senate.

We have an initial satellite in orbit which has successfully completed all experimental tests and is about ready to enter commercial service. We have completed design studies of various approaches to a satellite configuration that would provide a global capability in 1967, our so-called basic system.

After deliberate and careful consideration, the Federal Communications Commission has given the Corporation the authority to proceed with the development and activation of three terminal stations in the United States to work with the basic global system which we plan to have in operation by the end of 1967. These stations will be in the northeast part of the United States, the northwestern portion, and in Hawaii.

Today we are filing with the Federal Communications Commission the first tariffs for the provision of commercial service via the Early Bird satellite.

Thus, in less than 3 years, a bitterly debated document in the Congress and an idea have been translated into a vehicle which stands on the threshhold of providing the world's first communications service by satellite. This, then, is the dawn of a new capability—of a new facet to the communications picture which almost everyone agrees will exert a profound influence in the coming years on many facets of our every day lives.

Although communications is as old as the human race, it is perhaps not generally appreciated that high quality communications on an international scale is really only an infant industry. It has taken thousands of years for communications to progress from simple exchanges between individuals in isolated little groups to rather limited communications between the major industrial and commercial centers of the world.

But the pace of progress has been rapidly accelerating. As new and improved telephone cables have linked the major continents of the world the stimulus to rapidly expanding international contact has been striking. And yet, we should recall that the first trans-Atlantic telephone cable was laid only in 1956, less than 10 years ago, and the first cable across the Pacific went into service only last year. And now, with satellites, a new dimension is being added—a dimension that today is free of any real constraints on the type of traffic that can be carried—a dimension that is automatically global and, hence, can tie any country in the world to any other country without dependence upon linkage through any third country. It can span oceans or continents with equal ease, and, once such a pattern of global satellites has been deployed, the price of admission to a global communications capability is the cost of a terminal station. Depending upon the type of station being considered, this number may range from perhaps $2 million to $7 million, but, in any event, a most modest investment for a facility to link a country with the rest of the world.

I believe that the tremendous interest shown by countries throughout the world in desiring to become partners of the international satellite consortium is a striking indication of their desire and need for high quality international communications. The advent of this capability, in turn, will further stimulate the improvement and expansion of their own internal communications capabilities with the attendant effects upon all aspects of economic growth and development.

There appears to be general agreement that new communications facilities will further stimulate the present rapid growth in international communications. Some time ago, the chairman of the Federal Communications Commission indicated that we might be talking about a half billion dollar international communications industry by 1970, or perhaps a billion dollars by 1980. In presenting its estimates as to potential international traffic to a world-wide meeting under the aegis of the International Telecommunications Union late in 1963, our Government indicated that by 1980 it could be anticipated that two-thirds of the world's international communications traffic would be carried by satellite.

Thus, today, less than 10 years after high quality communications became possible on an international scale, we stand on the threshold of a new capability whose flexibility, scope and diversity seem certain to open up not only other areas of the world, but new communications possibilities that extend well beyond normal message and voice traffic. It has become feasible, for example, to think in terms of massive computer operations on a global scale, with a computer in one part of the world working through and with a computer in another part of the world. Thus, satellite use can be foreseen for such operations which involve data preparation, correlation, computation and data exchange. These possibilities have potential in finance, in manufacturing, in distribution of goods, in transportation, in procurement, in billing and a host of other related areas.

An interesting example of computer application might be illustrated by reference to a program which we are exploring with the Department of Civil Engineering at the Massachusetts Institute of Technology. The program is to explore the practical utilization of remotely located engineering input/output stations linked to large central computers via communications systems. The satellite system opens up possibilities for these stations to be geographically very remote from the central computer, such as in different countries, or even different continents.

Such possibilities are attractive for small and developing countries which do not have large computers, and in regions which have limited conventional communications capability. Civil engineering is a field of interest and of active endeavor by all the countries of the world, dealing as it does with transportation systems, water resources, highways, dams, and a countless variety of other systems. Basically, civil engineering functions are common the world over, thus, a computer-based system for civil engineering practice can be applied throughout the world.

A high-speed, high-capacity computer is far more economical for large problems if the machine is fully utilized and this, in turn, is only possible if a large number of users share the machine. Thus, communication linkages by satellite can provide access to the computing service that would be out of the question for most countries and that can be directly applied to the development of the basic resources of countries throughout the world.

I believe that the great appeal impact of live international television has now been dramatically demonstrated through the various television demonstrations via the Early Bird satellite. The applications to medicine can be most dramatic as illustrated by the heart operation shown on the inaugural program where a large group of surgeons in Geneva, Switzerland, witnessed an operation in Houston. The Royal Canadian Mounted Police found one of its most wanted men through the courtesy of Early Bird.

An international art auction was conducted by satellite, and a glimpse of the world in color and events as they happen has been brought to everybody's home. Early Bird may even have an influence on the future of professional boxing through its live transmission of the debacle in Lewiston, Maine, to potentially more viewers abroad than have ever previously witnessed a so-called championship bout. Unlike the fight, the transmission was live.

Another less publicized but dramatic demonstration of the potential of communications satellites occurred early this year when the first successful two-way communications were accomplished between a jet airliner and a ground station in California. A regularly scheduled Pan American 707-jet successfully conducted test communications after its departure from Hong Kong with a specially equipped ground station in California. A modified facility in Adelaide, Australia, also received clear transmissions from the aircraft. Thus, satellites offer a new potential to serve the needs for regularly scheduled commercial airliners flying the trans-oceanic air routes of the world.

There is interest in the possible use of satellites in connection with the gathering of world-wide weather data. In principle, a series of buoys located in the ocean areas of the world can, on a regular basis, transmit data via satellites to central facilities where the information is received, digested and translated by computers into world-wide weather forecasts.

You may have read recently of the proposal by the American Broadcasting Company to move ahead toward the activation of a satellite system to tie together its affiliated television stations throughout the United States by means of a satellite system. Although their initial cost estimates for the establishment of such a system are unquestionably optimistic, there seems little doubt that a real potential exists for providing such a service on a sound economical basis. We have been exploring their requirements with them; we have also been exploring the airline requirements and how they can be met through a satellite system.

Our preliminary investigations indicate that basically the same mechanical design configuration, with appropriate communications equipment changes, might well be responsive to both needs. It appears that such a satellite could be launched by qualified existing boosters, for example, by an Atlas-Agena, using a 10-foot-diameter shroud. This would permit a satellite of approximately 9 feet in diameter to be used. At a height of about 6 feet, a satellite having about 500 watts of primary power could be launched to synchronous altitude with the Atlas-Agena.

Such a large satellite could provide approximately 1 kilowatt of effective radiated power for the aircraft application and somewhat more for the television case. The basic communications equipment would, of course, be different for the two applications, but as I have indicated, the overall geometry and mechanical design could be the same. There are, furthermore, basically no new techniques that would have to be evolved with the possible exception of the demonstration in space of a proven design for a mechanically or electronically de-spun antenna. On the basis of the initial Corporation studies we may invite the industry, in the near future, to submit proposals for a more detailed study of such a satellite. In the television case, the satellite would have a capability for 12 television channels and, thus, would be able to serve the domestic needs of all the television networks.

But before I dwell too long, and perhaps overemphasize the future possibilities, let me return to our present program and the capabilities that are now with us and those that we project for the near future.

When our technical program was initiated shortly after the Corporation was formed, we immediately focused our attention on three basic types of satellite systems that might be considered to be practical candidates for the world's first global commercial system. We have described these three systems as, first, a medium altitude, random orbit system; second, a medium altitude phased system and, third, a synchronous system.

In the first case, the satellites are deployed at altitudes of the order of 6000 miles, and no attempt is made to position the satellites with respect to each other. Thus, a satellite of the simplest variety is achieved but at the price of requiring the largest number of satellites to achieve global coverage. Also, since the satellites are deployed in random fashion, there will be periods during which there will be no satellites in common view between a pair of ground stations. Hence, periodically, outages would be experienced in such a system. Since the cost of a satellite system, however, depends very strongly on the satellite lifetime that can be achieved, the simplest satellite design is a most attractive element. Telstar and Relay, furthermore, were both examples of the type of satellite that could be used in such a system.

In the second type of system that we considered, the satellites are deployed, again at the same altitudes, but in this instance the satellites carry provisions for adjusting the relative position of the satellites after they are initially deployed. Thus, the satellites can be arranged in such a way that continuous service can be provided between links; that is, the satellites can be positioned so that as one satellite descends below the horizon, another appears above the horizon. A smaller number of satellites is required than in the first case; a family of 12 satellites, for example, can provide excellent coverage.

In the synchronous system, of course, the satellites are deployed at a very special altitude, namely, an altitude of about 19 000 nautical miles. At this altitude, when placed above the equator, the movement of the satellite is synchronized with the rotation of the Earth so that to an observer on the Earth, the satellite always appears to be in the same position. Such a system requires the fewest satellites. Three such satellites appropriately placed can provide global coverage except for the polar regions.

However, because of small perturbing forces, such a satellite must contain a capability for periodic orbit adjustment. Additionally, the orbit injection problem is much more difficult than in the medium altitude case. Finally, this type of satellite presents an additional uncertainty for acceptable commercial telephone use. At these high altitudes, a significant time is required for a signal to be transmitted from one subscriber to another subscriber via the satellite, and for the return message to be received. This time delay is of the order of 0.6 second.

This, of itself, may present no problem to the average telephone user, but, since domestic telephone systems are two-wire systems, it is necessary to insert devices called echo suppressors into the lines so that a disturbing echo of one's own voice is not received in conjunction with the desired response. This echo results from the impedance mismatch between the international and domestic trunk lines which are four-wire systems, and the local extension lines to the subscribers which are two-wire systems. Since a perfect echo suppressor does not exist, the real question is whether the performance of the latest echo suppressors, coupled with the inherent time-delay phenomena, will produce a telephone circuit of a quality that will be acceptable to the vast majority of telephone users.

This appeared to be such an important and vital question in the selection of a system for global coverage that we decided that it would be highly desirable to deploy a satellite of this type at an early date and to submit it to experimental and operational use in order to compile the necessary data that would be essential for a final selection of the type of system that should be used for global coverage. Thus, Early Bird was born.

In addition, we activated design studies on each of the three types of systems. The design of a medium altitude, random system was approached by the American Telephone and Telegraph Company (AT&T) in conjunction with Radio Corporation of America (RCA). The phased system was undertaken by the Space Technology Laboratories of Thompson-Ramo-Wooldridge Corporation (TRW) and the Federal Laboratories of the International Telephone and Telegraph Company (ITT). Hughes Aircraft Company initiated work on an advanced synchronous satellite while proceeding with the development of Early Bird.

The contract for the development of Early Bird was let on April 15, 1964, and less than a year later the satellite was positioned atop a Thor-Delta rocket at Cape Kennedy destined for a spot over the Atlantic Ocean 22 000 miles out in space. The satellite itself is shown in figure 1. At 23 47 Greenwich Mean Time on April 6, the Thor engine was ignited. The first two stages performed perfectly, and, after the programmed coast phase, the third stage was fired over South Africa to place the satellite into an almost perfect transfer orbit. The initial inclination to the equator was about 18 degrees and in this orbit, the satellite travelled out to a distance of 22 680 statute miles above the Earth and down to 910 miles.

During the next few days appropriate attitude and velocity changes were effected through commands generated in our command and control center in Washington and sent to the satellite via the Earth station at Andover, Maine. Then on April 9th, with the satellite at its farthest point from the Earth's surface, the final apogee rocket motor was fired to place the satellite into a stationary orbit above the

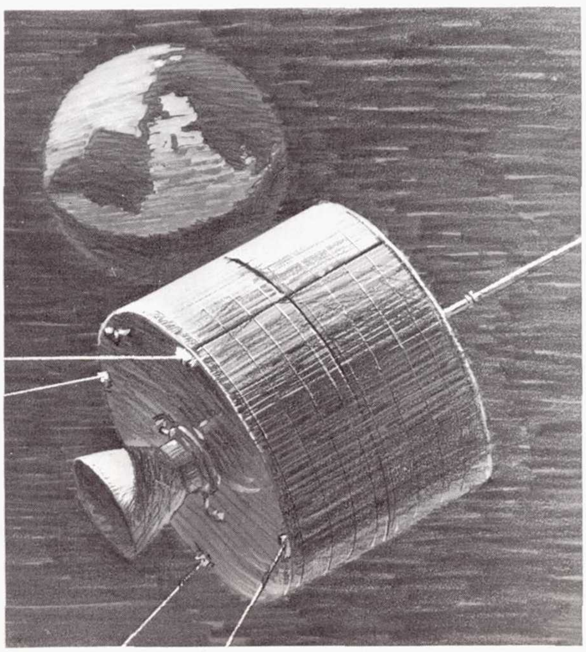

FIGURE 1.—*Drawing of Hughes synchronous satellite.*

equator and the Atlantic Ocean. The accuracy of this operation was such that the satellite was placed within 0.09 degree of the equator. Even while the satellite was in its transfer orbit, test television transmissions were sent from Andover to the satellite and back to Andover, and the signals confirmed that the communications equipment was working perfectly.

During the last few weeks the lineup of the individual telephone circuits on both sides of the Atlantic has been underway. In the meantime, an extensive series of television demonstration programs has been undertaken by the television entities on both sides of the Atlantic. As a general rule, Mondays were made available for television demonstrations, although exceptions to the Monday rule have been permitted.

It is interesting to note that in its first full day of television usage on May 3rd, Early Bird transmitted $11\frac{3}{4}$ hours of television from North America across the Atlantic to Europe and $12\frac{3}{4}$ hours from Europe to North America. This continuous capability has been in sharp contrast to the limited television transmission times for the two Telstars and the two Relays, where the maximum transmission period was severely limited and where transmission was only possible during appropriate orbits. Early Bird has a capacity for at least 240 two-way telephone circuits, a capacity that approaches the total capacity in all the cables that have ever been laid between the United States and Europe. It can carry a limited number of two-way telephone circuits even with television transmission in one direction and, as has been demonstrated, it can handle black-and-white television in two directions simultaneously, or color television in one direction.

And so Early Bird stands ready to perform its first commercial tasks. Its main usage will be to provide additional two-way telephone circuits across the Atlantic. A thorough program is being established to accumulate data on the customer reaction to the echo suppressor time-delay phenomena. It will take some months to accumulate sufficient data to make a final determination. But the answer will in large measure determine the altitudes at which the satellites which will comprise the global system of 1967 will be deployed and the orbital pattern that will be selected.

We have procured a second Early Bird and the parts for a third and are prepared to assemble these into a complete package. If the Early Bird proves to be highly acceptable for regular telephone service, a global family of satellites of this type could, of course, be established in the very near future. The creation of a global communications capability, however, would depend upon the activation of a network of appropriate ground stations. Hence, in this instance the ground station implementation schedule would control the institution of world-wide service. For the initial service via Early Bird, we have leased the station at Andover from the American Telephone and Telegraph Company and have invested approximately $900 000 to modify and adapt the station (fig. 2) for this usage. Pacific service is, of course, dependent upon the activation of suitable facilities in Hawaii and in the western part of the United States. Now that the FCC has rendered its decision on ground station ownership, the Corporation is moving with full vigor toward the implementation of these facilities.

Let me return now, however, to the selection of the satellite system that we have referred to as the basic system and which we contemplate capable of providing communications services of all types on a global basis. The design study of the AT&T-RCA medium altitude random orbit satellite yielded a configuration which is shown in figure 3. Its characteristics are shown in

7-watt transponders	solar powered
260 two-way channels	49-inch diameter
130 pounds in orbit	40-inch height
spin-stabilized	

The TRW-ITT medium altitude phased effort, in addition to providing equipment for initially positioning the deployed satellites with respect to each other, included a gravity gradient stabilization system to permit the radiated energy to be directed towards the Earth's surface. The model of this satellite is shown in figure 4. Its characteristics are

two 4-watt transponders	solar powered
1000 two-way channels	$57\frac{1}{2}$-inch diameter
260 pounds in orbit	34-inch height
gravity gradient stabilized	

Finally, the Hughes Aircraft Company design for an advanced synchronous satellite yielded the configuration shown in figure 5. Its characteristics are

two 6-watt transponders	solar powered
1000 two-way channels	56-inch diameter
150 pounds in orbit	57-inch height
spin-stabilized with antenna	H_2O_2 and/or H_2O control system

When our program was initiated, experience was limited as to the reliability of control systems neces-

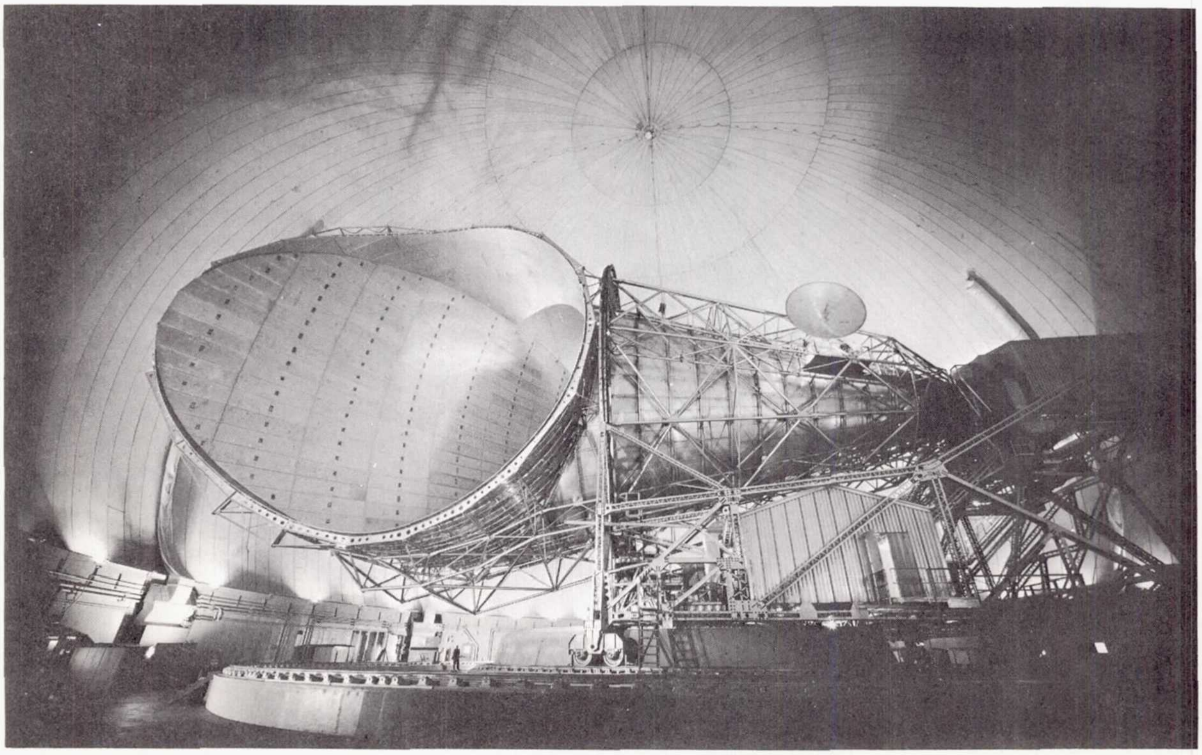

FIGURE 2.—*Ground station at Andover, Maine.*

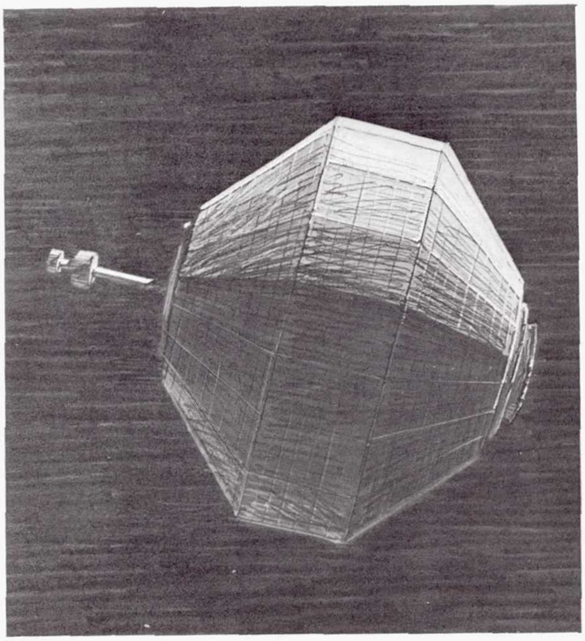

FIGURE 3.—*Drawing of medium altitude, random orbit satellite designed by American Telephone and Telegraph Company in conjunction with Radio Corporation of America.*

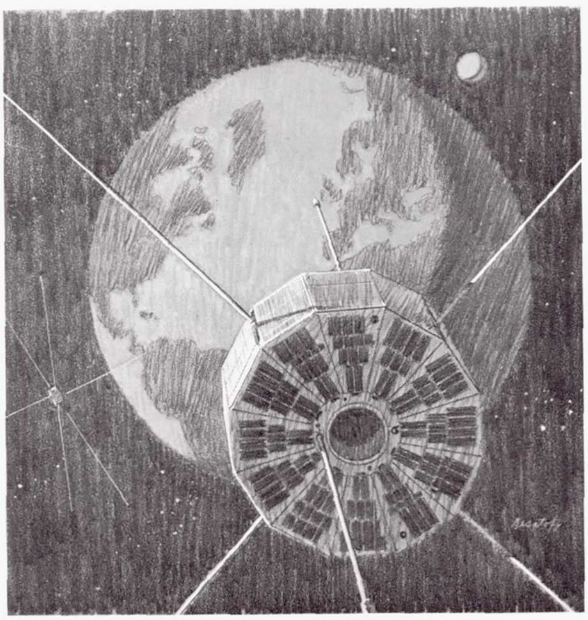

FIGURE 4.—*Drawing of medium altitude, phased satellite developed by Space Technology Laboratories of Thompson-Ramo-Wooldridge Corporation and the Federal Laboratories of the International Telephone and Telegraph Company.*

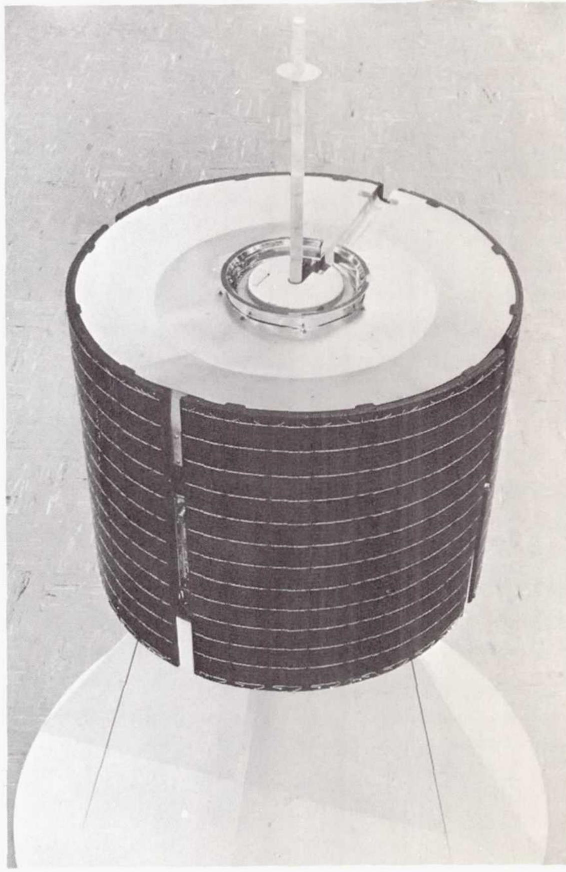

FIGURE 5.—*Hughes advanced design synchronous satellite.*

sary to properly position and maintain satellites in orbit. Although operating lifetime may still be a question, the successful operation of Syncom-II, Syncom-III, and Early Bird suggests that high confidence can be placed in such systems for initial emplacement and subsequent performance at least for periods comparable to those accumulated thus far. It is interesting to note that during the first 10 days after Early Bird launch, 55 commands were transmitted to the satellite and 2969 valve operations took place in the two H_2O_2 systems during 25 orientation and positioning maneuvers.

