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THE EXPLORATION OF SPACE

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I am very pleased to have this opportunity of speaking at Oklahoma State University, one of the institutions cooperating with NASA in the national program for the exploration of space. The aim is to report to you in general terms some of the results of our joint efforts, a little of future plans and to say something about why we are engaged in this task. What is actually out there in space that men and their spacecraft will encounter in voyages of exploration? What is there that will enable us to understand our earth better and the universe in which we live?

In five years we have learned a great deal which I can only sketch for you briefly. We have gained much detailed information about the composition of the earth's atmosphere at various heights. We view the atmosphere as a kind of four-layer cake with no sharp boundaries between the layers. Our normal activities on the earth and in airplanes are in the lowest layer composed chiefly of oxygen and nitrogen and extending to a height of about 75 miles. The second layer is composed essentially of atomic oxygen and extends from about 75 miles to about 620 miles. The third layer recently discovered is composed chiefly of helium extending from about 620 miles to about 1500 miles. Above is the hydrogen layer fading out into interplanetary space.

We know in major outline the density of the atmosphere at various heights and its variation with time of day and with solar activity. Sunspot activity has a large effect. We can trace variations in the density of the high atmosphere with the eleven-year sunspot cycle having measured the variations over about four years. We can also see the short-term effects of solar flares for these density variations slow up satellites in their orbits in tune with the solar activity.

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We have studied the ionosphere, the region of electrically charged atoms which bend radio waves to permit long-range communication. However, the region is stormy and serves as a poor mirror when the sun showers it with particles and radiation from disturbed areas on the sun. We are exploring the ionosphere by instruments sent into it by rockets and by satellites such as the US-UK satellite Ariel and several Explorer satellites. The recently US-launched Canadian satellite Alouette makes radio soundings from above the ionosphere to supplement information obtained by the only previously known method of study--sounding from the ground.

Every schoolchild knows of the Van Allen radiation belts, streams of charged particles trapped by the magnetic field of the earth, spiraling around the magnetic-field lines, reflected from North Pole to South Pole, and causing the auroral lights where the particles enter and are absorbed by the atmosphere. We have passed through the period of discovery of the radiation belts, the period of exploratory measurement with simple apparatus, and are now engaged in more refined and detailed measurements of the complete classification of various types of particles and their energy distribution. Our measurements are yielding a picture of the distribution of the protons and electrons in the region around the earth. We have even studied artificial radiation belts produced by high-altitude nuclear explosions.

We have learned the main features of the earth's magnetic field. We find that the moving magnified earth produces a magnetic shock wave in the interplanetary field, i.e., a region of sharp rise in magnetic-field intensity from the low values of the quiet interplanetary medium. Behind the shock wave is a region of transition to the earth's field exhibiting irregular variations in magnitude and direction.

These examples must suffice. We stand at the threshold of a comprehensive experimental attack on the manifold relationships between events on the sun and events on and near the earth through the use of orbiting geophysical observatories equipped with a variety of instruments for simultaneous measurements of a large number of physical phenomena.

CASE

The earth's atmosphere blanks out much information about the sun, planets, and stars in the ultraviolet and X-ray wave lengths as well as in some parts of the infrared and radio region. A substantial beginning has been made on rocket and satellite astronomy which has produced many important results. The orbiting solar observatory has been an important tool for studying the behavior of solar flares at wave lengths in the far ultraviolet and X-ray region. Gamma radiation from outer space has been measured with results that make doubtful one proposed theory of the origin of the universe.

We are at the beginning of scientific exploration of the moon by the unmanned Ranger probes, our technology just now approaching a sufficient reliability for the purpose. We expect to get television pictures of the moon's surface not only to settle an argument between scientists as to the character of the moon's surface but to provide data to design landing gears for landing on the moon.

Mariner 2 was launched on August 27, 1962 from the Atlantic Missile Range at Cape Canaveral by means of an Atlas-Agena-B rocket at an initial speed relative to the earth of about 23,000 miles per hour. The earth travels in its orbit around the sun with a speed of 66,000 miles per hour. Mariner 2 was injected on an inclined path opposite to the orbital motion of the earth so that its speed around the sun was reduced and it began to fall toward the orbit of Venus which is nearer to the sun. On September 4th, observations having indicated that Mariner would pass Venus at a distance of about 230,000 miles, a midcourse correction was made on command from the earth which reduced the miss distance to 21,600 miles. At this time Mariner's speed around the sun was reduced to about 60,000 miles per hour and it was behind the earth but closer to the sun. As Mariner continued to fall toward the sun its speed increased and it passed the earth on October 30th at a distance of 11½ million miles or about half the distance to the orbit of Venus. Mariner passed Venus at a distance of 21,000 miles on December 14th, 109½ days after launching. At that time Mariner was traveling at a speed of about 87,000 miles per hour, Venus was 21,600 miles away and the earth was about 36,000,000 miles away. Mariner had traveled 182,000,000 miles or nearly halfway around the sun. On December 27 it reached its closest point to the sun and continues as an artificial planet of the sun. Radio contact with it was lost on January 3, 1963 at a distance of 53,000,000 miles, a record distance for radio communication.

