A FUTURE FOR SPACE?

By

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In the early years of the space program, we worked hard to make significant accomplishments with the only vehicles available to us - those derived from the military missiles - in order to keep space activity from being predominantly a Soviet area of achievement. We did fairly well in those early years from 1958 to 1961 in making some important space discoveries, although we were a late entry and although we were almost hopelessly behind the Soviet Union in payload capability.

During 1958, this country's satellites discovered and explored the belts of energetic particles that surround the Earth and determined that the Earth is not an oblate spherical, but slightly pear-shaped. In the second year of our flight effort, we continued to measure the energetic particles and magnetic fields in space and we started flight testing of the Mercury capsule which was to pave the way for our manned space flight experience. In 1960, our program broadened to include the first Tiros meteorological satellite launches and the successful launch of the first passive communications satellite - the Echo satellite - in addition to continuing our investigation of particles and fields in space and the Mercury capsule development.

Most important during the period 1958 to 1961 was the work done to initiate the development of systems that would increase our space flight capability beyond the payloads permitted by the vehicles derived from the military missile systems. The Air Force started the development of the Centaur hydrogen-oxygen rocket designed to provide a deep space capability in combination with the Atlas booster. ARPA started exploratory development of the cluster of 8 H-1 150,000 pound thrust engines that led to the first stage of the Saturn I vehicle - a million and a half pound take-off thrust booster. NASA initiated development of the F-1 million and a half pound thrust rocket engine only a few months after the agency officially started its operations, and late in 1960, NASA started development of the 200,000 pound thrust J-2 hydrogen-oxygen engine.

Major firsts were registered by the Soviet Union during those early years. In 1957, the Russians launched the world's first Earth satellite and the first animal-carrying satellite; they had launched and recovered many sounding rockets that carried dogs to high altitudes previous to that orbital flight. In 1959, they impacted a payload on the moon and photographed the moon's far side. In 1960, they launched and recovered a dog-carrying satellite and in April of 1961 they launched the first man into orbit a month before our first manned suborbital Mercury flight and a year before our first orbital flight. They followed Gagarin's orbital flight with another orbital flight by Titov in August 1961.

In spite of this apparent Soviet emphasis on space flight and the boost it gave Soviet prestige throughout the world and the sense of achievement it gave its own people, there was a reluctance in

those early years of the space program to commit the United States to the kind of intensive space effort that would clearly demonstrate and re-establish our leading technological position in the world. Space exploration was not considered by many to be sufficiently well understood to justify a major increase in this country's program. As an example, President Eisenhower's last budget message submitted to the Congress on January 16, 1961, proposed a NASA budget of $1.1 billion and spoke with pride of our space accomplishments but cautioned that, "Further testing and experimentation will be necessary to establish whether there are any valid scientific reasons for extending manned space flight beyond the Mercury program."

Four months later, Gagarin's orbital flight, concern about the declining international image of the United States, our economic sluggishness, the need for a new vitality and objectives in this country led President Kennedy to propose a substantial increase in our space exploration activity with the goal of landing men on the moon in this decade. Though he recognized the scientific implications of such an undertaking, it was apparent that political, economic, and social factors played a major role in arriving at the conclusion that such a goal was necessary to assure a leadership position for the United States in all of its national and international interests. President Kennedy called for, "a clearly leading role in space achievement, which in many ways may hold the key to our future on earth."

We stand once again at a critical point in this country's program of space exploration when specific goals and objectives must be established. Though our ability to explore space is far greater than it was in 1961 and our accomplishments have been many and excellent, the decisions we face now are similar to those we faced in 1961. We must once again define the routes we should take to assure that we fulfill one of the important goals specified in the National Aeronautics and Space Act of 1958 - "the preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof...."

We have not yet achieved the position of leadership that was called for by President Kennedy and that has been reaffirmed by President Johnson. We cannot yet be sure that we will land men on the moon in this decade or that we will be the first to do so. Even if we are first, we now have no basis for assuming that we will retain the leadership that such a "first" would imply. The Russian effort in space is strong; it is growing; it is thorough; it is broadly based; it constitutes a larger commitment as a percentage of the gross national product than does ours. In 1965 alone, the Russians launched 63 spacecraft - more than the combined total of the two preceding years. So far this year, they have launched 20 spacecraft.

Our space effort is now at its peak and is starting to decline. The missions we laid out in the early years of the space program are now nearing accomplishment. Mercury, Echo, Tiros, Nimbus, OGO, OAO, Ranger, Surveyor, Lunar Orbiter, Gemini, Biosatellite, are among the many missions that are either already completed or will

be completed in the next year or two. In fact, the approved program plan now shows a rapid decrease in launches after 1967 to only two Mars Mariner flights in 1969, a few relatively small scientific and technology missions and several flights in the Apollo program. Even Apollo, the major effort to land the first men on the moon in this decade is now at its peak level of effort and is beginning to decrease. The first manned Apollo spacecraft flight in orbit is planned for 1967 and it is hoped that the first lunar landing will be accomplished in 1969.

The basic questions then are, "What will our space program be called upon to accomplish beyond the currently approved missions? How will continuity of U. S. accomplishment in space be assured and a flight gap be avoided, so that space does not become solely a Soviet area of achievement? Will this country's varied interests and commitments to our people and to the world include the establishment of new space goals - beyond Apollo - that will assure a leading role in space and in the world?" Will our space exploration capabilities be fully utilized or allowed to disband?