As a result of this experience and the inherent limitations of a medium altitude random orbit system with respect to continuity of service and the large number of satellites required for global service, it is our conclusion that such a system should no longer be considered for global deployment. As a matter of fact, RCA had already proposed a modification to its design to incorporate an ability to initially position the satellites with respect to each other.

It now appears to us that a design can be evolved which without major modifications can be used either in a synchronous orbit or in a phased system at any altitude between 6000 miles and synchronous altitudes. Accordingly, we now propose to invite the industry to submit proposals for the development of such a satellite and we hope to initiate active development in the coming months on a schedule that would permit full global deployment by the latter part of 1967.

We would anticipate that this satellite would have a capacity of at least 1000 two-way telephone circuits; it would carry dual transponders and would have a means for directing the radiated energy towards the Earth's surface. We would anticipate that a number of such satellites could be launched by a single booster rocket. We expect to formally submit these specifications to the industry in the very near future. In the meantime, Early Bird will pioneer the commercial use of satellites.

On the European side, Early Bird will work with four ground stations. It has been fully checked out with the French station at Pleumeur-Bodou, the German station (fig. 6) at Raisting, the British station at Goonyhill-Downs, and the Italian station at Fucino.

The Big Dome (fig. 6), which will be used to link Europe and North America through Early Bird, contains the huge antenna located at Raisting, about 20 miles southwest of Munich; it was built by Deutsche Bundespost and completed late in 1964. The inflated dome is more than 130 feet high and 160 feet in diameter. It houses the giant, 280-ton parabolic antenna which is controlled by a pre-recorded, computer-prepared, magnetic tape. Nearby, the administration and control building houses the computer and power supply facilities, as well as the radio relay equipment which connects the station to the German telephone and television networks.

FIGURE 6.—*Ground station at Raisting, Germany.*

By early next year, we expect a Canadian station in Mill Village to join the family of Earth stations that will be transmitting and receiving commercial traffic through the satellite.

Although I have given you some glimpses of what the future may portend, no one can, at this stage, accurately portray the pattern of the future. The era which we now enter will, however, without a doubt, open up countless new vistas, and perhaps it is not too much to hope that this facet of space technology will bring with it, through communications, the international contact and understanding that is fundamental to world peace.

COMMUNICATIONS PROGRESS AND PROBLEMS

Richard R. Hough
Vice President
AMERICAN TELEPHONE
AND TELEGRAPH COMPANY

It is a privilege to be part of this symposium dedicated to the peaceful uses of space, particularly since communications and space are so interrelated. Progress in communications is essential to advances in the exploration and use of space. And, conversely, advances in the development of satellites are extremely important to the future of communications.

In discussing the progress and problems of communications and this interrelationship, I would like to begin on the ground.

The information explosion touched off during World War II continues unabated. There are more of us; we want to communicate more; we want to communicate in a variety of ways. As a result, the demand for communication services continues to rise and the communications industry continues to grow rapidly to meet this demand.

Today there are about 89 million telephones in the United States, compared with 28 million at the end of World War II, and of course virtually every family has a radio and TV set. Roughly 84 percent of households in this country now have telephone service, compared with 46 percent at the end of 1945. Hundreds of millions of miles of cable, microwave routes, and wire crisscross every segment of our country. Thousands of switching centers join these facilities into a fast reliable network ready to make any one of 15×10^{14} different possible connections within a fraction of a second.

Approximately 340 million conversations a day are carried by this network, compared with 111 million 20 years ago. And over this network, not only do men talk to men, but machines talk to men, men talk to machines, and machines talk to machines. It offers a complete communications service, handling just about every form of electrical communication—voice, data, TV, facsimile, writing, and so on.

Overall it is a far-reaching machine made up of thousands of different components. New facilities are being added and existing facilities are continually being improved and rearranged to meet the burgeoning demand for communication services.

At this moment, for instance, telephone engineers are making the final tests on our first full-scale commercial electronic switching office which will be cut into service in Succasunna, New Jersey. This is the first step in a long-range program that will change the entire network from an electromechanical to an electronic operation with much greater speed and flexibility.

This type of growth and change has not been limited to the domestic network. Telephone service is now furnished between the United States and 184 overseas locations, and this traffic runs to 18 800 calls a day. In 1945, the figures were 37 locations and 825 calls. These figures sum up the quantity side of the story but do not indicate how the improved quality of service contributed to this increase.

In 1954, for example, before the first transatlantic telephone cable was installed between the United States and Great Britain, we handled about 182 000 calls via shortwave radio circuits over this route. In 1957, the first full year of transatlantic cable service, we handled more than 467 000—an increase of over 150 percent.

At present there are four cables in service across the Atlantic and another is scheduled for completion this year. The latest cable has a capacity of 138 voice circuits, compared with 36 in the initial transatlantic system. Still there are waits for circuits on this high-density route.

Other cables, as you recall, are in service to Hawaii, the Philippines, Japan, and points in the Caribbean. And I might add here that we are continuing our development work on a transistorized submarine cable that will have a capacity of about 720 voice circuits. This cable system could be designed to carry television if it should be considered desirable.

While overseas traffic accounts for only a small percentage of Bell System revenues, it is one of the fastest growing parts of the business—a business which in the overall continues to increase at a rate faster than that of the Gross National Product. In the postwar period the U.S. telephone industry has grown at the rate of 9.5 percent compared with 5.5 percent for the GNP. This points up the continually increasing importance of communications to our economic growth. This growth in communications is not merely a reaction to demand, for the very same technological advances that enable the communications industry to meet the increased demand also contribute to that demand.

And out of the research and development effort of the industry—work originally aimed at improving and expanding terrestrial communications—have come developments that are vital to the space effort. They have come out of the communications laboratories because the problems of space and communications have much in common.

Developments in microwave transmission; the transistor; the solar battery; the maser; negative feedback; the concept of systems engineering; advances in the switching art; printed circuits; microminiaturization of components—these and many other developments are playing their special roles in the exploration and use of space.

Communications of the most modern and sophisticated types are an indispensable ingredient of the space program. The worldwide communications network built for NASA for the Mercury project and improved on for the Gemini project is essential to the success of these programs.

Data from weather satellites are being received in Alaska and carried to Washington, over the longest broadband channel in regular use.

Guidance systems for the missiles themselves have their basis in communications research. And the computer, the major tool of our space program, owes much of its rapid development to the invention of the transistor.

By combining the outstanding achievements in the field of rocketry with those in the field of communications, the working communications satellite has been created. Echo, Telstar, Relay, and Syncom showed the way, and now Comsat with Early Bird is getting ready for commercial operation.

The information explosion, the growth of communications, and the research and development work of the communications industry have been essential to the exploration and use of space. Now the communications satellite opens up another aspect of the interrelationship between space and communications. Communications satellites have given man a marvelous new facility to add to the extensive network with which he has covered large parts of the Earth. And progress in Earth satellites now becomes important to the future of communications.

However, since communications satellites are, in reality, an addition to the terrestrial network they will have to justify themselves as to service and cost as part of this much larger communications picture. The indications are that they will do this, but many political, administrative, and technical problêms remain.

With a synchronous satellite, for example, there is the problem of transmission delay in telephone conversations. This effect must be further evaluated before final conclusions can be reached.

There is the problem of multiple access to a satellite system—the resultant reduction in efficiency as the number of ground stations using a single satellite is increased.

Also, the life of satellites is an unanswered question. They are designed and built to last a long time, but only time can measure the actual life achieved.

Then there is the problem of selecting the system or combination of systems that will do the best job.

And we must always keep in mind that communication is a two-way proposition. There must be someone on the other end who wants to communicate with us by means of the same facility. Agreements with overseas administrations and continuing coordination with them are among the problems frequently underestimated and always requiring attention.

But it is expected that these problems will be overcome and satellites will soon be proving themselves as a valuable addition to the Earth's communication network.

Let me go back to my point that satellites must justify themselves as to service and cost alongside alternate facilities available to the world's communication network. This is the way our present terrestrial transmission systems have found their places in the network. And the situation is far from a static one.

To go back a bit, in the 1920's scientists were working to put a dozen communications or more on a couple of pairs of wires. Then came coaxial and microwave radio systems that could handle thousands of telephone conversations. While in recent years microwave generally may have had the edge over cable, the economic balance now shifts back and forth between them. Only the other day, as a matter of fact, we announced plans for a new cable system between Boston and Miami that will handle more than 30 000 conversations at a time. It will be a "hardened," blast-resistant facility, and will be cheaper than microwave on a circuit mile basis.

Moreover, we have done a great deal of research, and this is continuing, on a hollow tube communications system with a potential capacity of several times 30 000 voice circuits. This can be implemented whenever circuit cross-sections of this magnitude can be justified on a single facility. Looking much farther into the future we see the possibility of vast amounts of information riding waves of light generated by lasers.

As the technology and demand have advanced, the balance among facilities—economics and service—has shifted. The great reduction in the cost of long-distance transmission facilities in the past 20 years has been due to the requirement for large circuit cross sections between points, and the fact that technology has made this possible on a single transmission medium.

The economics of satellites are dependent on their ability to provide large numbers of circuits. Most likely, therefore, they will prove of particular value on the high-density intercontinental routes, especially the North Atlantic route, for it is here the demand is large and rapidly increasing. Overseas telephone calls on this route last year totaled almost 2 million. We anticipate a continuing increase to a total of almost 5 million by 1970, and both cables and satellites will be needed to handle the traffic. In 1945 there were only 18 North Atlantic telephone circuits. Today there are 350, and about 800 will be needed by 1970.

Moreover, satellites look attractive here for another reason. They offer diversity. Diversity of facilities and routes is necessary to assure the continuity of communications since the best laid plans and workmanship of men are sometimes upset by hurricanes, floods, fires, and trawlers.

Continuity of service is a very important consideration in planning our construction program. A major objective in selecting facilities and engineering routes is to assure that communications will survive under the worst imaginable conditions.

Both cable and microwave are used to obtain diversity. Long-distance routes are chosen to avoid target areas. Almost all these routes that we have built since 1955, both radio and coaxial cable, have been laid out on what we call the "express route" principle. That is, instead of running from city to city and interconnecting downtown areas, they avoid major cities, military installations, and industrial complexes entirely. They connect to the cities by means of side legs. On both coaxial and radio routes, protection channels are provided that are automatically switched into service in the event of unforeseen equipment troubles.

Continuity of service is equally important for overseas links and is a vital consideration in the selection and installation of facilities.

Because of the opportunity for flexibility offered by satellites and because of the anticipated growth in transatlantic calling, the Bell System informed Comsat last year that if suitable facilities were available in 1966 or before, we would prefer to use satellite channels to cross the Atlantic until we achieved an approximate balance between cable and satellite circuits. By "suitable" we mean circuits comparable in quality and cost with circuits obtainable by alternate means. We are confident that the necessary circuits can be available when required.

Apart from high-density routes, however, it may be some years before communications satellites live up to some of the early claims made for them—especially claims that they would be an immediate boon to the underdeveloped countries. The fact is that the tempo of domestic economies in large areas of the world is such that they generate very little communications traffic. While this situation may change more quickly than is foreseen, the figures are not encouraging for Asia and Africa. In North America we have 43.4 telephones per 100 population; Europe has 8.7; South America drops to 2.5; in Africa and Asia the figure dips further to 0.8. In some of these areas the corresponding figures for television sets are only slightly higher and the pattern is similar. In short, the value of a communications satellite system in space is directly dependent on what a country has on the ground.

Yet the potential is there—the capability not only of telephoning but of sending television programs live or taped or filmed from the world's great cultural centers to every corner of the Earth. But perhaps the development of electric power and the building of transport and local communications systems come before communications satellites.

Be that as it may, satellites will be an important new addition to the world's communication network . . . a network which is the technical response to the communication needs of modern man . . . a network whose most extensive and highly developed portion is right here in the United States . . . a network that points up the interrelationship of the various types of communications facilities.

It seems to me that we in the West must make full use of our communications capability if the communications needs of the Free World are to be met. As the peoples of the world become more interdependent, as well as the people within nations, communications become even more essential to progress in the future than they were in the past; a more important factor in economic growth and a more important factor in survival.

We must push ahead on all fronts, recognizing the interrelationship of space and terrestrial communication facilities.

There is need for further diversity and flexibility. There is no need to take an either-or position on satellites and submarine cables, since both will be necessary. There is no need to take a rigid position on a synchronous or a medium-altitude system, since there is undoubtedly a place for each. There is need to take the fruits of research and make them available to man in the most convenient and economical form.

There is need to recognize, as the saying goes: "In its present shape it's not the best of all possible worlds."

As a people we are working to make it a better one, and the space program has excited the sense of adventure in men all over the world. But more important, the communications satellite part of that program has lifted men's hopes for peace. Some say that by using space for man to communicate with man we shall be able to bring the peoples of the world closer together and increase the chances for an enduring peace.

At a conference dedicated to the peaceful uses of space we might ask: "What are we in the communications industry really contributing to peace?"

On this I defer to the theologian Paul Tillich, who said recently that one basis of a genuine hope for peace is the technical union of mankind by the conquest of space. But he did not wish away the dangers of the conquest. He went on to say:

> Of course, nearness can intensify hostility; and the fact remains that the first manifestations of the technical oneness of our world were two world wars, proves this possibility. But nearness can also have the opposite effect. It can change the image of the other as strange and dangerous; it can reduce self-affirmation and effect openness for other possibilities of human existence and—particularly as in the encounter of the religions—of other possibilities of genuine faith.

FUTURE IMPLICATIONS OF COMMUNICATIONS TECHNOLOGY

Elmer W. Engstrom
President
RADIO CORPORATION OF AMERICA

There is an interesting symbolism in the composition of our panel today. I had the privilege of taking part in the First National Conference on the Peaceful Uses of Space under NASA sponsorship at Tulsa in 1961. On that occasion, too, I was preceded on the program by an illustrious speaker from the telephone company—Dr. Pierce. It was a hard act to follow—and I find myself in the same position today. But if this suggests a pattern, it is one that I find agreeably challenging.

In another sense, our panel represents a profound change. The discussion at the 1961 meeting had largely to do with the promise of active communications satellites which had not yet demonstrated their effectiveness.

If it is true, as I believe, that our highest achievements result from the harmonious blending of stability and change, then this pattern today augurs well for communications.

When we met at Tulsa in 1961, our attention was focused on the experimental programs then being planned for Telstar and Relay at low to medium altitudes. My own comments related to the problems and prospects of synchronous satellites of the Early Bird type, which then involved many unknown factors of economics and technology. The merit of the synchronous method was so compelling in its promise for system simplicity and multiple access from the ground that there has been a determination from the beginning to press for its realization.

Since then, we have passed through a cycle of successful tests with two Telstar and two Relay spacecraft, established the feasibility of synchronous satellites with Syncom II, and started initial operations with Comsat's Early Bird in synchronous orbit.

This is an astonishing sequence. As one who has been engaged for many years in electronic communications, I find it difficult to recall any comparable degree of technical achievement in so brief a period.

Having said this, I must state an important qualification. It is perhaps tempting, in the excitement and challenge of our space programs, to look upon satellite communications as a radical departure from all that has gone before. But if this view were to prevail, we should be unable to take full advantage of the new capabilities that satellites offer.

I stated in my 1961 presentation that the communications satellite is equivalent to the fanciful idea of a relay tower thousands of miles high. The principle is, in fact, identical to that employed in the ordinary relay towers that dot the landscape around us, carrying television, microwave, and other communication services overland. With its immensely greater height, however, this imaginary tower in the form of an active satellite provides a single relay link that spans thousands of miles on the surface of the Earth, whether over the oceans or overland.

Thus, from the standpoint of electronic communications as a whole, the satellite relay does not herald a completely new technology. It is instead a significant extension of a broad existing communications technology that is already in ferment in nearly every principal aspect from circuitry to theory.

To place this latest advance into proper context, consider for a moment the evolution of communications in this century. We entered the 1900's with well-established and growing telegraph and telephone services. In the second year of the century, Marconi accomplished his epoch-making transmission of the letter *S* across the Atlantic, and the age of radio was upon us.

For some years, electronic communications generally were hampered by the lack of suitable repeaters to receive, amplify, and retransmit signals over long distances. It is only within the past ten to twenty years that we have advanced to high-capacity, wideband systems for all forms of electronic communications. Overland microwave services emerged in practical form bolstered by the technology of World War II. In the mid-1950's, transoceanic telegraph cable capacity was substantially increased by means of new vacuum tube amplifiers and the first transatlantic telephone coaxial cable system was completed.

At the beginning of the 1960's, our communications systems were thus well along the road to unlimited service in technical terms. Coaxial cable and microwave relays provided high-speed, high-capacity overland circuits for all record, voice, data, and television transmission. Submarine cables and shortwave radio provided both voice and telegraph channels overseas from the United States.

The most serious remaining system limitation was the absence of any reliable means for transmitting wideband microwave frequencies across long distances without using relays every 30 or so miles. Obviously, this barred such transmission across the oceans. It also was a practical economic limitation over remote land areas.

It is worth noting here that we began to look into outer space for a solution even before artificial satellites became available. Experiments were conducted during the 1950's with the reflection of wideband transmissions from ionized meteor trails scores of miles above the Earth. The Navy developed and tested in 1960 a system using the Moon as a passive reflector for voice, facsimile and other traffic.

At the same time, new electronic technology began to suggest another possible solution. This has recently matured in a development program for cables employing transistorized repeaters to achieve sufficient bandwidth for television as well as voice and data services.

This is the communications environment into which satellites are now being introduced. It is evident, from this brief review, that satellite relays will have an immensely important function. It is just as evident that they are not systems in themselves, but rather links in systems that include other communications techniques as well.

Every international communications service today involves a sequence of functions. It begins with local telephone, teleprinter, or other connections available to the user. His message is conveyed by one of these means to a gateway station for overseas transmission. It is sent across the ocean or intervening land mass to the distant receiving station. Finally, it is delivered through local connections to the recipient.

Inasmuch as satellites will perform in this sequence as relays across transoceanic or transcontinental distances, they must be integrated smoothly with present and future communications systems that use other transmission methods at other stages.

To the extent that this is achieved, the advent of satellites will remove the last remaining practical barrier to world-wide communications by sight, sound, and data. They will add a new dimension of flexibility, for satellites can span land as well as ocean to provide direct links among many countries and regions simultaneously. Their ground terminals, unlike those for submarine cables, may be situated anywhere within direct view of the space relay.

This extension into space represents today the most dramatic single aspect of continuing rapid change in communications technology. This change holds immense promise for the future. At the moment, however, the promise is perhaps obscured by the turmoil that exists in the traditional pattern of our communications.

Technically, we are capable now of doing far more than we are prepared to do either politically or economically. This is especially true in our approach to international communications. We still operate under national regulatory procedures that were conceived at a time when a clear technical separation existed between voice and non-voice services.

Thus we have today one commercial carrier authorized to handle international telephone traffic but generally excluded from record service. We have five other carriers competing for international record business but excluded from public telephone service. The record carriers can, however, lease private line cable circuits over which customers can communicate by record and voice.

Now, a new entity has appeared with the creation of the Communications Satellite Corporation by Congress. Comsat will own and operate the Nation's satellite relays for international communications. The

Federal Communications Commission has just ruled that Comsat is the entity to own and operate, during an interim period, the initial domestic ground stations to complete the satellite-to-ground link in international service.

This fragmented pattern persists today in an era when technology has just about wiped out the differences among the various forms of communication. The wideband signals that pass through microwave relays and satellites, and will pass through tomorrow's transistorized cables, will include voice, data, television, facsimile, or message traffic without distinction.

Our procedures will have to be brought into line with these new realities if we are to make effective use of the great potential that unfolds before us in communications technology. And surely it will not help to consider satellites as something apart. This would simply extend the confusion outward into space.

It is not my purpose here, however, to explore in detail a problem that embraces basic questions of business economics and political philosophy as well as technology. I cite it simply to illustrate that rapid technological progress can and often does force us to review and either alter or discard many traditional practices. The results are usually salutary, but the process is apt to be uncomfortable. What I do emphasize is the need to recognize that we are at a time of change and that change is necessary. The developing technology and customer desire and demand will require this. In working out the solutions we may expect that certain organizational patterns will change or disappear. With the solution, we shall pass to a more useful, more sophisticated era in communications.

We stand now at the threshold of such immense capability in communications that we will be able to do whatever we may envision in linking people with people, people with machines, and machines with machines. I believe that the rate of advance in these areas henceforth will be determined by economic, social, and political considerations rather than by any significant technical limitations.

Strong and mounting pressures are at work to expand all forms of electronic communications. Everywhere there is a demand for greater numbers of conventional systems, to accommodate growing populations or to establish basic services where none yet exist. In the industrialized nations, there is a rising demand for new and sophisticated forms of communications to serve business, industry, government, and individuals.

The principal agents in this pattern of expansion are population growth, economic and technical progress, and increased knowledge from research and education. These will continue to determine the direction and rate of progress in most areas of communications.

Population growth is, of course, largely a quantitative factor. It continues to generate new demand for more telephones, more broadcasting facilities, and more of all other conventional types of service. The principal contribution of technology here is to make equipment and services available in growing quantity and at lower cost in order to place these within reach of more people.

The effort is achieving success, if we are to judge by the statistics measuring change in the first part of this decade. From 1960 through 1964, the world's population of television sets rose from 76 million to nearly 150 million. Radio sets rose from 330 million to more than 460 million. And telephones in use rose from 133 million to 178 million. This trend is, perhaps, to be taken for granted barring a world-wide catastrophe; populations will continue to increase and people will continue to demand more communications facilities.

The general upward trend in economic activity throughout the industrialized regions is a principal immediate source of pressure for new concepts and new applications for communications. This has motivated our progress in microwave systems, industrial controls, broadcast equipment and techniques, and, above all, computers and data processing.

The computer itself is a communications phenomenon. It incorporates in one form or another many techniques that have been developed for communications purposes in the past two to three decades. But the instrument that combines these is far more than simply another electronic device. The computer is the heart of a broad new technology that embraces information storage and retrieval, data analysis, communications, display, and electronic printing. In its various forms and functions, it is a highly versatile and comprehensive system of information processing for almost any conceivable purpose.

In the decade ending last year, the number of computers used in this country rose from a mere 500 to more than 22 000. The numbers, however, are less meaningful than the qualitative change that has occurred over the same period. The first computers were assigned almost entirely to routine clerical functions. Today they are used in several hundred different types of application from inventory control to market analysis. Even more significantly, computers are now being gathered into growing networks linked by high-capacity communications channels.