Mariner 2 was designed by Jet Propulsion Laboratory scientists and engineers at Pasadena, California. During the 109-day trip they had many anxious moments as various minor troubles developed and were overcome. Battery temperatures increased beyond those expected, but all's well that ends well. The mission was successful.

Nearly ten million measurements were made during the flight and all the data have not yet been analyzed. But some preliminary results have been reported. The cosmic dust experiment, measuring particles of a thousandth of an inch and smaller, shows that such particles are concentrated near the earth. The number of particles encountered in deep space is at least a thousand times less than near the earth.

The solar plasma measurements showed that streams of very hot ionized gas are projected from the sun to and beyond the earth. We are in a solar wind. When the sun is quiet, its velocity is about 250 miles per second, there are ten to twenty particles per cubic inch, an exceedingly low density, and its temperature is a few hundred thousand degrees. Disturbances on the sun, known as solar flares, eject clouds of higher velocity, density, and temperature and the solar wind has been observed to blow much harder for days at a time on numerous occasions, up to 400 to 450 miles per second. The solar wind is able to carry magnetic fields trapped within it and pushes back the earth's magnetic field to about 40,000 miles on the sunward side of the earth and stretches it out to much greater distances on the dark side. The solar wind travels faster than the normal plasma waves and is expected to produce a shockwave around the earth and other planets.

The magnetic field in interplanetary space is about 1/50,000th that at the surface of the earth, about equal to the magnetic field produced by the nail in one of your shoes at a distance of four feet. In scientific terms, under quiet conditions, the field is between five and ten gamma, varying slowly or remaining constant for an hour or two. In magnetic storms values up to 25 gamma were observed, and there are transverse components whose direction changes through wide limits with reference to the plane of the ecliptic.

The very high energy corpuscular radiation or cosmic rays remained very constant at the values expected for galactic cosmic radiation, about three particles per square centimeter per second. The low energy particle counters show a very low flux.

At the time of writing this talk, the data on the temperature of Venus had not been reduced. However, no magnetic field and no radiation belts were observed at the distance of 21,600 miles. From this scientists infer that the magnetic field of Venus cannot be greater than one-tenth that of the earth.

The U.S. space program includes the applications of space science to peaceful activities for the benefit of mankind which are widely known throughout the world. The very first Tiros sent back cloud pictures which gave the location and development of major storms over most of the globe. Hurricane warning services have been made more reliable and countries like Australia and Japan surrounded by large ocean areas for which there are few weather observations have been able to greatly improve their forecasts. The photographic records furnish much data for research on global weather; for example, major hurricanes can be traced back to their origin, sometimes beyond the Caribbean to the coast of Africa and their whole history studied.

Echo, Relay and Telstar are familiar to all as successful demonstrations of transoceanic communications satellite, the latter two having carried live television programs across the Atlantic as well as facsimile, teletype and telephone traffic. Congress has established an operational agency to bring about a global satellite communications system.

The U.S. program includes the development of manned space flight. Many of you shared with NASA scientists and engineers the tensions of the Shepard, Grissom, Glenn, Carpenter, and Schirra flights and look forward to the one-day flight of Cooper in a few months. This program has been so well described in the press and in magazines that I need not here review this great team effort between NASA, the Air Force, the Navy and countless industrial contractors. The global tracking network and its magnificent performance is a story in itself.

We have been engaged in the development of the large Saturn rocket since the establishment of NASA in 1958. This rocket with a take-off thrust of 1½ million pounds will sometime this year place 19,000 pounds in earth orbit, somewhat larger than the 14,000 pounds demonstrated so far by the USSR. We are thus increasing our capability to launch heavier payloads into space.

The U.S. program includes substantial work in advanced research and technology to lay the groundwork for the future. In addition to research in aerodynamics, structures, propulsion, guidance and control, life sciences, electronics, and other pertinent fields, developments are in process on nuclear rockets, electrical propulsion, and nuclear auxiliary power.

The U.S. program includes the applications of space science to military needs. For the most part the military applications are classified.