These multiple systems assemble, transmit, organize, and display many different sorts of useful intelligence. Already they are affecting fundamentally the basic operations of our public and private enterprises, although we stand only at the beginning of their development.

The third principal factor in spurring communications progress is the mounting accumulation of knowledge from scientific and social research, and from the broadening of education. These trends have generated a need for new and more effective methods for classifying and storing information for instant recall whenever and wherever it is needed. This is a further capability afforded by the combination of computers and communications in a system that provides access from many locations to a central electronic library.

The principal role of space technology in this future pattern will be to provide the vastly greater channel capacity and operating economy that will be needed over either land or sea for total communication among computers, control systems, information banks, and people.

Already, computers have been linked experimentally across the ocean. In one instance, computer instructions originating on one continent actuated automatic typesetting equipment to produce a newspaper on another. Satellite relays have carried medical information between the continents via closed-circuit television, and, as we all know, television broadcast service via satellite has become a reality.

This is a beginning, sufficient to demonstrate that any type of electronic information that can be transmitted from one side of town to the other may soon be just as easily transmitted to the other side of the world. This is equally true for a telephone call to a friend or a computer instruction to a machine tool.

From space technology we may also anticipate a continuing flow of useful new techniques and devices applicable to terrestrial communications. Space requirements are encouraging the development of more effective direct energy conversion methods to power electrical equipment in satellites and other spacecraft. As their efficiency is raised and their cost reduced, these techniques should be useful in generating power for communications equipment in areas without central power systems and in portable or remote installations.

Lasers give promise of enormously high capacity light-beam communications across the reaches of space. Similar techniques may eventually prove feasible for certain types of service on Earth. Advanced imaging systems developed for satellites and planetary exploration vehicles can be expected to extend our use of television techniques on Earth for specialized sensing and communications.

Finally, the entire space program continued to develop a general philosophy and proficiency in systems engineering that will be applicable on a broad scale to the advanced systems requirements of communications technology tomorrow.

The only certainty about this future technology is that it will transform our methods of living and working. It is possible to speculate knowingly on the technical aspects. But it is well to remember at that same time that what is technically feasible will not necessarily fit immediately within a reasonable economic or social framework. With this caution, let me sketch briefly some of the possibilities that seem to be opening on the basis of today's research and development trends.

Well before the end of this century, we should be able to introduce wideband high-capacity two-way communications facilities "piped" directly into the home. This "microwave pipe" would accommodate all types of communications service. It would deliver television and FM radio programs, and even a high-speed facsimile newspaper. It would carry telephone conversations in sight and sound. It would surely include means for opinion taking or voting, where all may respond or where sampling might be computer-programmed. It would provide direct access from the home to electronic libraries for reference, and to public utilities, stores, theaters, rental agencies and other commercial enterprises. It would furnish channels for all personal business.

For this last purpose, we would have simple domestic computing equipment to keep track of personal finances and household logistics. Through the "microwave pipe" the home computer would communicate automatically with computers at the utilities, banks, insurance companies, and other agencies with which we have business dealings.

Such an arrangement implies the existence of a new type of service organization—a communications utility analogous to the power, water, and other utilities of today. This, too, I believe, will evolve as a new consumer-oriented enterprise in the future. It would incorporate the principal service features of our present telephone, telegraph, community antenna, and other direct customer services, as well as many new ones.

All of our communications beyond the local area, both business and personal, would be channeled to a local or regional communications center for processing and transmission. This center would be part of a technically unified world network of cables, microwave systems, and satellite relays. Each such center would be able to tansmit all forms of communications—data, voice, telegraph, television, and facsimile. It would have electronic data processing and computing facilities to analyze and direct the high volume of diversified traffic, and to keep accounts and handle the procedures for payment.

Having direct access to a comprehensive worldwide system, these centers would transmit and receive without discrimination over cable, satellite, overland microwave, and any other available transmission paths in the system. The paths would be selected automatically by the computers on the basis of system loading and relevant technical consideration, just as present automatic switching systems select from among alternate telephone and radio channels.

Thus, in this unified structure of tomorrow, the user would not know whether he was communicating through a satellite or a terrestrial system. It would make no difference to him in any event, for the quality of the service would be the same.

A substantial part of the traffic over future systems will comprise computer data. This will be transmitted from one computer to another, or between computers and control systems, or directly between computers and individual users. Business enterprises, for example, would be able to maintain a central electronic computer facility. This would connect directly with input and readout equipment at any domestic and overseas branches, and in the plants and offices of suppliers and customers throughout the world. Top management would gain instant access to information originating in any part of a farflung enterprise and would possess means for communicating decisions swiftly throughout the organization. This would result in a degree of precision and control never before available to managers even in the smallest enterprise.

By the same token, our governmental and public services would have access to more complete, accurate, and current information than ever before as a basis for decision and action. For example, it should be entirely feasible in this future era to secure and maintain comprehensive current data on social and economic conditions, employment, public health, and other basic statistics that now require weeks and months to compile and analyze.

I have been referring so far to the broad systems aspect of communications in the future. Hand-in-hand with this general development will come the invention and introduction of many new peripheral devices to link the user more effectively to the system as a whole. Among these, for example, will be improved character-recognition devices and voice-operated inputs to accept both written and oral instructions or messages. New output and display devices will deliver information in printed, pictorial, or spoken form, depending upon the nature of the data and the needs of the user.

It is possible to speculate endlessly and with some assurance, for technology is now approaching the capability of providing almost any type of electronic information-handling process that can be conceived.

However, it would be idle to focus attention upon the technical potential and to ignore the fact that the present is beset with hazards and complications that the future will not necessarily dispel. The only purpose of speculation in these circumstances should be to state hopes and to formulate objectives.

Every significant new technological capability imposes a new responsibility upon those who exercise it. In a free society, we must be alert to the danger that the technical advances which tend to standardize and centralize information-handling facilities could impel our society toward greater uniformity and regimentation unless appropriate safeguards were erected. It is a subtle point, but there is potential peril to any free people in a trend which substitutes the anonymity of coded signals for the individuality of words and names.

Up to now, the history of technological advance has been remarkably uneven. Today's technology in this nation and the few other highly industrialized communities of the world is the product of little more than a century. The industrial revolution that launched this small proportion of mankind upon its present career of increasing wealth and power has failed even yet to reach the bulk of humanity.

Therefore, when we speak of global communications and farflung enterprises, it must be borne in mind that these are most likely to be created by and to confer benefits principally upon the small group of advanced nations. This is a situation that cannot persist indefinitely. The increased effectiveness of communications already has sharpened a longing among the less privileged majority for material advantages of which they are told, but which they do not have.

There is no quick or easy way to remedy this imbalance or even to slow its continued growth. One thing that may help is the determined use of our increasingly effective communications as a means for conveying the knowledge and skills that are so urgently needed in so much of the world. Among the new resources that will be at our disposal is a system of broadcasting directly from satellites to television receivers. Such a tool could be a powerful agent for teaching over large areas. It could also be an agent for communicating ideas that may help to transcend the nationalism that is now such a divisive force in the world. It may, however, be for a wiser generation than ours to develop this capability.

The theme of this conference is the peaceful use of space and, in this panel, to consider the impact of space upon our communications. I have discussed with you the broad context of communications and some future possibilities that arise as space adds a new dimension to our means for communicating.

It is clear that we are presented with an immense opportunity, but one that we must work as never before to fulfill. Our channels of communication are multiplying. It is incumbent upon us to use them not simply to further our material well-being, but to develop growing knowledge and wisdom among ourselves and all with whom we communicate.

THE ROLE OF THE SOCIAL PHILOSOPHER IN THE SPACE AGE

Robert J. Henle, S.J.
Vice President
ST. LOUIS UNIVERSITY

When I agreed to chair this session, I was visited by a member of the Planning Committee, only a few days ago, who asked me if, on the conclusion of the three main papers, I would make a few general comments on the role of social philosopher. I said, "Well, surely I'll make a few comments," so he then said, "In fact, you are really a fourth paper." I am not really going to give a fourth paper, but I am going to make those comments.

The three gentlemen you have heard are eminent in technology, eminent in scientific application. I am not a scientist; I am not a technologist. My training was in philosophy, and I suppose, my profession is education. But I think that the tremendous array of capability that has just been described to us in so many different ways, the opening potential of the future is simply one aspect of a totally new kind of society.

It is extremely difficult for human beings to put their own period, their own time, within a genuine historical perspective. As a matter of fact, it sometimes seems to me that the period about which people know least is the period directly before their own maturity, which means that the period of their own maturity is one which they understand very poorly. The period just before our own maturity has not really become well developed as history so that we can study it, so we have had no experience of it.

We notice this, for example, in students who have grown up since the second World War. There is a blank period in their lives, in their experience, and in their studies, so that when one tries to talk to them about what immediately preceded their own coming of age as freshmen or sophomores in college, we find we are trying to build on a blank. Well, this creates a very great difficulty for any human being trying to see his own society and his own time in a perspective.

It is extremely dangerous, therefore, for anyone to attempt to reflect upon this space age and to try to see it in perspective. Yet, I dare to do this because, it seems to me, that if you do make a study, a survey of the development of a civilization, the individual is important. The Roman citizen or the Renaissance man was a different kind of man from the kind of man to be found in a peasant society or among nomads. A space age man is quite another type of man.

We will have in our society certainly a highly sophisticated cosmopolitan type of human being, and as all these capabilities we have been talking about are translated into realities, and the whole world is brought into this kind of new society, every human being will be brought to a level of sophistication which will be beyond any level of sophistication in the whole past history of man—beyond anything that has been in the great urban centers. In relation to the kind of society that is emerging, the great cultural centers of the past will appear to us to have been parochial and limited. They will almost look to us as the peasant culture looked to the educated and cultivated Greek. The peasants were the barbarians, and even so the urban cultures of both the present and the past will, I am sure, look to men of the future as we move into this tremendously sophisticated era.

We have been talking here about capabilities for what we have been calling *communication*. I suppose this is a good enough general word, but I would like very briefly to do a little analysis of just what it is that these capabilities will be bringing to human beings. Let us consider the whole range—telephones, computer storage of knowledge, printouts, television across the world, and so forth. One of the things, clearly, that is going to come into, is coming into, and will continue to come into the lives of all our people, is a new kind of experience; a participation in actual events which is not exactly the same thing as physical participation and yet is closer to it than the kind of participation that an intelligent and imaginative person gets by reading a good account of something, by reliving historical events in his own imagination. Here we are participating, through a new capability, in actual events as they occur—events of all different kinds of people, of art, of Congressional proceedings, and so on—that our children will certainly have in the tremendous hookups of the future.

It is also a communication, not only with people presently alive at any given time, but a communication with the past that will almost approach a living participation. What if our students now in college could go to the library and dial in, and there on the screen, on the television in front of them, would appear the figure of Caesar as he stood on the Rubicon! And they could hear him talking in Latin to Labianus, his own lieutenant. What a tremendous difference this would be from reading the dry accounts of Caesar's Gallic Wars, or of the Civil War. The future student will be able to do this; he will be able to hear past Presidents, to see them. He will see the momentous happenings in the UN, in Congress. All of this will be part of his own life experience so that by the time he is 21 or 25 he will have had a wealth of actual human experience that no man now alive has really been able to have.

There is also, of course, the storage of knowledge, this time not really communication, nor actual experience, but the storage of abstract knowledge. In a sense, the thing I have been talking about is an experience which gives rise to understanding and knowledge. But when we talk about storing information on the computer, we are talking about abstract knowledge. We are talking about building up for ready reference the discoveries of the last hundred years, even the last centuries. But remember, in the last hundred years discovery has moved so fast that if there were a way of measuring knowledge we would have to say that the amount of knowledge that has been added to the store of the human race in the last 15 years probably is far more than has been added in all previous history.

This knowledge is, at the present time, almost beyond our control. It is almost getting away from us. We are almost losing it. But these capabilities that are now being revealed are capabilities which will put at our disposal, in an ordered and significant way, the vast knowledge and data sources of the world so that we can select what we need. The things that a student now goes to the library and spends hours doing, as a preparation for writing a thesis or dissertation, the kinds of things that people that are at work doing surveys have to do by the hours, this kind of slavish digging-out of knowledge, will be a thing of the past. We will be able to sit at our desks and get printouts of the selected knowledge that we need. We will have a control of knowledge beyond any control that man has ever had in the past.

Just think for a minute of the kind of knowledge control found in a tribe that has no writing. The archives of this tribe are kept in the memory of men. A few people in the tribe know all the tales, the songs, the stories, the history, the ethics, the religion of the tribe. They are the living human storehouse, but there is a limit to what can be stored in human memory. So when computers are substituted we put at our fingertips all this knowledge, a sophistication of abstract knowledge.

Finally, communication itself in the true sense is communication between human beings. One of our panelists spoke of machines talking to machines. I readily recognize that the transference of language from human beings to machines, as we now have them, has a certain validity. There is even a certain validity in talking about machines which can calculate and think, and machines which can talk to machines, and machines which can give instructions to machines or to human beings; yet, there is a tremendous and essential difference that we must never forget. Communication between human beings is not merely a kind of a transmission of some kind of coded order, or even of some kind of abstract information. Communication between human beings involves a certain totality. And the deeper, truer, and more real the communication becomes, the more it involves. A two-way interaction involves two human personalities totally. Nor only in a narrow abstract communication of knowledge or a mere piece of business being transacted, the communication of human beings that is most important involves the totality of human beings.

Let us think for a moment of the 85 million telephones we have just been told about. What kind of communications goes on over those telephones? How much of it is just talk and no communication? How much of it is communication at a very superficial level, a level where there is no real understanding? But if you think of the genuine communication of human beings, communication in which they are totally involved, you think of lovers talking to one another on these phones, of men talking to their wives, of men talking to their best friends, of men talking about important personal matters to other men who are interested. Here you reach communication which leads to true human social solidarity and understanding.

The abstract kind of communication alone, I am convinced, will not bring peace to the world. Nor will a sort of purely anonymous business transaction bring peace to the world. If we are pulling humanity together with these capabilities, the kind of communication that goes on between nations and people must be an involvement of people themselves wholly and totally. Otherwise, the capability for communication might speed up the world's business, but it will not stir the world's heart, and it will not bring a peaceful use to the world which is truly a human use. Consequently, man stands here with capabilities such as no human being had dreamed of 1000 years ago, such as no one had foreseen even 200 years ago—capabilities, but they are in the hands of human beings and they must serve human purposes. Therefore, it is essential that we constantly back away from our technology and realize that this technology is building a society for human beings, and that, consequently, we must always think that the kind of people we have in this society is going to determine the use of this technology. They, in turn, will be touched and changed by the technology itself. But we must not allow this to be a perfectly passive situation. We must react to this situation as human beings with human values, judge and make decisions, and manage and manipulate these new ways of communication so that there is not only a peaceful use, but a peaceful use for the betterment of human values in the world and the extension of human communication at the deepest level where man loves man, where people are interested in each other, in their basic concerns and their future welfare and happiness.

DISCUSSION

Chairman: Robert J. Henle, S.J.
Joseph V. Charyk
Richard R. Hough
Elmer W. Engstrom

QUESTION: Suppose, if you would, that at 6 o'clock this morning I turned on the television getting a clear picture, and the announcer spoke in very clear English that this was coming from a Russian satellite! Do you gentlemen consider that possible today and, if so, when? Also, I would like to ask another question. Considering that we are talking about putting 45 tons into orbit around the Moon, do you consider a 130-pound communication satellite adequate for today's needs?

HENLE: As to the first question with regard to automatic and instantaneous translation, I think in some reasonable form this is something that we can look forward to in the reasonably near future. With regard to the sufficiency of 130-pound or 150-pound or 260-pound satellite, I think Dr. Charyk should respond.

CHARYK: I think that depends on what the requirements are. Actually, our first satellite is only 85 pounds. Now it does have a capability, as I indicated, for about 240 two-way telephone circuits, has a capability for two-way black-and-white television, it has some capability for a combination of television plus telephone. Now, the matter of getting a greater capability simply rests on more power or on the ability to direct the energy towards the spot on the Earth where it is desired. Both of these things are also technically within our grasp. So I think that it is fair to say that, with the existing technology, we can develop satellites that will easily have the capability to handle the normal communication needs that we foresee in the coming year.

QUESTION: I, also, have two questions to ask. The first one, I think, should be directed to Dr. Charyk. At the present time, we are in a period of minimum solar activity following a period at the end of the last decade when we had, I think, the highest solar activity on record and we are coming into another period at the end of this decade. In your considerations of the operations of satellites, particularly synchronous ones in the future, have you considered the effects of the very probable greatly increased solar activity on the hardware, as well as on the operation of the system? The second question I guess should be directed to Mr. Hough. Considering that the dollar—the material value of the dollar—will stay the same, how much less it is going to cost us to communicate in the future?

CHARYK: The answer to the first question is really weight. In other words, this is a matter of protecting against radiation. We have in our satellite designs made liberal allowance for protection to handle all the normal radiation situations that we can anticipate. As such, we can anticipate lifetimes that are actually more—that are longer than probably the lifetime of the individual components themselves because of failures that they will experience for other reasons. So, as far as radiation is concerned, that is taken care of simply by weight. With the kinds of boosters that we are developing and that presumably will be reliable in the not-too-distant future, we have a little concern about being able to provide whatever protection will be necessary.

HOUGH: There are a lot of ways of trying to measure how much it costs to communicate. If you just talk about a voice conversation across the country, we are getting down to the point now in the cost where there is not a great deal left to chip away at.

For example, in the early 1920's, a 3-minute call coast-to-coast was about $16.50 during the daytime hours of a business day, and today it is $2.00. After 8:00 p.m., it is $1.00. And I think that these costs will continue to go down because, as we have heard here, there is still a lot of exciting things in the future in communications technology. In the future, we are going to see much more dramatic reduction in the cost of communication as we want to transmit much greater volumes of information; here some of the new facilities (among them satellites and the wave-guide system I talked about) are going to make it much cheaper in the future to transmit things like television and high-speed data. So, just as in computers, the bits per dollar have been going down rather dramatically over the years, I think the same thing is going to be true in communications as we look ahead. It is going to be a continuing progressive thing. I do not think I can tell you how much, but I am sure that costs will go down.

QUESTION: I would like to ask a somewhat technical question of Dr. Charyk. I would like to know specifically what band widths are available in present satellites such as Early Bird and what band widths are available in the contemplated satellites that are being worked on. I would also like to ask whether these satellites work by having a single band for input and a single one for output or whether it is some more complicated system?

CHARYK: The band width is rather limited in the initial satellites; however, in the designs which we are developing we are looking to band widths anywhere from maybe about 60 megacycles to about 150. The first satellite is really strained to pass a color television signal, and we have to use a few gimmicks to do it, actually. Now, this is a matter of development of certain new techniques which we think can be incorporated in our basic system which will not have the basic kind of limitations that our first satellite possesses. Now, in the Early Bird, itself, we have two transponders. In sending television, for example, both ways, we, of course, send it in one direction through one and the other direction through the other. Normally, if we are trying to do TV plus voice, we will have two-way voice going through one and television through the other.

QUESTION: This question is addressed to Dr. Charyk. What considerations are being given to the utilization of man in space as maintenance people to maintain a satellite system?

CHARYK: None very seriously. It is so much simpler to replace the satellite, so much more economical.

QUESTION: I would like to ask Dr. Charyk if he would comment on possible future foreign satellite systems and what problems or prospect these might entail for COMSAT.

CHARYK: Well, I think there is little doubt that other countries are going to be able to develop a capability for communications satellites with means to put them in orbit.

One country, outside of the United States, obviously has done so. Up to the present time, the group of countries with whom we are associated are dedicated to the concept of a single global commercial system, and, as I indicated in my address, these countries represent about 85 percent of the total international traffic generating countries of the world. Therefore, on a purely economic basis, one could not very well establish a competing system. On the other hand, I am sure that economic factors are not going to be very important in the motivations of other people who may want to do this.

QUESTION: In the amateur radio field, I wondered whether the communications satellite planning allows a band for this kind of activity. The amateur radio system has provided the industry with a lot of training and I wondered what the plans for the future in this area would be. Would you answer that?

CHARYK: We have made no provisions at the present time.

QUESTION: My question is for Dr. Engstrom. You mentioned that there might be a hazard of instrumentation and regimentation of the people, you know, with the advanced communications. I do not understand a lot of the hazards and advantages of our space program, but that seems like a real one to me because, even if it is on a small scale, most high school students have come in contact with this because our report cards are made out by IBM machines now. Allowances cannot be made any more, you know on grades, grade averages, on personal records, or capabilities because to that machine a student is just a series of punches on an IBM card. You know and I know that is on a small level, but as Father Henle said—this age of technology is just starting. It seems to me that as technology becomes more a part of everybody's daily life, the impersonality of the machine is going to become a greater hazard. Do you think, yourself, that it is a real hazard, and if it is, do you have any ways to ensure that the future communications will be the kind that Father Henle talked about and not this regimented kind?

ENGSTROM: Well, I applaud your question because I think it is a profound one. Let me first attempt a bit of an example, and then let me express the opinion that you requested. If, at some time in the future, you and I are going to be known in this world by a code number, that will not be merely for the purpose of finding where we are so that we may be reached because somebody wishes to speak to us, but it will be a compilation of all information that is of interest to anyone probably anywhere with respect to our personal situation, with respect to our business situation, with respect to whether we have paid our taxes and how much, and all of this. I think there is a problem of ethics, primarily, as to how access shall be had to this information.

Now, I want to first express my belief that this is coming, that this kind of store of knowledge will be available, because we will want it that way, because it will be important to our health and our well-being. Now, whether this will be turned to evil ends or good ends depends upon the particular society of which we are a part. If this kind of a situation had existed during Hitler's regime in Germany, you might easily guess as to what capital he would have made of it. So it is not the system that is moral or immoral, it is the fact that people may use the system and the information differently. This will determine whether the end result will be good or will be bad.

QUESTION: This question is addressed to Dr. Charyk and Mr. Hough. Mr. Hough mentioned several of the problems currently facing the communications satellite. In view of the missions currently envisioned for these satellites, when do you think these problems will be largely overcome?

CHARYK: Well, a number of problems were mentioned. Let us start with the time-delay echo-suppression problem. I think we both referred to this. I indicated that one of the main purposes for the Early Bird satellite was to compile information on the acceptability of service to such a satellite for commercial purposes. Another restriction is that if many stations try to operate through the same satellite, the capability is significantly reduced. Again, in order to maximize the capability of this particular satellite, we are operating only one station on each side of the Atlantic at one time.

In Europe, there are three major stations: one in Germany, one in France, and one in England. These have been netted together in such a way that the traffic to all of the countries can be handled through one station, and they are planning to operate their stations on alternate weeks. This is a rather unsatisfactory solution to the multiple access problem, but it is adequate for our initial service. We would hope that the satellite system that will emerge in 1967 on a global basis will, in large measure, be free from some of these restraints, and that it will also, of course, be selected on a basis to ensure that adequate telephone quality can be made available.

QUESTION: As a comment and a question, I do hope we used our communication equipment, this morning, to tape your address, Father Henle, so that it becomes a part of the official symposium record. I have a question to Dr. Charyk. What is the role of the passive communication satellite in space communications in the future?

CHARYK: Frankly, we do not see in the near future a very promising role. It requires a very large ground installation to pass a rather small amount of information. We think that the progress is likely to go in the other direction—that is, more power and directivity in the satellites pushing in the direction of smaller ground installations while increasing the quantity of information passed through the system.

QUESTION: Why limit yourself or ourselves to communication between men on Earth? I think the thing that will unite men on Earth is when we can communicate with other intelligences on other planets. As von Braun has said, everything leaves a trace back to what you said about Greece and Crete and, I believe, Julius Caesar and Aristotle or somebody; everything leaves a trace and I think that you will, in time, be able to go out into time—if there is such a thing—and space to retrieve sight and sounds of all of the thoughts and things that have happened in times past.

HENLE: I take it this was a short speech.

QUESTION: In light of the several comments that we have had, I would like to hop back to the first part of the first question that was asked, which I understood from my vantage point apparently to be a little bit different from the question as understood by Dr. Engstrom. Do the Russians possess the capability of putting up a satellite in the fairly immediate future by which, all of a sudden, we, our general population, that is, could be receiving communications from them in our own language (not a translation) on what seemed like a reasonable, rational, and convincing basis—if you will, propaganda to our people from them? Do they possess the capability, and what would be the social implication of this activity?

ENGSTROM: Well, I think the answer to the question as you have now put it is that the Russians today not only have that capability, but they have demonstrated it because they do have a satellite in operation. They have used it for speech and for television, and Dr. Charyk told me just last night that they had made some point of the fact that they had color television signals over it. Now, that satellite and our satellites, as they are constituted for communication purposes, are not very useful in a direct message to the person in the home. But, if we look forward to the time when we can have much more generating power of electrical energy on board a satellite and can afford to put into space a unit of substantial weight so that we can have a transmitter of a power that sends signals over a broad area of the Earth, this is a perfectly feasible thing for somebody to do. Then, I think we must go to Mr. Cleveland to find out whether it is proper to leave it up there, or whether we take it out of business, or whether somebody else might take ours out of business if we take it out. I think it is true that the use of this new tool and new facility will require a great deal of discussion, deliberation, and soul-searching with respect to the international aspects of what can be done.

HENLE: If I might pick up for a moment to comment on that. It seems to me that your question emphasizes the responsibility of future education in this country. The world is so constituted that it is impossible to keep people in any way from thinking by closing them out from the rest of the world. Future men of the world will need to make more and more personal decisions on all these basic issues. Consequently, they must be educated to the point where they can make reasonable, personal decisions. While I am thrilled and excited about the possibilities that are opening in front of education itself because of all these new devices, I shudder at the responsibility we will have to educate the man who will deserve and will be able to act as a human being in the new society. The education system will have a tremendous responsibility for producing the right kind of person.

May I make a further observation on this. I think this is part of a new environment that is opening up in the Space Age because, if we look back in history over many, many centuries, the world, as far as man is concerned, grew larger and larger through exploration. But, at this midcentury, something happened which has started to shrink the world, so that it has become instead of a large area for man to roam a very small island because nations that are separated from one side of the world to the other are, in effect, as near as though they were across the street from us, and we must learn how to live under these new conditions. We have not had any experience in doing this.

QUESTION: I thought I was going to be entirely scooped by the last discussion. The question I have is this. Suppose that it were possible, economically as well as technically, to place in the hands of every human being on this Earth a means of two-way communication. How, first of all, would one accomplish this on the basis of language? Are we going to teach everyone English tomorrow, are we going to teach them Russian tomorrow, or are we going to build a translator—an electronic translation device of which most existing ones, I understand, are rather poor considering this total communication aspect of the problem that Father Henle mentioned. Are there any plans afoot for this sort of thing?

Obviously, Mr. Johnson could not get through to the Russians today through some of the translation devices. There are many problems in communication, inflection of voice and so on, which could not be carried, so that essentially his message would be carried only in part. Are there any plans afoot for approaching this from any viewpoint at all? I would like to put this to Dr. Engstrom, I think, and to Father Henle, if I may.

ENGSTROM: I think this is a question more for a social scientist and philosopher to answer. May I make one observation which I think is also a part of the question that you have raised. I made reference and others have frequently made reference during the recent past to the ability to put a satellite over a given part of the Earth and to broadcast directly to the people. Now this is all right if this should be done over the North American continent where the United States and Canada have a common language, but if one should be stationed over the center of Africa, for example, there would be difficulties because of all of the languages of all the tribes and all of the variations of each language. So, this is a problem of massive dimensions, and, having stated the problem, I now leave it for the philosopher.

HENLE: Well, if we look at what has historically happened to human language prior to sophisticated organizations into nations or empires—which were bound together by military roads in the case of the Chinese Empire, and the waterways of China, or by the Mediterranean and the military roads of the Roman Empire! Human language tended to be highly differentiated into very, very limited geographical dialects. This is a problem which still exists in Africa to which reference has just been made. In large sections of Africa, every little village, even a subdivision of a tribe, has a variant on a common background language, and very often people of the same tribe can not really understand each other at all.

But, in the past as communication and the necessity of pulling sections of humanity together develop, two things emerge. There is the emergence of what is called a *koine*—some language that is not native to most of the people using it, but which through historical accident or for some other reason, such as because it is the language of the conquerors or of culture, becomes the language which everybody uses to communicate. Or, in some of the more sophisticated countries that have a school system through which a standardized language can be taught, there is the emergence of a standardized form of the dialects of the country. For example, high German in Germany, the French of the French Academy, and the English of London. These become a national language and gradually tend to close out the older dialects.

I, myself, think that what we will come to first is several koines in the world. Our languages will not disappear, but Russian and English, and perhaps Spanish, will develop as rather common languages. In most of the countries of Latin America right now, English is a required second language all the way through school. They do not have very good teachers in many places, but they recognize the fact that it is a second language which is becoming necessary. So, I think the world will become a world of people who do have a speaking and understanding command of two languages and maybe three. Given a long enough period, I could see one of these languages becoming the world language, and other languages, simply because they cannot compete, dropping out just as the old dialects dropped out in France and in Germany.

I am not altogether pleased with this, although it obviously has a tremendous advantage. One of the great riches of human civilization has been our cultural diversity, and I would regret that we lost these highly differentiated kinds of individual languages that have been so fascinating in revealing to us the development of human beings. But, as far as I can see now, the survival of these is going to be a matter for a few antiquarians. So, I think we shall go through a stage of two or three languages becoming the common languages of the world and, perhaps, eventually arriving at a one-language world. Then, of course, we will have to find a way to translate this into Martian.

THE CHALLENGE OF SPACE

(*Luncheon Meeting*)

Chairman
Charles Sommer
President
MONSANTO COMPANY

INTRODUCTION

Charles Sommer

I know you all share my pride and my own inner feeling of excitement and pride of being present during the St. Louis Bicentennial Space Symposium and the Fifth National Conference on the Peaceful Uses of Space. I am certain all participants will leave this important three-day meeting with a clear conception of our Nation's readiness for leadership in the Space Age, and we will all be better prepared for the tasks ahead. During the Symposium it has been made apparent that— thanks to the many people at this luncheon today—the United States is well on its way toward pre-eminence in every phase of space activity. I join all the others of our City in saluting you, as the Nation salutes you, and as the rest of the Free World surely must salute you.

A glance at the Symposium program indicates the vast impact this new era will have on all manner of human affairs. Fortunately, our Nation has the persons with foresight and resourcefulness to anticipate and cope with this impact.

We know that the missile space industry although only in its infancy, is about to pass our automotive industry as the Nation's largest industrial employer. And beyond industry, in such fields as medicine, law, education, and politics, the impact of the Space Age is bringing change and innovation. Obviously, the preparation for travel to the stars is as much a matter of attitude and social economic conditioning for a nation as one of producing the necessary hardware.

Today, it is my great pleasure and honor to present to you, a man who has contributed mightily to the proper development of both. He claims, modestly, that he is in the launch vehicle business.

Dr. von Braun came to the United States in September, 1945, under contract to the U.S. Army. He and about 80 of his associates and their families received American citizenship in 1955. At the direction of the President, the Army Ballistics Missile Agency development team which Dr. von Braun headed was transferred to the National Aeronautics and Space Administration installation at Huntsville, Alabama. The group was made responsible for developing and launching NASA's large space vehicles. At the Huntsville installation, Dr. von Braun directed the development of a 200-mile Redstone rocket, which was America's first large ballistic rocket. Special versions of the Redstone were used in launching the Free World's first satellites to the Earth and Sun, Explorer I and Pioneer IV, and on the first successful space flight and recovery of animal life . . .

Thanks largely to Dr. von Braun, American rockets now probe outer space and our Nation's satellites circle the Earth to provide new and better means of communications, navigation and weather control, and manned space flights.

Here to speak to us today is the man who got them off the ground, Dr. von Braun.

CHALLENGE OF THE CENTURY

Wernher von Braun
Director
NASA MARSHALL SPACE FLIGHT CENTER

I am delighted to be again in St. Louis, the Gateway to the West. Through this area passed countless pioneers when the West was expanding, drawn by the opportunity and freedom of the open frontier. The first locomotive to be operated west of the Mississippi River made a 5-mile run from St. Louis in 1852—just a little more than 100 years ago.

Today we stand in the gateway to another frontier, the ocean of space, which stretches to infinity. We are building the transportation systems to explore this new environment, but our progress thus far could be compared to that 5-mile run made by a wood-burning locomotive on the Pacific Railway of Missouri in 1852. Its ultimate destination was the Pacific Ocean, but that primitive engine made many more runs before it got there. So far our astronauts have not ventured 200 miles from Earth's surface—but we shall continue until we have explored the Moon, the planets, and indeed the solar system. We are building a space transportation system to be operational, to be useful, to carry scientific instruments, passengers, and cargo to and from chosen destinations in space. And we want the operational system to yield a tangible return on its investment.

When I arrived in St. Louis today, I was met by my good friend Jim McDonnell of the McDonnell Aircraft Corporation. Now he and Walter Burke are real pioneers in the Space Age. They developed the Mercury spacecraft that carried America's first astronauts into space aboard Redstone and Atlas rockets. And they are now producing the Gemini spacecraft. We wish everyone in this program continued success.

Our science and technology have just barely become equal to the challenges of space exploration. And they have become equal only at enormous cost. Like any individual, partnership, or corporation that intends to remain in business, we have two approaches to getting the space program on a sound economic basis—we can increase its productivity, and we can lower its cost. We must adopt a more hard-headed attitude and consider not only whether a space project is technologically possible, but whether it has promise of contributing to the economy or the strength of the country.

As our space technology grows and matures, our transportation systems will become cheaper, and more and more opportunities for using them to advantage will be opened to us.

One of the first returns from our space transportation system, of course, is knowledge. Knowledge is power, the ability to do more creative, useful things, here on Earth, as well as in space. It is impossible to place a price tag on the value of the new scientific knowledge and engineering technology advanced through research and development in the space program.

We will soon have operational meteorological, communication, navigation, and geodetic satellite systems. These systems will give us our first tangible returns from our space program, the kind of hard cash returns that make cash registers jingle, the kind of returns that business leaders and stockholders understand. We shall soon be able to place into orbit and to send further out into space much larger payloads, with greater capabilities.

Ever since the Space Age began, the United States program has suffered from a booster capability gap. This handicap will soon be removed. The Saturn IB will carry payloads of 18 tons, and the Saturn V will place payloads of 140 tons into Earth orbit. At our present level of effort, we should be able by 1969 to produce and launch up to six Saturn IB and six Saturn V vehicles a year. Even without uprating their performance beyond the payload figures just quoted, we will have the capability of orbiting almost 1000 tons of payload annually with these two launch vehicles by the end of this decade.

The ninth Saturn I in a series of 10 research and development firings was launched from Cape Kennedy on Tuesday morning of this week, placing the second Pegasus meteoroid technology satellite into orbit. The second Pegasus is operating just as well as the first one, and is sending us valuable data which will be extended to gage the possibility of an astronaut's getting hit by a meteoroid in space. We hope that our unbroken string of successful launches in this program will hold through the launch of the tenth and last Saturn I later this year. Naturally, the success of the Saturn I launch program has been a source of acute embarrassment to us.

The Saturn IB will be the first man-rated Saturn. It will place three astronauts into Earth orbit in the Apollo spacecraft for prolonged periods and for practice of the rendezvous and docking maneuvers which will be needed later on the lunar landing mission. The first flight booster for the Saturn IB was manufactured at our Michoud Operations in New Orleans by the Chrysler Corporation. It was shipped to the Marshall Center where it went through its static firing program with flying colors, and it has now been returned to Michoud for checkout before being shipped to the Cape for launching in early 1966.

The first flight version of the S-IV stage—the second stage of the Saturn IB—is undergoing static testing by the Douglas Aircraft Corporation at Sacramento, California. The first manned Saturn IB flight is scheduled for 1967.

Now, let me talk a little bit about the big one—the Saturn V Moon rocket that will carry our astronauts to the Moon. The first stage of the Saturn V Moon rocket is well into its static test program. The first firing was held at the Marshall Center in April—3 months ahead of schedule. The Boeing Company is producing S-IC stages for us at Michoud.

A battleship S-II stage—the second stage of the Saturn V—is being put through its static firing program by North American Aviation at Santa Susana, California. All five engines have been fired successfully. The Saturn V will use an S-IVB stage as its third stage. This stage is farther ahead of the other Saturn V stages, as it is also used in the Saturn IB.

The first test flight of the Saturn V is scheduled for 1967. The first manned flight is set for 1968, leading to the lunar expedition, hopefully by 1969. And we have a very good chance of doing so.

When the Saturn IB and the Saturn V become operational, we must make certain that we are not handicapped by a payload gap—that is, we must have worthy payloads to match our huge booster capability.

For years we have had to miniaturize our payloads, trying to squeeze every bit of scientific equipment we could into the limited lifting capacity of our launch vehicles. The advances in the art of miniaturization of equipment have been amazing—without them NASA's impressive advances in the space sciences and applications would not have been possible. Miniaturization buys more than weight and space savings. It also increases reliability by making room for backup systems, providing redundancy in case of malfunction of equipment. But we will not be forced to miniaturize as heavily in the future. We could not miniaturize the astronauts in our manned space flight program, anyway, so we might as well get used to using bigger, sturdier equipment.

The enormous transportation capability being developed in Project Apollo will enable us to produce and launch vehicles and spacecraft at a fraction of the initial development cost, as Dr. George E. Mueller, Director of NASA's Office of Manned Space Flight, explained to you in his discussion of the Apollo Extension Systems.

Our present-day launch vehicles with their relatively small payloads can be compared to the small puddle-jumping airplanes used in the beginning of commercial passenger and air freight service. If you had suddenly given one of these early pilots a Boeing 707, he could not have used it. He did not need it, for he was practically begging for business, even with the limited carrier capacity he had.

The air traffic grew with the transportation system. Our position today in space transportation systems is similar. The Saturn vehicles will be the heavy duty carriers of the next two decades. Our space traffic must grow with them.

NASA has been making studies for some time to exploit the growing payload capability of our space launch vehicles to the best advantage. Using the space transportation system developed in Project Apollo will enable us to produce and launch vehicles and spacecraft at a fraction of the initial development cost. This hardware can carry a variety of payloads, both manned and unmanned, into Earth orbit, into lunar orbit, and for investigation of the lunar surface, as Dr. George Mueller explained to you in his discussion of the Apollo Extension Systems.

We have already come up with thousands of ideas as to how the Saturn launch vehicles could be used profitably—but we need more suggestions. The Saturn V, with a payload capacity of 140 tons, can place into Earth orbit in one launch the weight of all the payloads NASA has launched since it was formed in 1958. This space-hungry and weight-hungry monster can gobble up experiments in a hurry.

Right now our experimenters are still standing in line to get their equipment into space. But we shall need more and more suggestions for useful experiments, and we need them now, for it takes time to plan, design, and build the necessary equipment. NASA has held conferences with scientists from all over the country—not just those already involved in the space program—asking them to join hands with us to help unfold the mysteries of the universe. We ask them to think big—not in terms of a puddle-jumping airplane available in 1920—but in terms of a Boeing 707.

We would like to know what the geologist thinks of using a satellite for locating mineral deposits. How could the agriculturist use satellites to measure crops, to estimate crop yields on a wide scale? Would they be useful to the wildcat oil speculator? Could they be used for flood control or for better management of our shrinking water resources?

We want *you* to start thinking about how you can use the tools we are developing for space exploration. You have been coming to these conferences on the peaceful uses of space for 5 years. You have probably been sitting here for the past 3 days waiting for someone to come up with a bold new idea that would show a practical application of benefit to you.

When I asked one of the attendees at last year's conference in Boston to tell me frankly why he was there, he said: "To tell the truth, I'm really more interested in the useful pieces of space than the peaceful uses."

I hope you soak up enough information about the current status of NASA's programs and its planning to give you some food for thought when you get home. Perhaps a seed for an idea will be planted, and you, yourself, can come up with that bold new idea for a useful piece of space.

I have been asked to spend a few minutes on what comes next after the Apollo Extension Systems.

As you know, any forecast of what space exploration will be like more than 5 years from now is not a forecast—it is a prediction, in the same league as crystal ball gazing. But since this is an after-luncheon gathering and not a program planning session, let us let our imaginations roam.

Space projects of the future will naturally be based on the extension of today's technology, just as our achievements today are based on discoveries and advances reaching far into the past.

One of the key elements in determining the direction of our progress in space is the availability and capability of dependable, economical, operational launch vehicles.

The Saturn launch vehicles will be the backbone of our space program for years to come. Recovery and reuse of the first stage of the Saturn V is under consideration for the decade of the seventies. By improving the Saturn V's propulsion systems, and possibly developing a new engine for the upper stages, we can increase its payload capability by more than 50 percent. In the long run, however, reusable space vehicles will give us the higher reliability and improved economy we seek.

As long as we use expandable launch vehicles to honor round-trip tickets for passenger transport, we must face a 5-million-dollar fare for Earth-to-orbit flights and a 50- to 100-million-dollar trip fare for a lunar round trip in the early to mid-1970's. This is obviously a long way from commercial space flight, even though 2000 new millionaires joined the ranks of the wealthy last year.

We would like to see Earth-to-orbit trips as convenient and cheap as a trip to Europe and a flight to the Moon no more expensive than a trip around the world today. To realize this ambition, we would need to average more than 49 successful flights out of 50 from Earth to orbit and return with a space vehicle carrying 50 passengers on each flight. And for a lunar flight, we would have to have approximately 24 out of 25 successful flights with 10 passengers aboard each time. We cannot expect to open the first commercial space line to Earth orbit until 1985 or later.

The reusable vehicle seems to be the key to development of an economical Earth-to-orbit transportation system. Passenger conveniences must be improved so that scientists, engineers, technicians, military personnel—and even politicians and journalists—can make the trip.

One of the methods we have been studying several years combines the experience gained in the X-15 rocket plane program with present Saturn know-how, for building a high performance two-stage rocket "plane"—called the Reusable Orbital Transport. It appears entirely practical to develop a vehicle that would not subject passengers to more than 3 g in ascent or descent.

In the orbital transport under study, the first stage would fly mission paths similar to the X-15, with the second stage, carrying passengers and cargo, launched from a piggy-back position. The second stage would fly into and out of orbit, gliding to a power-off landing after reentry in the same manner the X-15 does now as routine procedure.

It would offer passengers who are in a hurry transportation over global ranges with about 1-hour flight time. If we can develop a single or two-stage chemical rocket aerospace vehicle and learn to fly it over and over before it is worn out, the high-income traveler should find the operational cost acceptable. But, of course, the thing we must have is the demand—the traffic, cargo, and passengers—to make the system economical.

After we have tried our wings in the immediate Earth environment, our next major step in exploring and utilizing the solar system is the Moon. And after that, the planets.

The Moon is a big place, and it will probably require more than a decade of hard work before we explore its environment in the detail that we would like. Look at Antarctica, for example. We have had hundreds of people there at a time for more than a decade, and the number is still increasing.

During the 1970's we shall have to be satisfied with a lunar transportation system based on the Saturn/Apollo spacecraft capabilities. By the 1980's we can look forward to a reusable Earth-lunar transportation system, which should make transportation costs 30 times more economical than those of the Apollo system. The development of nuclear propulsion systems is a prerequisite for such an improvement.

Such systems would use a chemical reusable rocket plane to orbit, a reusable nuclear ferry from Earth orbit to lunar orbit and back, and a single-stage chemical lunar shuttle bus to carry cargo and personnel between lunar orbit and the lunar surface. The nuclear ferry vehicle would be refueled in Earth orbit and the lunar shuttle in lunar orbit. We have studied this system in quite some detail. Costs for a lunar round trip could be reduced to about 3 million dollars a man, using a solid core nuclear propulsion device. If and when we learn to manufacture propellants on the surface of the Moon, this concept could be further improved, and one round trip might cost less than 1 million dollars per person—compared with roughly 100 million dollars today. We are basing our expectations on a solid core nuclear propulsion system based on the KIWI reactor being developed jointly by the Atomic Energy Commission and NASA.

We are just now beginning to explore the planets, having made one probe of Venus, with another on its way to Mars. Manned exploration of the planets will have to wait until nuclear propulsion and more economical large launch vehicles are available. The first manned flyby missions to Venus or Mars could be made by the mid-1970's if resources are allotted for this purpose and all the tricks of the trade are called upon.

The first landing on Mars or on one of its moons must wait until the 1980's.

What are the essential requirements of a transportation system for taking men to Mars? For launches from the surface of the Earth we would need improved Saturn V's, post-Saturn launch vehicles, or even better, reusable launch vehicles, coupled with orbital operations and nuclear propulsion. Life-support systems, power supplies, navigation and communication, environmental protection, and Earth-landing systems would have to be developed or improved greatly over requirements for the lunar landing mission. Before we can go to Mars with a group of scientists for an extended stay, we would need, more than anything else, a highly efficient nuclear propulsion system for the deep space portion of the journey. Without a nuclear propulsion system for a manned expedition to Mars the logistics would be staggering, and the cost would be prohibitive.

Our trip to the Moon is merely a scouting expedition, such as an army would send out before advancing over unfamiliar terrain. It is a demonstration that the pilots and their machine can make the journey, like Lindbergh in his *Spirit of St. Louis* crossing the Atlantic. After Apollo will come the invasion of the main body for man's true assault on space. Pilots and passengers, scientists trained as observers and experimenters, will follow in wave after wave to explore space in a big way. We must set up bases, establish logistics lines, maintain communications and furnish reinforcements for continual, frontal assault. The research and technology required to reach the Moon will open all kinds of doors to future space operations.

The year 2000 should find mankind well on his way toward exploitation of the solar system. This is the challenge of our century. We must not limit our vision, suppress our curiosity, or dilute our determination.

Men should be living on the Moon as a matter of course by the end of this century. In fact, we should just be paying off the "20-year FHA mortgage" for construction of our first lunar bases. Scientists, engineers, and technicians will live in several bases scattered over the Moon's surface, visiting their neighbors by rocket ship. They will have ground vehicles for shorter trips in the area of the base. These Moon residents will perform a variety of research, manufacturing, and commercial work and will be able to supply most of their own life-support needs. They will use their water over and over again, grow much of their food supply, and provide their own oxygen with the help of plants.

A radar astronomy observatory on the far side of the Moon, shielded by the Moon's mass from all radio interference from Earth, will be studying the Sun and stars.