In manned space flight, we recall that President Kennedy on May 25, 1961 announced major new goals for the space program, the development of the technology and tools to permit the exploration of our nearest neighbor in space, the moon, by man himself. A specific target was to land man on the moon and return him safely before the end of this decade. The first step in this program beyond the Mercury project is Project Gemini which has been under way for about a year. The objectives are to provide manned flight in earth orbit for periods up to two weeks as compared with one day for Mercury. This will enable us to determine man's performance under weightless conditions for times longer than required for a flight to the moon and back. Further objectives are to carry out scientific and engineering investigations of space that require manipulation or supervision by man; to develop the technique of bringing two satellites together in space (which we call rendezvous) and joining them (which we call docking); and to demonstrate control of reentry and landing on land, instead of in the ocean as was done with Mercury. The Gemini spacecraft carries two men and is to be launched by a modified Titan II booster developed by the U.S. Air Force.

We are hard at work on the three-man Apollo spacecraft capable of safe return to earth from the moon and a two-man lunar excursion module designed for operation in the vicinity of the moon and for lunar landing and take-off. The Apollo missions begin with earth orbit missions in some of which separation and rendezvous with the lunar excursion module will be practiced with docking and transfer of astronauts between the two vehicles. These missions may utilize elliptical orbits more and more elongated until the moon is circumnavigated without landing. The final mission involves

slowing down of the Apollo spacecraft near the moon to enter a lunar orbit, the landing of two men in the excursion module on the moon, return to rendezvous in lunar orbit, abandon the lunar excursion module, and return of the three men to earth in the Apollo spacecraft. In the course of reaching this goal we will have developed a national capability to accomplish many other missions in space.

In particular we require a launch vehicle much larger than Saturn and this launch vehicle, the Saturn V, is well under way. It uses a cluster of five F-1 rocket engines, each of 1½ million pounds thrust. The development of the F-1 engine was begun when NASA was established in 1958. The Saturn is itself a large rocket, about 22 feet in diameter and 190 feet high, about the height of a fourteen-story building. Saturn V is a truly enormous rocket. With the Apollo spacecraft as payload, the complete space vehicle is roughly a two-thirds scale model of the Washington Monument in Washington, D. C. Saturn V is 33 feet in diameter and 373 feet in height. It is capable of putting more than 100 tons in earth orbit or 40 tons to the vicinity of the moon. First launch is expected to occur in 1965.

There is no question that the rate and scale of the U.S. effort is largely determined by considerations of international policy and the cold war, and possible extension of weapons development to space. But space exploration has major significance for the economic development of the Nation far beyond the direct effects of the spending of billions of dollars. NASA is making a special effort to accelerate the transfer of new knowledge and techniques to all industry. We recall how the development of the airplane brought us large supplies of aluminum, a previously rare and costly material. In time this new material found its way into lightweight structures for trains, buses, buildings, and ships and into countless applications in our homes. The space age has given us high-temperature ceramics, ablating materials for heat protection, cheap liquified oxygen and other gases, and many processes and techniques which can keep our whole industrial system alert and constantly increasing its capabilities to build useful products to meet old and new needs.

While the new technological developments offer the earliest contributions to economic development, in the long run the scientific knowledge obtained in the great unknown environment of the celestial bodies and interplanetary space may bring much greater returns. For, judging from past experience, advances in scientific knowledge are the foundation of advances in technoogy, which are a key factor in economic development.

There are many ways of placing in perspective the large costs of space exploration by a large nation. For example, the total cost of the Mercury program to each inhabitant of the United States was about one dollar per year for three years. You may judge for yourself whether the results of the flights of the astronauts were worth this amount to the Nation. The lunar landing program is more expensive; the estimated cost to each inhabitant of the United States is about twenty dollars per year for five years, hopefully a little less.

In conclusion, let me emphasize there is no single and simple answer to the why of space exploration. The why rests on the collective motives of two hundred million people. Some are interested in space as an intellectual gold mine of new scientific knowledge. Some seek the material rewards of exploiting a vast unexplored domain for treasure as real as the spices from India, gold from the New World, or furs from the far North. Some see space as another arena of battle and conflict. Some hope that the nations of the world may work together in the exploration of space for peaceful purposes and for the benefit of mankind. In the National Aeronautics and Space Act Congress declared this to be the policy of the United States. Those who are engaged in the work have various motives. Some seek fame, some material profit, some intellectual satisfaction, some a sense of public service. Because of the sum total of all these motivations, the Nation continues to support a major effort in space exploration with determination to lead in space science and technology.

We live, in the language of the old cliché, at a great moment in history. Man has begun to lift himself above the restrictions of his planet into a new and strange environment and to expand his intellectual horizons. This is no visionary activity but one essential to the strength and security of our Nation and to the future of man in the universe.

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