Some people still say that man cannot exist on the Moon—that there is no atmosphere or water, and the extreme temperature ranges are unbearable. Well, man has learned to live here on Earth under unbearable conditions. He lives under the ocean in a submarine for weeks at a time. He flies across the country at an altitude where life would be unbearable without protection—but he rides in comfort in a pressurized cabin, reading, watching movies, or sipping a martini. And we do not have to breathe hot desert air—we have air conditioning. Our astronauts have already carried their own environment into space. We have the technology to be self-sustaining in space, independent of our natural environment on Earth. There are three steps in the expansion of culture: exploration, base establishment, and colonization. The last stage, colonization, is not reached until people become permanent residents of a new area. They live there with their families, develop their own economy and society, and become more than self-sufficient—even building up a favorable balance of trade with older established societies.

If we can make our space transportation systems economical enough, who can say that man will not colonize other heavenly bodies?

We have seen ancient civilizations rise and fall, but their cultures have been transmitted to other people, in later ages and other localities. The ideas of these ancient people have been transmitted through two methods—buried under ashes, later uncovered by archeologists, or from the depths of men's minds. During the period of the Dark Ages in Europe much of the noble character of the Roman civilization was preserved in the minds of monks, and later brought back into common use to make major contributions to our civilization today.

Knowing the tenacity of men's minds, I find it easy to speculate that the human race might some day spawn another civilization on another heavenly body.

Given enough energy, to use freely for any purpose we choose, we might be able to transform the environment of Mars, for instance, to make it more amenable to earthlings. We might learn enough to change the surface temperature of the planet, or the make-up of its atmosphere. It might take decades for man to learn enough to undertake such a project, and even centuries to accomplish it. But if he should succeed, he would truly be walking among the stars.

Let us hope that in thus challenging nature—learning to walk among the stars—we attain the most significant goal of all—learning to walk the Earth with our fellow man—in peace.

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SPACE EXPLORATION OPPORTUNITIES AND IMPLICATIONS

Chairman
Thomas H. Eliot
Chancellor
WASHINGTON UNIVERSITY

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SPACE EXPLORATION AND ITS ATOMIC ENERGY IMPLICATIONS

Gerald F. Tape
Commissioner
U.S. ATOMIC ENERGY COMMISSION

Atomic—or more precisely nuclear—energy will provide opportunities for more advanced space missions in future years. As an alternative to chemical and solar energy, it provides unique features which will permit the undertaking of missions of greater complexity and longer duration.

The main thrust of the research and development program of the Atomic Energy Commission is on energy—the energy derived from the nucleus, that is, from nuclear fission, from nuclear fusion, and from nuclear decay.

The utilization of fission energy is generally accomplished through a thermodynamic cycle where heat is transferred to a working medium, such as water or a liquid metal, and used to drive a turbine to produce mechanical energy and if desired electrical energy through the use of a generator. In some instances, methods employing direct conversion from heat to electrical energy have been employed, thereby bypassing the need for rotating machinery.

The utilization of energy resulting from the change from one isotopic species to another through radioactive decay follows a similar process wherein heat is derived from the energy of the decay products, that is, alpha, beta, and gamma rays.

The Atomic Energy Commission has fostered the development of civilian nuclear electric power to the point that nuclear power is being selected for some new large electric power plants because of its favorable economics in competition with other power sources. An analogy to the development of civilian nuclear power can be drawn for the utilization of nuclear energy in space missions. The requirements of today's fully approved missions for on-board electric power can generally be satisfied by non-nuclear energy sources, that is, batteries and solar cells. Similarly, chemical propulsion systems have been developed or are under development for the approved missions and early post-Apollo missions. But as mission times grow longer, payloads become larger, and the demands for on-board electric power increase, nuclear energy sources must be introduced.

Basically, nuclear fuel is compact and long-lived. The complete fissioning of one gram of uranium-235 releases almost 25 000 kilowatt-hours or 3 kilowatt-years of energy. Obviously, I have not taken into account the efficiency of utilization of the heat or conversion to electricity; however, it is clear that even with extremely low efficiencies for the utilization of the fuel, nuclear fuel is extremely compact.

Similar considerations hold for isotopic fuels wherein the power density of the isotopic compound may run over a thousand thermal watts per cubic centimeter for the shorter half-life alpha emitters to a few watts per cubic centimeter for the longer lived alpha and beta emitters. With isotopic power sources, the initial power level is set by the quantity of material in the source; the rate of heat release is dependent upon the specific radioisotope used and the initial quantity. The rate decreases with time, decreasing to half of its initial value in a time equal to the half-life of the decaying isotope.

The compactness of fission and isotopic fuels makes it possible for the overall system to be relatively compact even though much equipment is necessary to convert fuel heat to electric power or to thrust.

ON-BOARD ELECTRIC POWER

In a recent report by the National Aeronautics and Space Administration to the President,[1] the Future Programs Task Group identified spacecraft electrical power sources as one of several areas requiring support of research and technology today in order that long-range missions can be undertaken in the foreseeable future.

The NASA report notes that "possibly the most clearly defined need for a major advance in technology is in the area of spacecraft electrical power sources." Figure 1 taken from the NASA report indicates the anticipated trend in power level requirements for various future missions. These start with today's technology of a few hundred watts and increase to levels of a hundred kilowatts and more.

Summarizing from the NASA report, it is noted that the current Mariner spacecraft uses on the order of a few hundred watts obtained from solar cells. Planetary exploration spacecraft such as Voyager will require about 1 kilowatt, and six- to nine-man orbiting laboratories will require many kilowatts. With the introduction of more advanced missions, such as extended lunar expeditions, manned Mars fly-by missions, and large manned space stations, the power requirements will approach 50–100 kilowatts. Missions requiring power in excess of 100 kilowatts can be visualized and, indeed, power consumption by ion engines, or any other primary propulsion system that is electrical, would be on the order of several megawatts.

The NASA report also points out that radioisotope sources have a great potential range of application from the point of view of weight, size, and lifetime, and that many future missions depend upon the development of isotopic power sources in the 500- to 1500-watt power range. Nuclear reactor power plants will be needed for missions such as extended lunar base operations, manned interplanetary flights, and electric propulsion. In addition to the normal developmental efforts required for any new device, nuclear systems such as gamma-emitting radioisotopes and nuclear reactors require shielding, and that shield weights are a significant problem. Furthermore, the report notes that when the isotopes plutonium-238 and polonium-210 are used, consideration must be given to availability since they are reactor products.

In considering the types of missions for which nuclear-powered electrical systems are required, we must examine the criteria by which they will be rated.

[1] "Summary Report—Future Programs Task Group," a report by the National Aeronautics and Space Administration to the President, published by the House Committee on Science and Astronautics, April 1965.

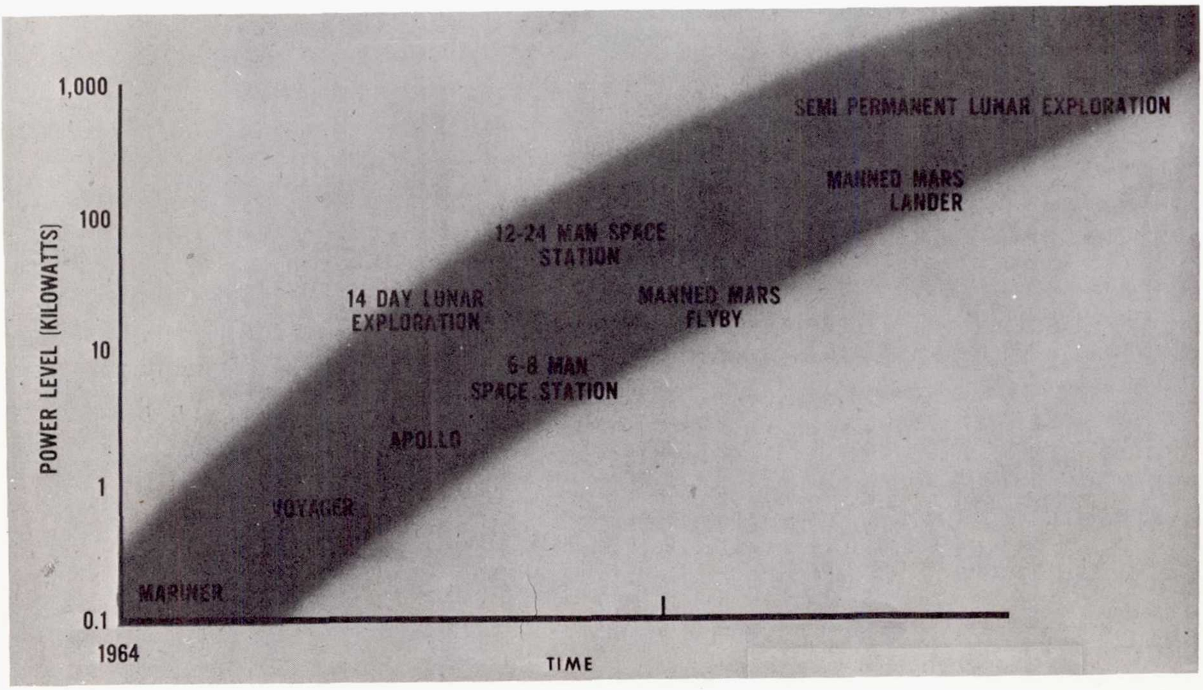

FIGURE 1.—*Spacecraft power requirements.*

First, we can generally forget about the short-lived missions. If a power system must operate for only a few days to a very few weeks, the use of either batteries or fuel cells will probably permit the lightest, smallest, cheapest power package.

The weight of the system to be launched is of obvious interest. A reactor has to be of a certain minimum weight and have a shield to protect the payload or crew from radiation. Where this weight is acceptable, a considerable amount of additional power can be produced without greatly increasing the weight of reactor or shield. Because of the shield weight solar cells and radioisotopes will be lighter than reactor systems at the very low power levels, but because of their ability to produce additional power, reactors will pull ahead as power levels get higher. This minimum weight feature of reactors is a vital factor in planning future power concepts.

The size of the system often determines how difficult it will be to package in a given launch vehicle envelope. Solar cell system size is determined by the area which must face the sun in order to intercept the solar energy needed. On the other hand, the size of nuclear systems will depend on the radiator area required to dispose of the waste cycle heat. Generally it takes less area to dispose of energy than to intercept it from the Sun, and nuclear systems therefore will be smaller in area than solar systems.

Reliability is so important that the weights, sizes, costs, and other system characteristics should not be compared without taking differences in reliability into account. Since by and large nuclear power is a newcomer, the reliability of specific nuclear systems remains to be demonstrated.

From these criteria you can begin to see a trend, illustrated in figure 2, which is similar to the previous figure contained in the NASA report. However, in this instance we have been so bold as to add a time scale along the abscissa and have further delineated with horizontal lines the power ranges in which the different types of energy sources may become predominant. The sloping lines bracket the anticipated increasing power requirements with time. Solar and isotopic sources are for missions of longer than a few days to a few weeks duration. For these long-life missions at very low power, reactors are excluded because of their high minimum weight. At the highest power levels solar systems will be too large and the quantity of isotopes required would make their use infeasible. In the middle there is a region in which solar, isotope, and reactor systems will compete.

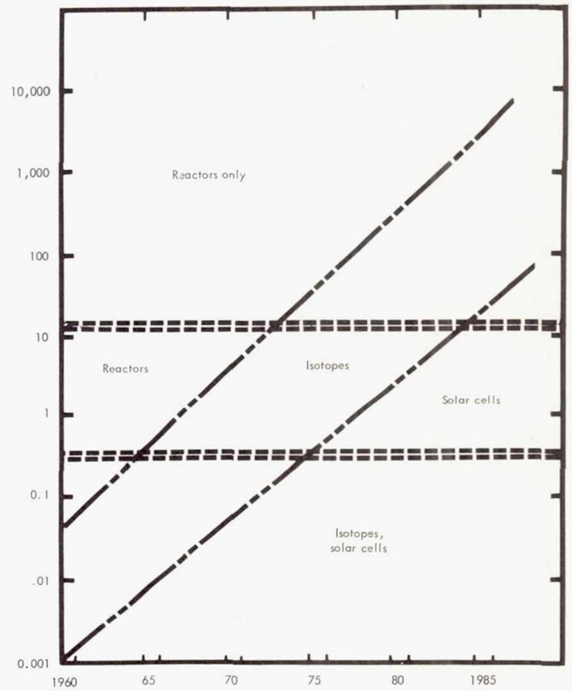

FIGURE 2.—*Power levels and power concepts.*

Both isotopic and reactor power units have been launched and operated in space. SNAP-3 and SNAP-9A, 3 and 25-watt plutonium-238 fueled isotopic units, respectively, are Defense Department satellites, the first SNAP-3 being launched in 1961. The launch by the Air Force on April 3, 1965 and the orbital startup of the 500-watt SNAP-10A marked the world's first operation of a nuclear power reactor in space.

Figure 3 is an illustration of the SNAP-10A atop the Agena upper stage. A cutaway drawing and the flow diagram of the power unit is shown in figure 4. The SNAP-10A unit was designed and built by Atomics International and integrated into the Agena rocket by the Lockheed Missiles and Space Company. Liquid sodium-potassium metal alloy is heated to about 1000° F as it flows through the reactor core. The thermoelectric pump mounted above the reactor uses a small part of the heat contained in the fluid to cause the liquid to flow, using no moving parts. The heat from the liquid metal is radiated to space through thermoelectric converters. Thus, after the shutoff of the controller, a few days after launch, the entire plant operates with no moving parts except the smoothly flowing heat transfer fluid.

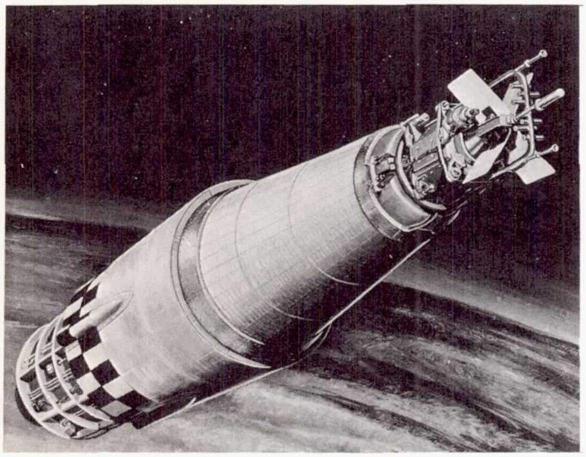

FIGURE 3.—*SNAP-10A in orbit.*

On May 16, after 43 days of successful operation, the unit failed to report; later, diagnostic systems aboard the unit indicated the reactor had shut down. Analysis of the data and laboratory tests have shown that the shutdown was probably caused by a sequential failure of electrical components initiated by a voltage regulation failure.

In addition to the many confirmations of assumptions and design methods, SNAPSHOT (the orbital test of SNAP-10A) has given us valuable information which will be used in future designs. For example, the ground handling and launch support activities for SNAPSHOT imposed no new or unique equipment or procedural requirements. The SNAP-10A system with its reactor fueled and with its liquid metal system filled was shipped from Santa Susana to Vandenberg Air Force Base by commercial carrier. The planned reactor safety measures imposed no constraint on personnel access to the launch vehicle. In all respects, the SNAPSHOT launch proceeded in a routine manner. The reactor behavior during the 43 days of power operation in orbit coincided with the ground test experience. During system operation the converter isolation resistance decreased with a resulting power loss of 7 watts. The behavior was similar to ground test experience and apparently attributable to pyrolytic decomposition of system organic outgassing products on the hot insulator surfaces of the converter. Preliminary information indicates that the estimates of the effective heat sink temperature of space were more conservative than necessary.

The SNAPSHOT inflight measurement of greatest technical value was the verification of the effectiveness of the radiation shield. This quantity is indeterminate by a factor of 10 to 100 in any ground test environment. The containment and shield walls of a ground test environment scatter an appreciable dose around the shadow shield and into the payload region. The space results reveal that shield performance on the average was essentially as predicted.

Finally, the first generation SNAP-10A system demonstrated 600 watts initially, no control after startup, and 535 watts at the end of 43 days. Overall, the SNAP-10A flight test proves one vital thing: it is possible, and *practical,* to build a space reactor power plant, to put it through a usual rocket launch sequence, to start it, and to have it operate in orbit.

DEVELOPMENT OF ISOTOPIC UNITS

Comparing isotopic space power systems with the familiar solar cell systems for low-powered, long-lived applications, the advantages of isotopic systems over the solar powered units are:

a. less battery storage needed because electrical generation is stable and independent of Sun and shadow conditions

b. smaller in size and less sensitive to space vehicle configuration constraints because of higher power per unit area and no dependence on solar flux or orientation (as the power level increases, the orientation devices for solar power systems become the limiting factor in their reliability while the isotope units are completely static)

c. less sensitive to the severe temperature and radiation environments of space

d. provision of a completely reliable and predictable source of heat for thermal control, or other uses, in the space vehicle

For certain interplanetary probe missions such as the Voyager mission, advanced Pioneer solar probes and lunar surface explorations, isotopic power systems appear to be far superior to other types of power systems. The inherent long-lived, reliable operation of radioisotope thermoelectric generators offer significant advantages for systems using continuously operating Earth orbital satellites, for example, communication, navigation and meteorological satellites. In these cases, the development costs associated with integrating the nuclear unit into the satellite can be written off over a number of missions, and the longer operating lifetime makes it possible to avoid the logistics

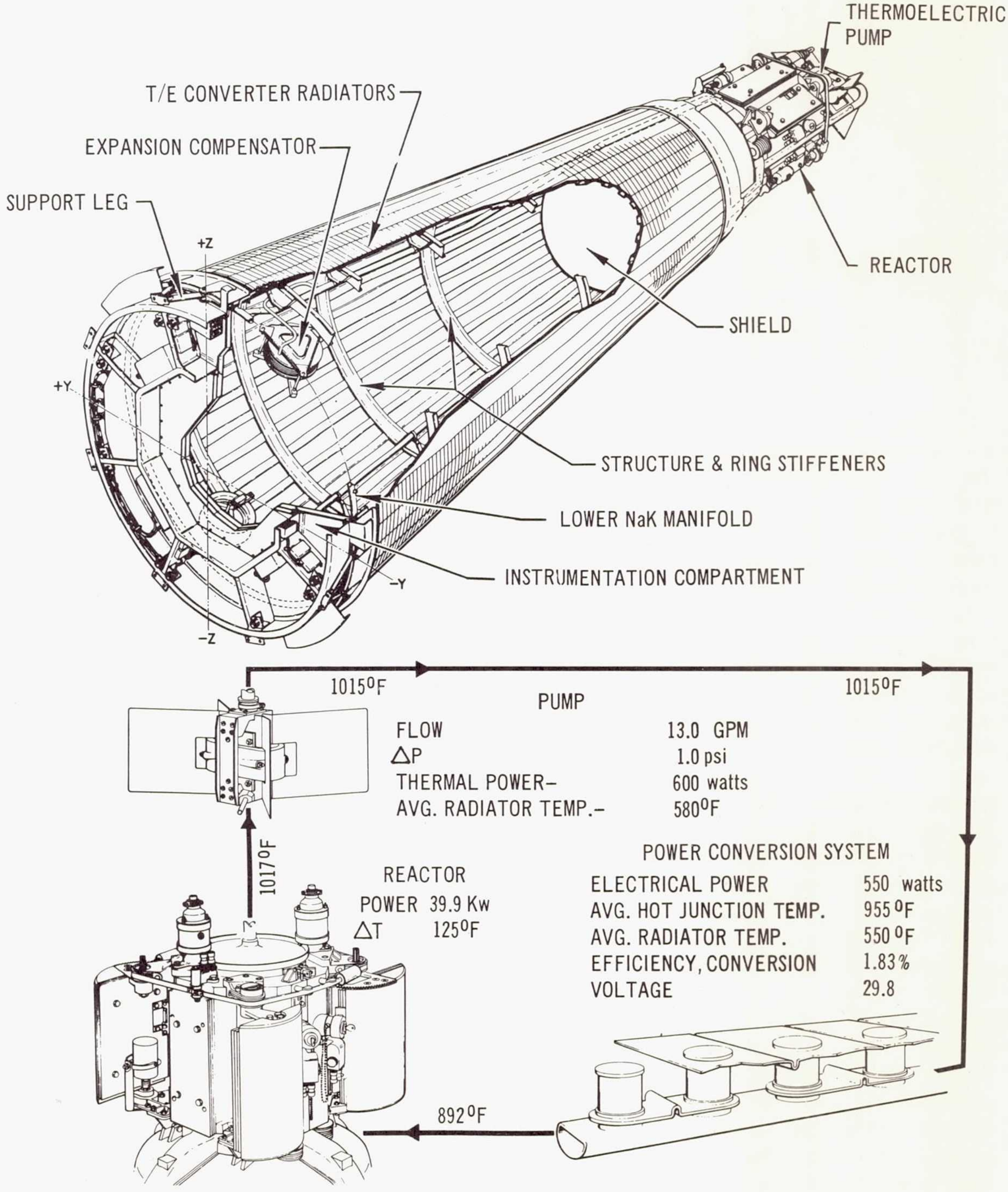

FIGURE 4.—*SNAP-10A system and typical cycle conditions during actual operation in orbit.*

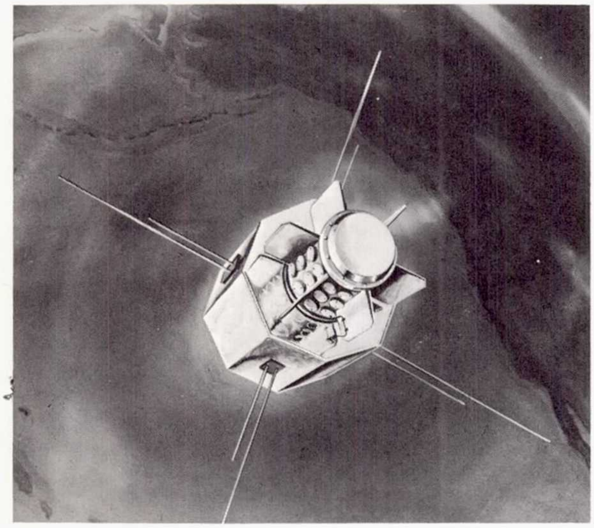

FIGURE 5.—*SNAP-9A in orbit.*

costs of additional launches needed for shorter-lived satellites.

The SNAP-9A (fig. 5) is a 25-watt, plutonium-238 fueled generator developed to provide the electric power for a DOD navigational satellite. In September and December 1963, successful launches were completed. These operational power systems are still performing as expected. In April 1964, a third launch with a SNAP-9A unit aboard failed to achieve orbit because of a launch error and burned up in the atmosphere on reentry. Debris collection at very high altitudes confirmed the prediction of this mode of destruction of the source and the fact that radiation levels will not be a hazard to the public.

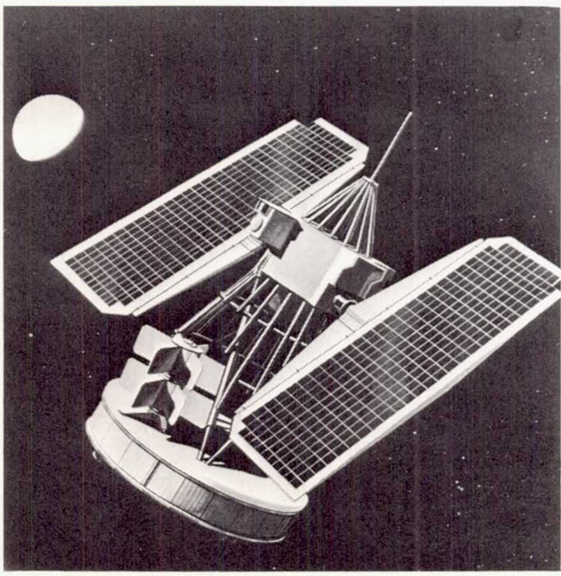

FIGURE 6.—*Nimbus-B in orbit.*

Several satellite programs are considering the use of isotopic power units for future space applications. The SNAP-19 generator is designed to produce 30 watts for at least 5 years. The unit is 22 inches across the fins and 10 inches high. It weighs 30 pounds. It will be fueled with the alpha emitter plutonium-238 isotope which has a half-life of about 90 years. Two SNAP-19 generators will be mounted in tandem to deliver at least 50 watts to Nimbus-B (figure 6) a developmental, meteorological satellite.

The SNAP-25 program is aimed at producing a 75-watt plutonium-fueled system that will weigh about 37.5 pounds. This would be a 2-watt-per-pound system much superior to the 1-watt-per-pound SNAP-19. Approximately 2 years will be required to develop the technology to the point of flight-qualified, ground-tested prototype generator system hardware. This system will be used to power the experiments in the Apollo Lunar Surface Experiment Package (ALSEP) that will be placed on the surface of the moon by the Apollo astronauts.

We recently initiated work on a 50-watt plutonium-238 SNAP-27 generator for Surveyor power needs in the Lunar Surface Advanced Application Program.

The AEC has also initiated the design of isotopic power sources for the low kilowatt range. These sources would be used as subsystems for space electric power supplies for various manned and unmanned missions requiring 1–10 kilowatts. For example, a conceptual design of a 500-watt modular thermoelectric unit having a lifetime of 120 days and using polonium-210 was predicted to be very competitive on a weight basis with fuel cells for manned missions. Because of higher thermodynamic conversion, isotope-heated Rankine and Brayton cycle units are under investigation for use in the 1–10 kilowatt power range.

DEVELOPMENT OF SNAP REACTORS

The SNAP-10A described earlier is one of a family of systems under development which share a common reactor technology. This family using the zirconium-uranium-hydride technology is the principal effort in the SNAP reactor program for space power up to about 100 kilowatts.

SNAP-8 is one of the same family but operates at

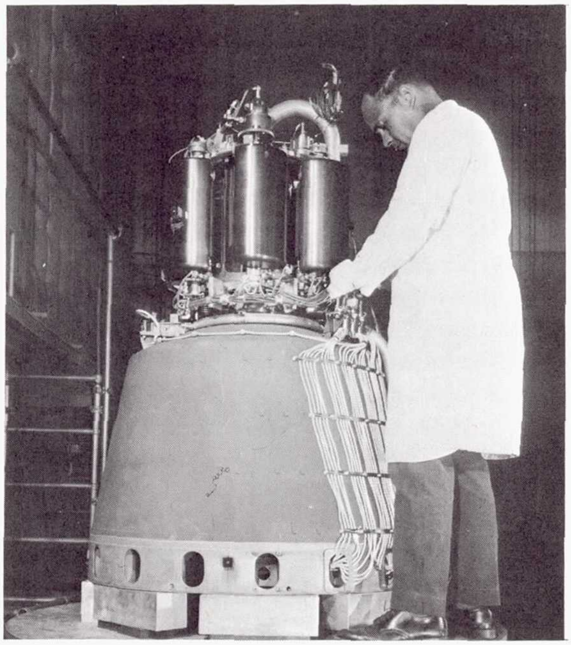

FIGURE 7.—*Photograph of SNAP-8 reactor.*

a higher temperature, 1300° F. A SNAP-8 reactor (figure 7) has just completed over a year of power operation in which it demonstrated a 1300° F capability. The NASA SNAP-8 mercury Rankine cycle power conversion system, which was being developed concurrently with the SNAP-8 reactor, has been ordered into a termination phase by the President's FY 1966 budget.[1] This was to be a rugged, reliable, "state-of-the-art" system applying conventional conversion machinery technology. The system was designed for 35 electrical kilowatts output with growth potential to approximately 100 electrical kilowatts.

Still within the temperature range of this reactor family, in order to increase the electric power output, a more advanced turbine-generator using mercury vapor also is being developed. The unit is called a combined rotating unit because the turbine, generator, and mercury pump are all mounted on the same rotating shaft. Several successful 90-day tests with a 3.5 kilowatt unit have been completed. There are under development thermoelectric modules which, with the SNAP-8 reactor, will be able to produce about 20 electrical kilowatts, and perhaps more if we are able to achieve a possible increase in system efficiency.

Even more advanced technology is required for the large power systems needed for future missions, especially those which will use electric propulsion. For example, the SNAP-50 concept is a high temperature turboelectric system using liquid lithium to cool a reactor made of refractory metal and potassium vapor to drive the turbine generator.[2] With a reactor outlet the temperature would be around 2000° F; and at the 1000-kilowatt power level, the SNAP plant would weigh only about 20–30 pounds per electrical kilowatt, as compared to about 200–500 pounds per electrical kilowatt obtainable from the 1300° F reactor systems and the isotope systems mentioned earlier. Several technological developments, all of which are ultimately dependent on high temperature operation with refractory metals, are under study for systems to produce more than 100 kWe.

Figure 8 is our basic planning chart showing where each of these AEC programs fits in the overall picture. Note the position of the orbiting units SNAP-3, SNAP-9A and SNAP-10A. The diagonal band repre-

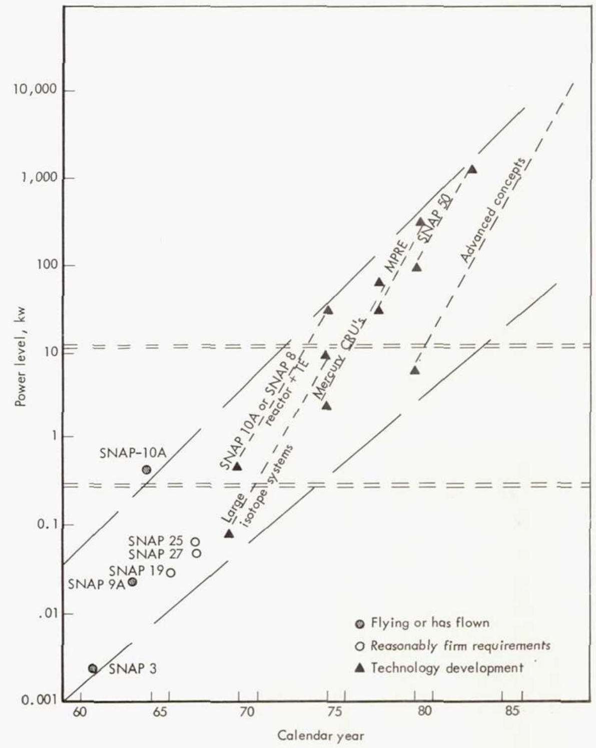

FIGURE 8.—*Requirements schedule and AEC program.*

[1] Subsequently, the President's FY 1967 budget requested funds for continuation of the SNAP-8 power conversion system development.

[2] In July 1965, the SNAP-50 Program was redirected from the 300 KWe system development at Pratt & Whitney to a broader based technology program at Lawrence Radiation Laboratory.

sents the estimated required power levels for the years shown on the horizontal axis. The dashed lines represent the power level or range of power available from each of the concepts discussed. Note that the next generation of isotope and reactor systems will be available to meet the requirements of the late sixties and early seventies. Then, in the late seventies and early eighties, when the big power needs first occur, one or more systems presently under development as an advanced concept will be available. By following such a program we expect to be able to meet the requirements of the future.

NUCLEAR PROPULSION

The past year has seen dramatic progress in the development of nuclear rocket propulsion and, as a result, marks a milestone in the history of propulsion capability. The series of successful tests of this past year was the surface manifestation of work initiated at the AEC's Los Alamos Scientific Laboratory late in the 1950's.

In the nuclear rocket program, known as the ROVER program, the AEC, working jointly with the NASA, is providing the technology for the systems that will be required as our efforts in space proceed beyond the Apollo manned lunar landing program. The distinguishing feature of a nuclear rocket is that the energy of the nucleus is used to heat directly a propellant which is then expanded through a nozzle to produce thrust.

A schematic sketch of a nuclear rocket engine which employs a nuclear reactor is shown in figure 9; the major components being the nuclear reactor, the liquid hydrogen turbopump, and the jet nozzle. Liquid hydrogen is stored in a propellant tank, not

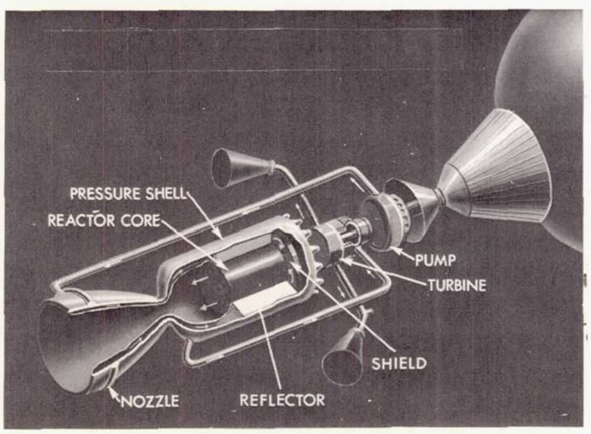

FIGURE 9.—*Nuclear rocket engine.*

shown, and pumped through the reactor system where the enormous energy of the nuclear chain reaction is used to heat the hydrogen to very high temperatures. In using hydrogen as the propellant, we are using the lightest molecular weight material and, therefore, the most efficient propellant for a rocket propulsion system. It gives a specific impulse, which is the measure of efficiency of propellant usage, at least twice as great as that of chemical rocket engines. Since propellant weight is the largest fraction of a rocket vehicle's gross weight, the propellant weight savings enables much larger payloads or, alternatively, smaller vehicles to provide a given payload.

To provide the technology necessary to develop these nuclear rocket systems, we are working in a variety of fields. The major portion of the effort has been and continues to be in graphite reactor systems. During the past year four such reactors have been tested successfully. In these tests there was demonstrated a specific impulse of more than 760 pounds of thrust per pound per second of propellant flow (as compared with 300 to 450 for the most advanced chemical combustion rockets) at a thrust equivalent of approximately 55 000 pounds. Also, it was demonstrated that the reactor could be restarted and recycled to full power. Most recently a single reactor ran for 7 minutes, was shut down automatically by a spurious signal, and 4 weeks later was restarted and ran for an additional 18 minutes. The length of the second run was limited by the hydrogen supply. Full-power operation occurred for 16 minutes out of the total 25 minutes of operating time. This is a long time in any high-thrust rocket test, particularly at such an early stage of development.

Two of these four reactors were designed and tested by Los Alamos which is providing the basic graphite reactor technology for the program. The other two reactors were designed and tested by the industrial contractor team of Aerojet and Westinghouse as a part of the NERVA nuclear rocket engine program. The work of the NERVA team is to use the basic Los Alamos reactor technology to design and perform the engineering development of the reactor, the development of the non-reactor components that go into the engine, and the integration of these components with the reactor into a complete engine system.

A number of difficult technical issues had to be overcome to reach the present stage of development. It was clearly necessary to develop a satisfactory nuclear fuel element. This development involved gaining a profound understanding of the fuel element material, a combination of uranium and graphite, and of methods of fabrication. The methodology of control of the nuclear reactor, particularly under transient conditions, extended the state-of-the-art of reactor control systems. The design of the reactor to heat gas to very high temperature in an extremely compact size involved complex materials, structural, and nuclear interactions.

Taken together, the tests of the past year show that these problems and others have been solved and that graphite reactor engines can provide the high performance which such systems have promised. Nevertheless, much more work is needed to bring them to the point of operational capability.

Future work is aimed at extending the operating life of the reactor (missions using nuclear rockets will require their operation for up to approximately 30 minutes), pushing for even higher performance from 50 000- to 250 000-pound thrust) in terms of higher power and higher temperature, and operating the reactor together with the nonreactor parts of the engine to gain an understanding of the interactions and interrelationships of the entire system working together. The present program is a ground-based technology effort. Therefore, ultimately it will be necessary also to proceed into full-flight rated system development. Such systems can be available for actual operational use by the mid-1970's.

In addition to this graphite reactor engine activity, the nuclear rocket program encompasses somewhat longer term efforts. One of these embodies a refractory metal reactor. This work is concentrated on tungsten reactors and is being conducted at the Argonne National Laboratory of the AEC and the Lewis Research Center of NASA with work on a fast reactor and a water-moderated, thermal reactor, respectively. There are related efforts on a fast reactor supported by the AEC at the General Electric Company. Basic work on tungsten systems is proceeding in order to determine their feasibility and to determine whether they have any significant performance advantages over graphite reactors. Since performance in the last analysis is limited by the reactor fuel element, the primary work on tungsten reactors is on the fuel materials and fuel element structure. At this time, we do not see any reason to expect a higher specific impulse from tungsten reactors than should be achievable with graphite reactors; the principal gain from tungsten reactors is longer operating duration and, for low-thrust systems, lighter weight. These characteristics may be important in certain specialized missions.

Both the graphite and tungsten reactor activities are based on so-called solid core reactors. This means that the nuclear fuel is retained in solid bodies. The temperature which can be achieved is therefore limited to temperatures at which the solid material retains its structural integrity.

Because of this limitation in solid core reactors, it is to be expected that systems in which the nuclear fuel is used in liquid or gaseous form, thus bypassing this limitation, would be of interest.

Another propulsion concept which has been examined is the nuclear pulse, such as the so-called Orion, (fig. 11). In this concept, small nuclear explosive devices are repetitively ejected from the spacecraft and detonated, providing pressure pulses which operate against the spacecraft through a shock absorber system; these pulses propel the spacecraft. Here again the practical problems of development are great.

Theoretically, the advanced concepts—the liquid and gaseous reactors and pulse systems—have specific impulse potential in the range of 1200 to 4000 seconds. The potential for operational maneuver in space for such systems is large and makes such systems interesting. However, their possible time of availability cannot be predicted without significant technological development.

Thus far in the discussion of nuclear rockets, we have touched upon systems using the energy of the

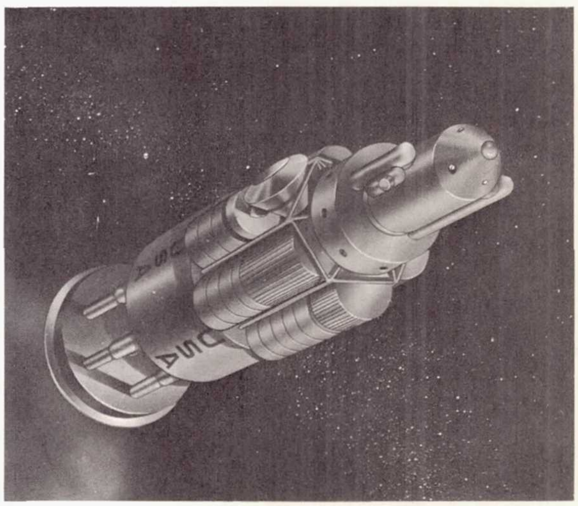

FIGURE 10.—*Orion in space.*

fission process. These systems provide high specific impulse in high thrust systems. Another type of nuclear rocket employs the energy from radioisotopes to heat the propellant. (Such a system is the Poodle, obviously a small Rover.) It offers the possibility of a specific impulse of 750–800 seconds, but in the very low power and, therefore, low thrust range. Work on this system is at an early stage. Figure 11 shows a radioisotopic thruster unit capable of producing $\frac{1}{4}$ pound of thrust along with a possible application of four such thrusters for altitude control or station keeping.

Characteristics of the Poodle are:

a direct-cycle, low-thrust radioisotope-heated rocket engine using liquid hydrogen for the expelled mass about 750-second specific impulse thrust levels of $\frac{1}{4}$ pound per thruster minimum thermal requirements of 1600° C (satisfied by current technology) polonium-210 fuel

- low radiation field
- high-temperature compound
- high power density
- moderate cost
- high potential availability

Such systems are attractive for many missions:

- Earth orbit transfers
- solar and planetary probes
- satellite antidrag maneuvering
- attitude control
- may use boiled-off fuel

The applications are, of course, quite different from those of the Rover or Orion systems.

Referring again to the NASA report, the Future Programs Task Group notes that the two most promising applications for nuclear rocket propulsion are for manned planetary exploration and direct flights of manned spacecraft to the Moon.

Figure 12 schematically shows a Mars mission starting from Earth orbit, proceeding to a Mars orbit, a Mars landing mode, a return to Mars orbit, and finally a return to Earth. The total mission requires approximately 400 days. In this kind of mission, a large vehicle would be assembled in Earth orbit, and that vehicle would then be propelled by a cluster of nuclear rocket engines out on a trajectory toward Mars.

The first stage of the clustered engines would shut down and the vehicle would then coast toward Mars.

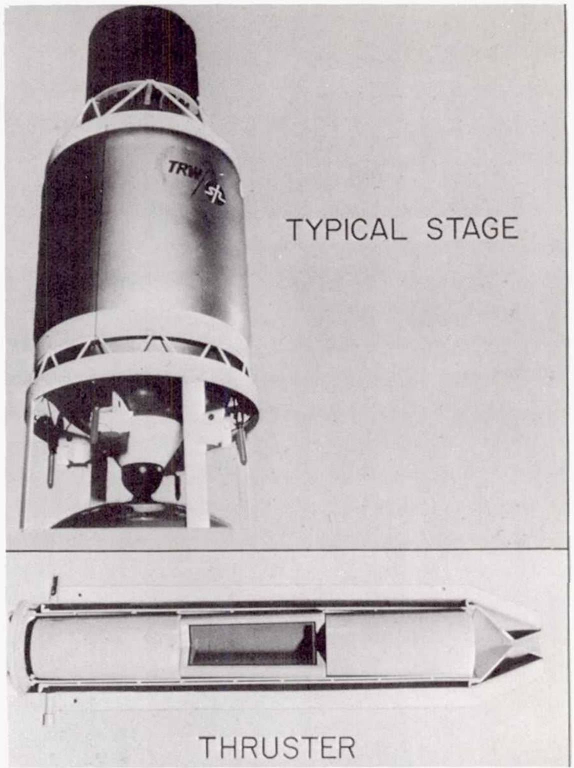

FIGURE 11.—*Radioisotope thruster.*

A second stage would be started to put the spacecraft into an orbit around Mars. Men would land, stay 30 or 40 days—whatever is required, although that time is limited by the movement of Earth and Mars—in order to assure a proper trajectory on the return

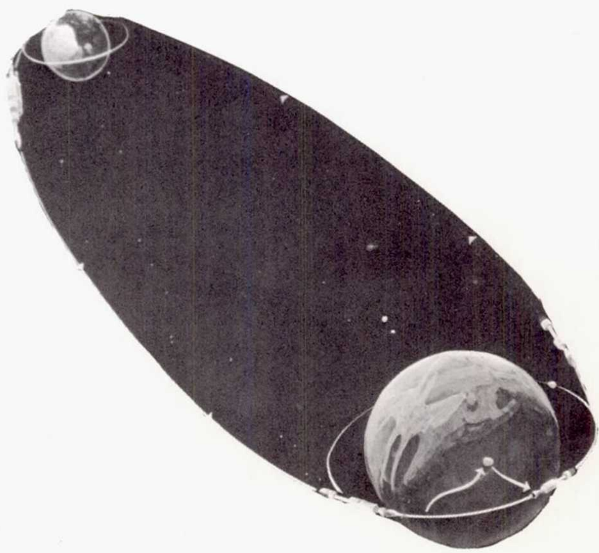

FIGURE 12.—*Mars landing mission.*

to Earth. The men would then return to the orbiting spacecraft.

A third stage, also nuclear propelled, would return the men to Earth. In this case, therefore, we have three stages, each one nuclear propelled. There is a strong probability that the engines in all three stages could be the same, so that there would be a greatly simplified development program.

Figure 13 illustrates how with standardization on a single propulsion module it may be possible to cluster units using, for example, a cluster of three for departure from Earth orbit, a single unit for establishing Mars orbit, and a single unit for Mars departure. Its use as an upper stage in Saturn V is also illustrated.

The weight saving by the the use of nuclear rocket propulsion for a Mars mission is extremely important when one analyzes the requirements with respect to the time of mission launch. Opportunities to launch occur only at about 2-year intervals and the best launch opportunity occurs approximately every 17 years.

The curves in figure 14 reflect the estimated typical weights required in Earth orbit at the time of launch opportunity over the next 25 years. There are two pairs of curves, one for aerodynamic braking during Earth return, the other for propulsive braking during Earth return. The advantage of the nuclear systems is quite apparent. It is conceivable that the Mars mission could be accomplished through nuclear propulsion at every opportunity with adequate flexibility to allow for program changes with time.

Similar arguments can be advanced for the utilization of the nuclear powered upper stage on the Saturn V vehicle to provide a capability for direct landing on the Moon. The added payload would be directly available for carrying life support systems, elec-

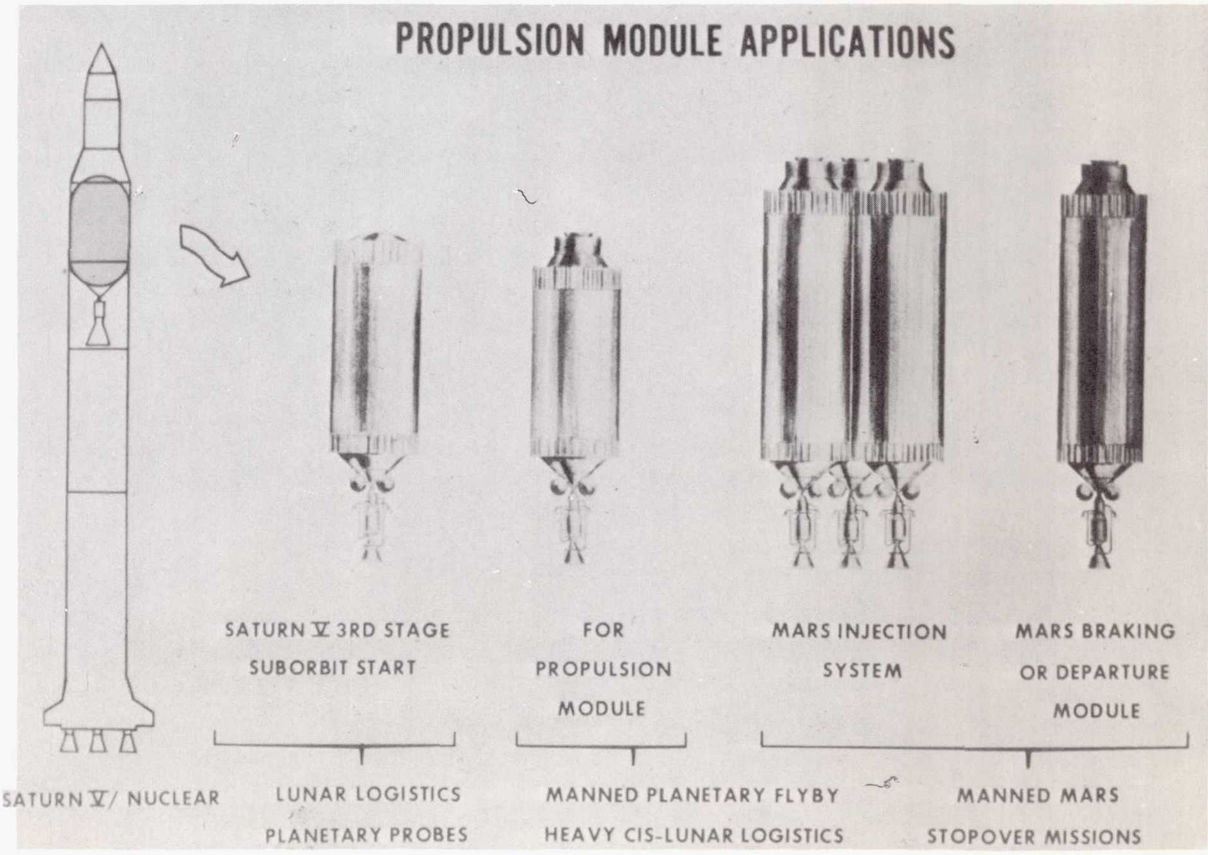

FIGURE 13.—*Nuclear propulsion module applications.*

trically-powered equipment and supplies which would considerably enhance the opportunity for lunar exploration.

CONCLUSION

The Nation is working diligently to accomplish the presently approved space missions which include the manned lunar landing and extensive utilization of instrumented satellites in Earth orbit and in outer space. The NASA report of its Future Programs Task Group has examined the opportunities available through the exploitation of nuclear propulsion and nuclear electric power. The AEC program is making significant progress toward providing the technology and the systems to fulfill these opportunities as they develop over the next two decades.

By letter of April 17, 1965, to Chairman Seaborg, the President congratulated the Atomic Energy Commission for its accomplishments and conveyed some of his views in relation to the program. He said, "In the field of space, we should continue the development of isotopic and reactor SNAP devices to enable us to take advantage of their unique application to the generation of electric power for our spacecraft. The recent successes of the nuclear rocket reactor tests indicate that nuclear rockets can be ready for the long-range space missions of the future."

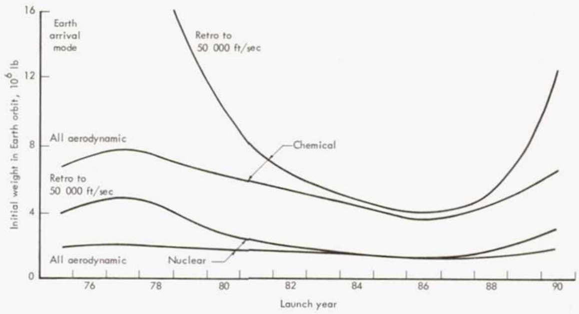

FIGURE 14.—*Earth-orbit weights for manned Mars missions.*

A vigorous and advancing program of space exploration and scientific investigation needs nuclear power to extend its mission capabilities. The objectives are attainable.

OPPORTUNITIES IN SPACE EXPLORATION IN THE FUTURE—AN IMAGINATIVE PROJECTION

L. Eugene Root
President
LOCKHEED MISSILES & SPACE COMPANY

As we enter this last session on the peaceful uses of space, it must be evident to us all that the potential impact of the Space Age on our lives and our civilization is so great that, however imaginative we may be, we may still underestimate what is to come. As Dr. Bisplinghoff suggested in a speech a few weeks ago, imaginative children and science fiction writers may be better predictors of what will hapen in space 30 to 35 years from now than the engineers and scientists deeply involved with the current space program. Nevertheless, it is a prerequisite that advance planners face such a challenge, and the recent summary report of the NASA Future Programs Task Group is indeed an effective plan for the necessary developmental activities of the next two decades. It is the purpose of this paper to reach even further into the future, to examine the situation which might prevail by the end of this century, and to test the direction of the current plans.

Our starting point is the space developments of today which are generally categorized into manned and unmanned operations and into the vicinities of operations—near Earth, lunar, and deep space (including reaching toward the Sun as well as toward the outer planets as a part of deep space). The current space program of our Government represents a reasonable attack on the exploration of the physical environments in these regions, and on sustaining man in these environments.

Let us make the basic assumption that all-out war will not occur during the period we are exploring, because the impact of such an event can only be to void any and all forecasts. Let us recognize that the possibility of a major physical discovery, such as an anti-gravity device, could be equally disturbing to forecasts. We can now consider the future of the space program in a very broad sense.

The direction of our lunar program seems clear enough. After Surveyor and Lunar Orbiter missions and the subsequent Apollo landings, the post-Apollo activity is reasonably obvious—an era of lunar exploration, evolving by the end of the century into a limited colonization of the Moon. Planning and developments toward this goal are already under study. NASA has and is continuing to carry out a series of studies of post-Apollo activity on the Moon, pointing toward the developments necessary to permit unlimited residence on the lunar surface.

Similarly, the future of the deep space program—beyond the Moon to the planets—is equally clear. The current unmanned planetary program, as exemplified by the Mariners and the new Voyager program, will bring information on the potential of life on the other planets. Our unmanned vehicles will make deeper penetrations—to Mercury, Jupiter, and Saturn and eventually to Uranus, Neptune, and Pluto with both orbiting and lander exploration systems. We will go closer and closer to the Sun and we will look back at our solar system from deeper and deeper vantage points.

If we overcome the limits of our current technology which now confines us to "nuclear space engines" which operate only on the ground, and courageously proceed with the advanced developments necessary to having space-proven nuclear boosters, it is reasonable to assume that we will carry out manned explorations of Mars and possibly of Venus.

For near Earth-orbiting vehicles, the early technology developed in the Discoverer satellite series has led to unmanned utility vehicles such as Telstar, Tiros, and Early Bird which have become household words. The natural developments over the next 30 years can be expected to become more and more a part of our daily lives. Advances in communications satellites will provide the path for global video-telephone, with perhaps instantaneous translation into the local language; meteorological satellites will give complete short- and long-range weather predictions, and become the catalyst to the true beginnings of weather control; navigational satellites will replace the traffic lights on the street corner for the air, ship, and space traveler; and the scientific satellites will become ever more comprehensive. We can expect these utility vehicles, which will influence people throughout the world, to include major contributions from the global science community, through the international cooperation in space fostered by NASA and by such organizations as ESRO, the European Space Research Organization.

In one region of space, however—the near-Earth manned satellite—the picture by the end of the century is not so clear. For the immediate future we are preoccupied with manned stations in terms of relatively limited-population satellites, a couple dozen people at the most, which necessarily represent our first steps in this direction. With your indulgence, I would like to exercise the prerogative of a planner and attempt to paint a picture of a truly large space station as we might find it at the turn of the century, based on potential space building blocks resulting from our National space effort.

To prepare you for what I am about to discuss, it would be a real advantage if I were a pilot and could request you to fasten your seat belts—not only to take care of the rapid mental acceleration you are about to experience, but to make sure you do not leave before I am through. Let us project to the year 2000 and visit our U.S. space station orbiting a few hundred miles out. We see a virtual small town, built up principally over the last two decades, as a series of modular additions through agreement and participation of the complete scientific, technological and governmental community. Its basic start was the orbital launch facility built to send the first U.S. manned expedition to Mars in the 1980's. Its mushrooming during the 1990's is, in a small way, comparable to the housing explosions of the last half of the century. This space town owes much to that first von Braun expedition to Mars and its predecessor programs—development of all the basic technologies of space assembly, space resupply and rescue, essentially continuous closed-cycle life support systems, large satellite orbit station-keeping, large space-power systems and extremely lightweight space vehicle structures.

Its complexion has changed drastically in the last 5 years, triggered by the opening of the Space Hotel —a full year before the Soviet Union opened their exclusive Praesidium resort in space. The presence of the rapid-turnover year-round tourist population has resulted in a significant increase in service type organizations and major increases in the transportation and warehousing operations. The city has an average population of over 4000 people, although even the permanent residents are assumed to return to earth every 6 months. The stay time of the residents ranges from a minimum of 3 weeks for resort guests to 6 months for technicians, workers, and staff support personnel.

The biggest single group is the government-operated Goddard Research Laboratory. This is not really unexpected since space scientists were among the first residents of the community and their laboratories have been growing in size for over 25 years. Nevertheless they are indeed a select group, representing less than $\frac{1}{2}$ percent of the current U.S. Government research staff. It is interesting that this is about the same ratio of Government research personnel we had operating in Antarctica when that region was in a somewhat similar stage of development in the late 1960's. The laboratory complex includes a master central computer facility and a master library file which makes literally millions of documents available to any of the research personnel through the rapid recall and printout system.

Over the past 10 years the Government research community has been joined by the smaller but gradually increasing number of industry research teams. These groups, financially supported by their own firms, have been carrying on product-oriented development work, most of which has been initiated as a direct result of Government research. Some of the early industry research has already spawned a small but growing industry, oriented principally around products whose processing involves the very high vacuum and extremely low temperatures of space.

A small established university research staff divide their time between their own research and the teaching of the special Graduate Student Laboratory Program in Space Sciences. Sixty graduate students are selected each quarter for the Government fellowships which fund their participation in this program. Their program includes experiments in astronomy, meteorology, optics, communications, radiation, fluid mechanics, cryogenics and heat transfer, biotechnology, and high-vacuum technology. The experiments have been limited to those which can be conducted only in space, but even so there has had to be a selection of the most important phenomena to be illustrated, since the time is too short to cover all the textbook space experiments.

In addition to the laboratory program each student participates in one of the professorial research programs as a research assistant. It should be obvious that these 240 fellowships are highly prized and these students represent the outstanding U.S. space scientists of the future. It is interesting that many of the Government research staff have begun to augment their normal work activity by participating in this graduate program, some as teachers and many as graduate students.

The next largest group in the space city is made up of the guests and staff of the resort hotel. This is, of course, one of the most exclusive hotels in the world, travel costs being what they are; but we have high hopes of bringing the cost down over the next few years and are already planning major expansions for the hotel facilities. At the present time, however, it can only accommodate about 7000 people per year, or only 5 out of every 1 000 000 of the population from which it draws its trade. It has to turn down 3 out of every 4 reservation requests it receives. Its crowning glory is the world-famous Starlight Room which provides gourmet dinners served under a naked view of the heavens. Its other features include swimming pools, ice skating rinks, bowling alleys, a theater, a sun room, a low-gravity room and a zero-g room, and the tourist observation room which provides telescope views of Earth. It includes a library containing all of the current popular volumes on electronic recall, with readout facilities in each room. Its Space Arboretum, while not very large, attracts many of the tourists who enjoy this Earth-like feature in space. And for those who prefer games of chance, there is the well-equipped Las Vegas Room.

The hospital complex in the space city is principally a research hospital, but for the community it operates, as well, a complete medical and dental center. The principal research activities relate to diseases of the inner ear; the fluid mechanics of the blood system (where the zero-g research room eliminates a principal variable in our Earth research); rapid recuperation systems after the installation of artificial hearts; and the use of the space radiation and cryogenic environment in the treatment of those rare cancer cases which do not respond to our Earth treatments. The rehabilitation of victims of long-time arthritis, through the removal of calcium deposits by the use of the new wonder drugs, has not progressed well on Earth, because of the pain when they try to use long atrophied muscles, and some work is now underway to see if such rehabilitation is speeded up in a low-g environment. Recently the hospital started exploration into the use of weightlessness, the unusual isolation environment and the euphoria often experienced in space, in the treatment of severe psychoses.

With the exception of the Defense Department contingent, who are primarily a part of the joint defense-services peace-keeping space forces and whose operations are highly classified and cannot be discussed here, the remainder of the personnel in the colony are principally those required to service the station and its users. The 300-man maintenance and construction force include the highly skilled extravehicular technicians who keep the station structure in repair, provide for the mating of new structures to the station as they are delivered from Earth, and handle all of the new internal construction required within the city. This group handles all activity external to the space station except transportation to and from Earth; as such, their activities are also concerned with the use of the city as a way station for lunar and planetary spacecraft.

The utilities complex provides, for the entire space city, the usual space utility needs—power, light, communications, atmosphere, water, and thermal control. The power system, a combination of solar and nuclear supplies, is relatively standard. A standby battery supply is maintained, capable of handling the minimum required safety load, life support, and communications for the entire city for a period of 1 week. The atmosphere and water systems provide solid waste disposal as well as the regeneration of both oxygen and water. The communications network includes a direct link to the master communication satellites for all voice and video circuits.

The services complex has evolved over the past 10 years as a series of small shops handling the sale of supplies and services for the small city. Shops selling food, drugs, and clothing and barber, beautician, and cleaning services have been in existence the longest, but a few souvenir shops and other specialty tourist attractions have recently been added.

The space liner transportation center is the hub of the activity for the basic Earth-to-space station traffic but the center also handles the lease and sale of the small electric vehicles used for local traffic throughout the city. The U.S. Aerospace Industries Space Liner Agency provides a continual standby of vehicles capable of returning almost 50% of the city personnel to Earth in case of any major emergency. Last, but not least, the city hall complex which includes the office of the city manager, provides the business and administrative functions necessary to the operation of the space center, including the operation of the police force and the local bastille.

That is the end of the tour. Now you can return to Earth 1965 and unfasten your seat belts. Now before we lose the effect of our trip, and to be responsive to the sound and inquisitive mind, let us try to answer the first question. Why did we want to go to this space town? In a way, space is like a mountain top, so let us consider why we go to a mountain top. At first we make an initial climb to the top of the mountain because it is a challenge; Bobby did it. When we reach it, there is nothing left to do but come back down. This is the stage which we have currently attained in space stations and space programs in general. Then there is a second stage at which we recognize that a mountain top has some utility. We then start building structures like television repeater stations or wide-view observatories to improve our capability of looking at the heavens and this, of course, is exactly what is planned in the second phase of space stations, both peaceful and military.

But actually the mountain top does not become economically useful until someone builds a pathway to the top, and we then find a resort and hotel located there. If you look at the attractive mountain tops of the world you will find that this has happened to a very large number of them. The special features of the mountain-top resort are its isolation, its weather, and its view. Certainly our space station would win a competition with a mountain top in at least two of these categories and conceivably its manufactured weather could be as attractive as the uncertain climate of the mountain top.

Next, is it economically feasible? Here our reasoning becomes more complex because I must bridge the gap and return to the realities of 1965. We need an assumption as to the cost of transportation in space and I would like to use as basis of a first look, the two-stage Saturn 5 vehicle. Here is a rocket of the immediate future, capable of placing about a quarter of a million pounds of payload into earth orbit at a cost which by the late 1970's should be as low as $50 000 000, or roughly $200 per pound. Let us consider first the cost of transporting the space station to the sky. If we examine some of the current studies of larger orbiting space stations, (although still small by our standards) we find generally about 5 tons of structure, equipment, life support, and all other items per person. If we were to use the same figure, the 4000-man station would require about 20 000 tons in space and at our $200 per pound, this would represent an investment of about $8 billion in transportation costs. Perhaps another $20 billion would be required to manufacture the station hardware and equipment, so that for the time period 1980–2000 this station would cost an average of about $1½ billion per year, not really an impossible consideration at all.

Next consider the economics of sustaining the personnel in space—food, beverages, toilet articles, drugs, clothing and so on. While a few pounds a day will be sufficient for an astronaut operating with a closed-loop life-support system, our tourist and our technician will not live so conservative a life, so I have assumed a liberal 10 pounds per day per person would be required. The 4000-man space city then would require upwards of 7000 tons per year, or roughly one Saturn V launch every 5 days, at a total cost of about $3 billion per year. Cost of transporting the personnel to the station is a bit more complicated. Because of the need for oxygen during transfer, limitations to launch accelerations, emergency recovery systems, and other problems related to human transfer through an unfriendly environment, it has been assumed from previous studies it will take 500 pounds of payload to support a 200-pound man during the transfer. The resulting costs, 40 percent of which would be involved in handling the tourist trade, would then run another $3 billion per year. In other words, the total cost of establishing, manning and maintaining this space city would run about $7½ billion per year, even at rates predicted for 1975.

While these gross numbers are much less formidable than expected, there is one major economic fly in the ointment. The round trip tourist cost for a 3-week stay at these prices would run about $200 000 per person, a number too high by a factor of at least 10–20. And so we must find a way of reducing these costs by such a factor. It is interesting to note that if such a reduction is made, the yearly operating cost of the space city, both government, industrial and commercial, would run to less than 20 percent of our current NASA budget.

There is almost a factor of 10 in the reduction of costs to early orbit as we progress from the Atlas/Centaur booster to the two-stage Saturn V of 1975. It certainly does not seem improbable then, that the next 25 years may produce an additional factor of 20, but it will not come without action on the part of the Government and aerospace community in particular, and the American public in general. It reassures me to note that Dr. von Braun, just a few weeks ago at a meeting in Washington, predicted a reduction in launch costs by a factor of 10 in the next 30 years.

Here are some of the steps to be taken. First, we must get our own long-stay-time orbital space station activities out of their current study phase and into hardware as quickly as possible. The Soviet Union, as a part of their activities toward a lunar landing, may have such space stations in the very near future. We must accelerate our Earth-orbital programs, because only from such space testing will we find the problems involved and the paths to their solutions.

We should vigorously examine all aspects of our potential future launch technology: nuclear rockets, recoverable boosters, high-energy fuel systems, and high-pressure rocket engines, with a view toward accelerating those programs which offer the chance of making major reductions in the cost of transportation to Earth orbit. For example, the use of recoverable boosters alone could make an order of magnitude reduction in the cost of round trip personnel transportation.

We should attack the operational aspects of our launch systems for ways of reducing the base operations costs of space ferrying. It is interesting to note that in some current studies, over 50 percent of the costs estimated are for non-flying items related to checkout, launch operations, engineering, reconditioning costs, and so on. Here is a fruitful field for the use of advanced technology to reduce the cost of transportation. We should do the long-range planning involved in establishing a space city, as well as the planning for a manned mission to Mars, so that our planetary program can provide in every way possible for the natural steps to the longer term use of near space.

And lastly, but far from least, we must obtain broad support for such a long-term program, soliciting the active participation of the U.S. public in our planning through Congressional support and suitable funding allocations; and, through meetings like this one, we must establish a program which will initiate the concept and desirability of the personal use of space by the U.S. citizen.

CREATIVITY, EDUCATION, AND SPACE EXPLORATION

C. S. Draper
Chairman, Department of Astronautics and Aeronautics
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

INTRODUCTION

Creativity is the complex of many human qualities that combine to bring new things or conditions into existence. This across-the-board definition is by usage particularly associated with contributions that confer significant benefits on society. Thus, the telephone, the electric light, and the jet engine are all products of creativity.

In these terms, creativity has many phases that are more or less loosely coupled into a loop which may be considered as starting with *flash-of-genius* concepts that in the normal course of events are judged at a later time against feedback information on results achieved in the real world of society. These judgments, interpreted in the light of wisdom and imagination, stimulate new inputs from creativity which in turn move through the loop of progress to provide ever improving benefits for the public.

These benefits do not appear directly from novel ideas, but are realized only when a sequence of links in a fairly well-defined chain of events have provided essential functions, each of which involves some degree of creativity. Elements of the chain that follow initial conception are invention, patenting, entrepreneurship, innovation, realized public benefits and feedback from the effects of these benefits. In the past, preoccupation with flashes of genius and inventions has been so great that creativity has almost completely identified with new devices, chemicals, and processes. Events in the world of practice prove that this viewpoint is fallacious. Without patent protection, salesmanship to return some significant reward to inventors, entrepreneurship for promotion of industrial and business activities that lead to public benefits from innovations, the overall chain itself will be ineffective, a condition that is likely to be shared by individual links.

Creativity is essential for success in any and all links of the chain and depends upon a pattern of human abilities that contain a mixture of the same essential elements. First, and most important, is strong self-reliance, mental habits of striving always toward true understanding of natural and humanly generated circumstances on the basis of careful and intelligent observations, interpreted in terms of imagination and an attitude that takes all available science, technology, and industrial practice into account, while always approaching frontier problems of technology from the standpoint of ingenuity and fundamental principles. This habit of thinking for himself without expectation or hope of outside help is a basic characteristic of any truly creative individual.

CREATIVITY AS AN ESSENTIAL NATIONAL RESOURCE

In a world that is today divided into groups of deadly serious and progressive rivals, the balance of a nation's science and technology in comparison with the states of corresponding capabilities for its competitors is a matter of the greatest possible concern. Falling even slightly behind in this race will surely cause a deterioration in the prestige and the influence of a country, while an unbalanced breakthrough by one nation may well spell disaster for its potential enemies.

All significant advances in science and technology depend upon the leadership of creative scientists and engineers. These advances are essential for the wellbeing and, perhaps, the long-range survival of any country seeking to build an image of leadership. It follows that the identification and effective development of creative individuals are matters of first order urgency for the governments involved.

Under the modern conditions of universally available scientific knowledge and widely spread technology, it is not to be expected that secrecy can protect any existing advantageous position for very long, or that piracy from some other nation's pools of qualified manpower can provide much creative help for lagging capabilities. This means that each progressive country must depend upon its own resources of potentially creative citizens.

In times past, native ability with not much assistance from formal education has produced many innovations leading to great benefits for the public. Today, circumstances are very different. A great variety of simple and basic inventions is in common use, while highest level creativity is largely concerned with complex devices and carefully organized systems to accomplish sophisticated results. Pioneering problems are no longer concerned with pipe wrenches and incandescent electric lights; rather they deal with such things as automatic controls and satellite communication systems. To qualify people for making contributions of this kind, academic education must be provided to build up mathematics and the humanities as background knowledge in the fundamentals of science, for all students who show any spark of creative ability. It is surely very important for society to devote whatever attention is necessary to detect and fan such sparks.

EDUCATION AND CREATIVITY

Creativity in the modern world requires background knowledge great enough to give real understanding of situations in terms of natural laws. Adequate depth of this understanding and effective reactions distinguish creative individuals who have ability and desire to adventure into the frontier regions of human activity. However, knowledge and understanding alone are not enough to generate inventions and innovations. The mental attitude of going beyond ordinary approaches to seek unprecedented solutions for across-the-board new problems, and the habit of self-reliance in the face of disbelief and criticism, are essential qualities in persons who are able to distinguish themselves in creative roles.

Conventional academic education provides excellent backgrounds of fundamental knowledge, but often tends to suppress rather than to nurture creativity. This undesirable effect stems from unrelieved stress on learning in terms of formal information with its overwhelming preoccupation with grades and class standings during the last years of high school and the lower classes of college. The damage comes not from too much learning of facts and methods, but from too few opportunities that not only permit, but stimulate students to exercise initiative and self-reliance in analysing practical situations and applying imagination in working out solutions from problems that have no unique "correct" solutions. It is not to be expected that high school or college students will produce many significant contributions, but if they have any worthwhile potential for creativity they will react well when given an introduction to real world environment and opportunities to deal with its problems. It is important that students work alone as far as possible beyond the shadows of teachers asking for exactly gradable answers to synthetic problems. It is this contact with nonacademic attitudes, situations, and methods that is important, rather than an avoidance of conventional problems which are, after all, very well designed to impart knowledge of natural laws and scientific methods by unambiguous and simple illustrations.

Some students will be annoyed, frustrated, and generally unhappy about dealing with situations involving various problems, all having not one, but an assortment of more or less unsatisfactory different answers. If this frustration and unhappiness persists after a few experiences and real discouragement appears, the students involved are evidently not strongly gifted for creativity and should be allowed to seek distinction in other fields. On the other hand, students who are potentially creative realize, for example, that many automobile types exist because there are different ways of making good cars and feel satisfaction in applying first principles for finding their own means for meeting challenging situations.

This potential for creativity can be nurtured by continually providing selected students with chances to exercise and develop their capacities for dealing with typical pioneering problems of the practical world. Science fairs and prize competitions provide excellent opportunities of this kind, but these incidental activities need to be backed up by courses in which comprehensive projects, strongly involving personal initiative and stressing practical results are carried out by students working alone, or in small groups. Activities of this kind need not occupy a major part of student effort, but should occupy enough time to get across the idea that successful practice requires more than the acquirement of much knowledge and requires some facility in the use of well-established methods. In other words, the mental attitude, acquired by many students during their academic years, that they have been taught answers for which they are to search out suitable problems during their careers of practice, must be modified toward more flexibility if they are to progress creatively in science and technology.

Academic education, even with effective attention to creativity, needs to be supplemented by a few years of experience in a properly stimulating environment if graduates are to achieve their full potential for contributing to society. The medical profession has long recognized the necessity for medical school graduates to serve a period of internship in a working hospital before they are allowed to practice. In a similar way, graduates "read" law in the offices of some legal firm before they are ready to start careers of their own.

The same principles apply to scientists and engineers with real potential for leadership in their professions. Service in an organization which deals effectively with research and development on pioneering systems of technology is especially helpful in providing experience of this kind. Benefits approach the optimum when the working atmosphere is that of creativity obviously producing significant results. By including in the overall activity a good cross section of the typical difficulties that must be met and overcome during the progress of any advance in technology, developing individuals are given additional preparation for dealing with "the world of practice." Experience of these kinds provide excellent "coupling" education between the completion of academic requirements and careers of distinction in creative service to society.

SPACE EXPLORATION AND EDUCATION

Education of the sort described places severe strains on the dedication and perseverance of even the most talented students, with particular trials for those of high natural creativity who tend to become impatient with formal learning and yearn to get on with the business of making their own independent contributions. A central theme, strong in universal challenge, is needed to stimulate both gifted and ordinary students to exert the sustained effort that must be invested to learn in a half dozen years a good share of the basic knowledge that mankind has accumulated during many centuries. For example, at the end of medieval times, art, literature and commerce provided motivation for the expanded learning of the Renaissance. Three centuries ago, science itself inspired a revolutionary attitude toward education that, once started, has conferred many benefits on mankind including a host of creative individuals.

Space exploration is today continuing the trend initiated by science many years ago, first firing young imaginations with the ambition and perseverance needed to carry students through basic schooling, and then providing challenges great enough to bring out the highest abilities of these students as they become graduates in science and engineering.

The whole fabric of education is affected by space exploration which draws together substantially all the elements of science and technology under conditions that require more sophisticated observations, more difficult than anything previously attempted by human beings. With vehicles that must be self-supporting for considerable periods of time to be designed for the special conditions of space, all available resources of science and technology must be applied at the ultimate levels of refinement. When manned flights are considered, the interactions of men and machines leading to optimum performance for complete systems must be worked out with great care in patterns that have never existed before.

For example, three men living for some weeks in very confining quarters with no chance of getting off between the start and completion of a mission, represent in a very intensified way the problems of the human race living within the closed system that we call Earth. Reliability and operating times before failure of equipment must be treated with levels of respect that they have never commanded in past times.

In addition to the new technology of space traveling vehicles, the vast new stores of knowledge becoming available from observations made from stations no longer restricted to the Earth's surface, offer challenges to science that will surely increase rather than decrease during many of the years ahead. Faculty members as well as students are inspired by this prospect not only to modify long-standing courses, but to develop subjects covering important areas that have received little or no attention before. This activity is, of course, greatly stimulated by support from government organizations with wise policies toward education.

The overall effect of space exploration is thus to advance education generally, to stimulate the development of new areas of learning, and to provide strong motivations for students to follow academic careers through to completion. More especially, the challenges of space exploration and the opportunities associated with its accomplishment are very effective for the development of creativity in talented individuals.

Effects from this creativity in terms of innovations and benefits for society go far beyond the space program itself. It may well be the verdict of future history that the general stimulation of education and creativity has been a greater return from funds and work invested than any direct results from space activities. In any case, prospects are exciting and the effort involved will contribute largely to the general progress of our country and its image as a leader among the countries of the Earth.

THE SOCIAL CONSEQUENCES OF THE SPACE AGE

Harold D. Lasswell
Edward J. Phelps Professor of Law and Political Sciences
YALE UNIVERSITY

A comprehensive anticipation of the social consequences of the Space Age would explore every sector of society. As a convenient check list of the social process I employ eight categories: government, law and politics; basic knowledge and current information; economic production, distribution, consumption, investment; health, safety, and comfort; education and the professions and occupations; social class and personal prestige; ethics and religion.

More formally, the social process is a value-shaping and sharing process in which the institutions relatively specialized to each value outcome are open to change. The values: power, enlightenment, wealth, well-being, skill, affection, respect, rectitude. Knowledge of space is a form of enlightenment whose consequences for the whole social context concern us here. Anthropology and general sociological theory cover all social processes; social psychology explores the changing individual in relation to his personal and physical environment. Various bodies of specialists deal with the several value-institution processes. I shall emphasize the governmental, legal, and political implications and give some attention to other sectors.

GOVERNMENT, LAW AND POLITICS

A question of overwhelming importance for inquiry, as well as for every man, is whether the next few years will bring steps toward peace and security, or whether the precarious balance of power now prevailing in global politics will be maintained, or become yet more precarious. As usual, the growth of knowledge regarding space flight is the result of the dedication of particular scientists to the cultivation of enlightenment and skill. However, the encouragement and application of space technology has been guided mainly by considerations of political power, hence subordinated to the prevailing structure of world politics.

From the analytic standpoint the fundamental fact of the global arena is the expectation of violence, which is the expectation that, whether one likes it or not, organized violence will probably continue to be employed by the nation states as an instrument of policy. The United Nations is not, as yet, perceived to be an inclusive institution that affirms and applies at least minimum public order. The UN was devised with a built-in veto as a means of preventing it from arriving at decisions enforceable against the Soviet Union, the United States, or other powers with a seat on the Council. The UN registered in its fundamental structure the determination of the major political elites of the globe not to be authoritatively coerced by a majority vote.

In a divided globe the significance of space science and technology has necessarily been perceived by responsible people in terms of war potential. The effective leadership of the United States and the Soviet Union grasped the strategic implications of the control of outer space, and plunged into a race in which all strands of modern development are interwoven, and in which "peaceful uses" are characteristically emphasized as a means of obtaining more effective arms development (ref. 1).

The implication of this analysis is not that the power elites of the Earth recognize no authoritative and controlling limitations whatever on their freedom of action. They do, in fact, perceive mutual advantages in clarifying and adhering to many prescriptions of international law. Apparently it is evident to both super powers that neither power is able to block the other completely and finally in space. Hence, the space powers have begun to crystallize orderly expectations of common interest in the penetration of the larger environment. They are in process of stabilizing a legal order in outer space that takes account of the most useful parallel in past experience, namely, the law of the oceans.

Since Grotius the oceans have been recognized in international law to constitute a vast resource open to all, and beyond the exclusive domain of any state. The dimensions of outer space vastly transcend the oceans, and in the words of one important commentator, C. Wilfred Jenks (ref. 2):

> The principle of the freedom of space, which, until October 4, 1957, could be put forward only as a principle derived from the basic astronomical facts, already rests on a solid basis of established practice supported by world-wide acquiescence.

The requirements of outer space have gradually been overcoming or modifying traditional practices in regard to air space. It has been recognized that the utmost freedom in the use of airspace for purposes of international air transport cannot be accepted as permissible in the presently divided world arena. But air space and outer space are a physical continuum, and the effective utilization of the latter calls for a complementary use of the former. The problems involved are being clarified by examining the various objectives that may be served by recognizing *occasional exclusive competence* of nation states in outer space.

The accumulated experience gained in regard to the oceans has been suggestive. Beginning in the eighteenth century, for example, Britain initiated the practice of extending limited coastal authority over the adjacent seas in order to protect fiscal integrity by the enforcement of fiscal laws, customs regulations and antismuggling measures. Any value category, in addition to power and wealth, may be at stake (for example, well-being, as in the case of health measures). A variety of "limits" have been proposed and accepted for general or particular purposes, a result that is presently in active discussion in regard to workable "boundaries" between air space and outer space (ref. 3).

I have been referring to emerging trends in public order in reference to claims that relate to access and competence in the domain of space. Other problems are also under active consideration, such as those in regard to the maintenance of at least minimum order (peace and security); the nationality of spacecraft and the promotion of optimum order in space; jurisdiction over space activities and spacecraft; the enjoyment and acquisition of resources ("Who owns the moon?"); the establishment of enterprisory activities ("communication satellite corporations"). On all these matters, expectations about prescriptive norms are in various degrees of explicitness. A point of primary significance is that nation states are admitted to have a voice in crystallizing the law of outer space even though at the moment they possess no capability for the manufacture of spacecraft. (Similarly we do not exclude a landlocked power like Switzerland from a voice in the law of the oceans).

None of the developments in space technology that are now visible indicate that any power is likely to obtain a decisive advantage over the other. Hence the steps that have been taken to establish unified expectations in regard to law in space have not been redundant.

It is not to be assumed that even if weapon control agreements fail, all is lost if bomb-bearing satellites, in addition to surveillance and communication satellites, are put into orbit. No one can reasonably contend that his sense of security is increased if the bomber satellites of the rival coalition are flying overhead. But if one's own delivery systems are functioning the "balance of terror" is likely to subside as a source of acute anxiety into "business as usual." The world community has amply demonstrated its capacity to adjust to formidably dangerous conditions of mutual deterrence.

We may add that the political balance will not necessarily collapse if raids and clashes occasionally occur in outer space. In this connection we note the suggestion that world conflict may be held in check, if not reduced, by a division of responsibility for penetrating different space sectors or zones, including the use of large artificial satellites. The historical parallel is to the supposed alleviation of conflict in Europe when energies and ambitions were turned outward, and colonial empires took shape. Given the geometry of Earth, the participants in the power process must eventually surround one another, or be surrounded. Will the geometry of outer space be taken advantage of to defer any final confrontation indefinitely?

Of more immediate importance is the question whether the utilization of resources in the space effort will presently be viewed as politically disadvantageous. Hence initiatives may be welcome to enlarge the scope of cooperative activities, and to cut back absolute or relative expeditures, employing the liberated funds for other weapons or for raising levels of consumption.

Quite apart from the difficulty of unscrambling space expenditures from other security measures, the result will hinge on the weight that is given— especially by the Soviet elite—to the total political gain resulting from "firsts" in space. Excellence in nuclear and space science and technology has contributed enormously to the prestige of the Soviet Union and to every group or doctrine that can be thought to be distinctive of the Soviet World. The Soviet Union has benefitted to a notable degree from its prowess. It was within the range of established expectation for the United States to take the initial lead in mastering atomic energy. It was astounding and heartening to the less industrialized peoples to see what could be done to overtake—and in some ways to surpass—the United States. The result was to cast in the shadow all the doctrines and groups that are distinctively associated with the U.S.A. Chairman Khrushchev's exuberant comment has not ceased to reverberate (ref. 4):

> The launching of artificial earth satellites is a kind of culmination of the competition between socialist and capitalist countries. And socialism has won it.

A question is whether the see-saw that is likely when the United States has come closer to Soviet technology will yield such benefits to Soviet policy. Presumably Communist China will eventually develop space capability. In the meanwhile will other expenditures be judged to offer higher political advantages?

The pressure against the space budget in our own country comes from many sources. Up to the present the pro-space coalitions formed by political leaders, generals, civilian officials, scientists, engineers, and manufacturers have been able to carry the day against rival interest combinations. In the scientific community there is some reluctance to work in programs that seem unilaterally committed to one side in the power struggle. Many men of science long to serve mankind directly; and this perspective is widely shared among liberal Americans.

In fact, the relative freedom of communication that is a guaranteed part of our system of public order makes it possible for the multivalued orientation of American society to find public expression. In totalitarian systems, on the other hand, the censorship maintained by the ruling elite seeks to subordinate all communications to what are perceived as politically useful message content. A strict censorship has been applied, for example, to news or comment on the military significance of Soviet space activities, all of which have been linked in the Communist controlled media to the rhetoric of peaceful use. Since comparative openness is part of our institutional system, many American activities in space are justified to the Congress and to the electorate as means of national security, which seems to suggest a military orientation that is absent from the Soviet approach, and which is readily distorted by propagandists hostile to this country. High-minded scientists and students, among others, are frequently put in the awkward position of supporting proposals for international action that entail criticism of American policy; yet, when the issue is joined, these proposals founder on the rock-like determination of Soviet leaders to maintain the structure of limited authority and control established at San Francisco.

Undoubtedly the demand to create a world federal system on the model of the American constitutional plan is a continuing theme of liberal politics. In all probability this demand will continue to be frustrated by the policies of foreign elites who refuse to subordinate themselves to a non-Communist majority, and also by the political groups in the United States who refuse to occupy a corresponding position of subordination to a Communist majority. Hence it is to be anticipated that, for the visible future, the world of space will continue to show the bi- or tri-polar characteristics of a divided world. Our fundamental separatisms will be disseminated into man's enlarging habitat.

CONSEQUENCES OTHER THAN POWER VALUES AND INSTITUTIONS

Even a cursory glance at the probable future of social sectors other than power is highly suggestive of future developments and of appropriate problems of investigation. Consider, for example, *enlightenment,* the social processes studied by sociologists of knowledge and all who concern themselves with the communication media.

It is remarkable how little attention has been given by universities to the task of assessing the social consequences and potentialities of the coming conquest of space. No great institutes have devoted themselves to a many-sided study of the legal, political, intellectual, economic, and other impacts, actual and potential, of the new era. It is not enough to say that as high priests of the intellectual life, universities are inherently conservative. Conservatism is not strong enough to block intellectual and organizational freshness of approach in dealing with many other topics. The most probable explanation seems to be that historians and social scientists are not accustomed to think contextually of the future, and therefore to select problems of inquiry in the light of their estimate of probable future developments. They have been trained to think of "hard facts" in general rather than to think of an intellectual strategy of choosing which category of hard facts to pursue.

When we consider the future of enlightenment it seems safe to predict that the present lack of interest in the social consequences of the Space Age will soon be abandoned. I foresee an explosive upsurge of concern with the opportunities for obtaining knowledge of man and society, as well as of nature. Already I observe indications of a changing approach among universities. The imperious tempo of change has made it necessary to take the future into account, not simply for public policy, but for research policy. As man moves into space he reaches toward a variety of environments that will require cultural as well as biological adaptation. If a major objective is to maintain a sense of identity among men (and a comprehensive common civilization), continuing attention must be given to the growth of distinctive identities, expectations and demands, and of distinctive institutions.

It will soon be tempting to suggest and promote prototypes and pilot projects to initiate and study space communities (at first, stations) of somewhat distinctive social composition and. of contrasting political, economic, familial, and other institutions. As a means of diminishing the conflicts that have arisen from the segregation of the races of man on Earth by continent and region, it may be important to screen future communities for the purpose of ensuring biological diversity in all settlements.

It is plausible to predict that institutions will be developed to conduct *continuing surveys of the social consequences of space,* and to share the flow of information throughout the world community at every level—official, unofficial; scientific, lay. An inclusive, selective and reliable survey may be planned to make use of *techniques of varying depth* designed to describe changes in both perspective and overt behavior.

The continuing survey would be planned to throw light on *the relative importance of factor-combinations* whose significance is apparent to specialists on the culture of various areas, or whose influence has been demonstrated in small scale, highly controlled experiments. The techniques adopted would take into consideration the problem of discovering present predispositions to respond to relatively extreme environmental contingencies.

It is conceivable that continuing survey arrangements will be made by voluntary cooperation among governmental, university and specialized agencies of research. In this way the social consequences of all value-institution sectors (power, enlightenment, wealth, well-being, skill, affection, respect, rectitude) can be covered for all nations. However, it may be convenient to plan one or more *commissions on the social consequences of space* to take the initiative in encouraging voluntary cooperation, and in providing for gaps to be filled.

Partly for lack of time I leave *economic* consequences to one side. As yet there have been few economic advantages obtained from new resources in outer space. The partial exception is in communication, as exemplified in the satellite. However, it would be a mistake to suppose that the shaping and sharing of wealth for space purposes has gone forward free of impact on the current Earth economy. Estimates can be made of the volume of current outlay and investment in the space programs of the U.S.S.R. and the U.S.A. The direct effects are not restricted to either economy, since all countries are implicated as suppliers of raw materials, as processors, or as manufacturers. In estimating the significance of these involvements it is necessary to take into consideration the alternative uses of the resources devoted to space programs. What economic activities suffered? Speaking of the aggregate, what can be said about the "opportunity cost" of space—the potential gains that were given up in order to push onward and outward?

We can do little more than take note of such questions. Similarly, it is not presently possible to present much solid information about the impact of space programs on the *health, safety, and comfort* of mankind, social biology, or medicine. In some ways the most interesting issue in this connection is the future of mental health. Examining the matter in the most general terms, one may reason as follows: Changes in traditional boundaries arouse uncertainty; uncertainties generate anxiety among individuals who suffer from resented discrepancies between aspirations and realizations; anxieties find partial expression in withdrawal from participation, in autism, and in somatic disturbance; anxieties also find partial expression in active and often destructive participation in the life of the society; news of activity in outer space modifies the traditional boundaries of society, generates uncertainty and anxiety, and contributes to forms of illness that are commonly called neurotic, psychosomatic, psychotic, or characterological ("acting out").

At present we cannot assess the impact of directing more attention to outer space. Some observers hold that the era of space conquest is therapeutic and preventive, since it provides an opportunity for the transfer of concern with the primary circle to preoccupation with great achievement, and to the formation of self-images in which the primary ego becomes identified with space heroes and heroics.

I shall not attempt an inventory of the professional and occupational *skills* that will be brought into existence during the Space Age; or enumerate the educational establishments required to train and re-train talent. The detail involved is truly vast.

Let us give further attention to the future of human identity, and to sentiments of self. When we deal directly with *affection* (intimacy and loyalty), a searching question is whether the children and young people of the globe are acquiring more universal and less parochial loyalties than in the past. A frequent phenomenon is that when young people who have spent years in fantasied space travel and adventure discover the backward state of contemporary technology, they are deeply disappointed. Evidently they are thrown back on more limited enterprises. But disappointment with the present level of achievement does not necessarily imply that national, ethnic, or racial perspectives are relegated to a secondary position.

A consequence of world division is that children and young people are inducted into the role of potential combatants on behalf of parochial rather than of universal entities. Hence the imaginative young adventurer in space is encouraged to think of himself as an "American" or a "Soviet Russian" when he lands on Mars. Are the young people of the smaller powers more universal in outlook?

When we examine the impact of the Space Age on *respect* relations in society, several conclusions at once emerge. A new set of heroic figures has risen to inflame the imagination of the world. The astronauts are spectacular vindications of the primacy of man. Not only has the wit of man devised the technology but he is essential as a versatile guide when emergency problems are encountered. The omnipotency dreams of early life are stirred once more as man soars like Icarus yet returns unscathed.

Not only specialists but men, women, and children of many positions in society are fired with ambition to be the "first" in space travel and settlement. The demand to overcome a growing sense of insignificance, to act responsibly, and to express a supreme loyalty to man's potential—all are intensely important.

Sooner or later the Space Age will probably raise profound questions about the boundaries of the concept of "man." In the most dramatic form the identity question and the problem of self-respect would arise if we ultimately encounter beings of unmistakable intelligence whose scientific and technological culture excels our own, and whose biological plan is very different from ours. The human species is sometimes described as an ex-quadruped with a backache from standing straight; other advanced forms may be built on a different plan. If we are culturally inferior it would obviously be to our interest to bring into existence if possible a public order that accorded us all the equality that our capacities make possible. The same policy would be appropriate to societies of equal culture. Hence it would be tempting to enlarge the interpretation of "human dignity" to include all advanced forms of life. On the other hand, if the new society possesses inferior culture and biological capacity, the temptation would be great to interpret "man" narrowly to our own advantage.

The identity challenge may emerge as a by-product of the sophisticated technological requirements of the Space Age long before there is contact with sentient forms. I refer to the use of computers. It is possible to imagine computers that are programmed for outcomes and strategies of such complexity that their processes are substantially equivalent to our own.

Anticipation of novel problems of identity and respect must not distract us from recognizing that the issues connected with human dignity, in traditional terms, are far from settled among us. It is true that the political elites of the globe are almost unanimous in proclaiming their verbal adherence to the conception of man's dignity (formalized to some extent in declarations of human rights). But it is an open secret that the institutional practices of many nations—totalitarian or not—often fail to harmonize with these affirmations.

Trends thus far cast doubt on one of the most far-reaching hypotheses that has often been suggested regarding the effect of the Space Age. The suggestion is that the new era is a fatal blow to all traditional conceptions of religion and ethics (*rectitude*) and therefore a solvent of social order. Space news popularizes the dimensions of the universe and the technoscientific interpretations of the world. However, we note that the Vatican has expressly welcomed the advent of the Space Age. It appears that some traditional religions—Buddhism, for instance—find nothing surprising in recent innovations.

IN LONGER PERSPECTIVE

The opportunities and perils of man's expanding habitat may conceivably provide the incentives required to consolidate a legal, governmental and political order that embraces all mankind. The potential significance of the Space Age for human enlightenment is evident. Whether we refer to the map of nature or of man himself it is clear that a more comprehensive and realistic image is growing day by day. The long run implications for wealth are formidable. New resources can be brought within the domain of man; and if wisely used can afford abundant opportunity to great numbers of human beings. The health, comfort, and safety of man are already affected by the age of space; we are probing more deeply than ever to learn the limits of human tolerance and to supplement our limitations.

The impact of the new era of skill is also formidable. The new technology brings into existence new occupations and professions; and the refinements that arise in a new and vast division of labor will surely provide innumerable opportunities for latent talent to achieve expression in socially acceptable ways. In terms of love and loyalty the age of space provides an urgent opportunity to transcend parochial identities and to place lesser identities in relation to the inclusive whole. The new age is characterized by unprecedented mobility in space; and this carries with it remarkable opportunities to achieve mobility in society, ultimately obtaining the benefits of "the frontier" on a truly astronomic scale. In regard to standards of conduct and justifications of life, the Space Age emphasizes responsibility. It subjects every recommended norm to the discipline of exposure to the whole context affecting man and all advanced forms of life.

If we are to keep the perspective most appropriate to the intellectual tasks of the Space Age, it is perhaps worth repeating that (ref. 3):

> No emphasis upon the importance of research, teaching, and advice can . . . detract from the obvious fact that the burden and opportunity of decisive commitment rests ultimately not with scientists and scholars, but with the statesmen of the world community . . .
>
> The statesmen of the contemporary earth-space community can have an unprecedented impact upon history. They can take the risks involved in peaceful transition to an inclusive system of minimum public order, and thus smooth the way to an optimum order of undreamed of abundance and benevolence. In default, they fail to take the risks required: by their timidities and their mistakes they can end history—as man records it.

The critical question is whether as man moves outward he achieves maturity within.

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