It is already too late to assure continuity of space accomplishment with any new major mission goals at a rate as high as we have been experiencing. With the long development lead times involved, no new mission objective that requires major new hardware could be developed to carry on the high level of manned space flight activity and accomplishment such as in Mercury, Gemini, and Apollo, or to carry on the high rate of activity being maintained in our unmanned space science and our satellite applications flight program.

Only by using systems that are available or are being developed for the currently approved missions will we be able to provide some level of space program continuity. Fortunately, our current program is providing a strong capability for space activity in systems such as the Apollo spacecraft, the Lunar Excursion Module (LEM) that will carry the men to the surface of the moon, the Saturn V vehicle that will launch the Apollo-LEM system on the lunar landing trip, and the Saturn I B vehicle that will be used to launch the Apollo spacecraft into an earth orbit for flight testing. We must use these systems if we are not to retreat to simply an observer role.

The goal of the Apollo Applications Program (AAP) that is being proposed is to define enough significant space experiments that will use available hardware to provide needed data for future missions and to assure continuity of space activity until new missions that are defined can be developed and start their flight activities. AAP therefore can play an important role in this country's space program if we are to appear truly competitive in this area of technological achievement.

However, this program is not yet approved, nor is it fully defined. But enough experiments are being defined to permit a start at filling the space accomplishment gap that already appears inevitable. Hopefully, enough funds will be provided in the FY 1968 budget to permit the AAP to play its role as an assurer of continuity. If the level of activity is not sufficiently high to bridge the gap between Apollo and any future missions goals, then the full value of AAP will not be achieved. On the other

hand, if AAP is approved and supported at the full required level, without definition and initiation of future space flight exploration goals, then we may not have sufficiently clear space mission objectives to assure a truly useful AAP program. If AAP is to support long term goals, these goals should be defined.

I believe that we can specify clear and long term objectives that will continue to challenge our science and technology, that will increase our space exploration and satellite application capability, that will provide a continuing high rate of accumulation of important space knowledge, that will assure this country's leadership position and the resulting benefits for the United States and mankind.

One of the major undertakings that has been suggested for our follow-on post-Apollo program is planetary exploration leading eventually to manned exploration of Mars and, if it turns out to be hospitable, Venus. Such a program would be a long term effort including unmanned flights to Mars and Venus with well instrumented spacecraft, manned Earth orbiting research laboratories and space stations, manned planetary flyby and orbiter missions from which unmanned capsules could be landed on the planet, and, finally, manned landings on Mars and, if possible, on Venus.

A manned planetary mission program would certainly provide an umbrella and a focus for a long term, broadly based, challenging space program. Indeed, it is the broad base of such a long range program objective that I believe provides its major justification. It would challenge technology; it would require increased capabilities in almost all of our technological disciplines and in our

basic capability to travel in space; it would provide a vast fund of scientific knowledge and understanding of the solar system; it would help to better understand the origin of life and man; it would maintain the vital challenge that has generated the interest of all of our people and particularly our young in science and engineering; it would have a significant effect on our relations with the other countries of the world and could become an important force toward cooperation and unity. Our accomplishments in space were a happy highlight in the reporting of this country's world-wide interests and activities during the past two weeks. Also, space vehicle development became an important item for consideration in discussions affecting the cooperation and unity of Western Europe and discussions on operations on extraterrestrial bodies appear to offer an area of agreement and cooperation with the Soviet Union. Such a broadly based program plan would continue to offer all of these opportunities.

In the conduct of such a total planetary mission program, nuclear energy would play an important role. Nuclear systems now under development and systems based on technology that is now being developed would be required to provide power and propulsion for the wide variety of missions that would be required in this total effort.

Such a total program plan would have to start with unmanned spacecraft sent to the planets. Voyager is the name given to the program aimed at exploring the near planets, Mars and Venus, with such large, heavily instrumented, unmanned spacecraft. These spacecraft would orbit the planet and drop small capsules to the

surface of the planet to measure subsurface, surface, and atmospheric characteristics and to initiate work aimed at detecting life. Study groups of the Space Science Board of the National Academy of Sciences have called for emphasis on such investigations on scientific grounds.

But even this important mission which has been part of space program thinking since 1958 is not approved. With its persistence in launching spacecraft towards Mars and Venus at every opportunity, the Soviet Union leaves little doubt that it has considered planetary exploration as a major objective of its space program. However, even if approval for Voyager were included in our FY 1968 budget, the first Voyager missions to Mars could not be conducted before 1973. In the meantime, Mariner spacecraft will go to Venus in 1967 and to Mars in 1969. These spacecraft weigh several hundred pounds and are essentially the same configuration as the Mariner II that passed Venus in 1962 and indicated very high surface or atmospheric temperatures, and Mariner IV that took the first pictures of Mars in 1964 as the spacecraft passed within 6200 miles of the planet. These spacecraft are, however, too small to provide all the data looked for by the scientific community. The current thinking on Voyager involves launching two spacecraft systems, each weighing about 20,000 pounds on a single Saturn V vehicle at each Mars launch opportunity beyond 1973. The objectives will be to place 2500 pound spacecraft into orbit around the planet and land capsules carrying hundreds of pounds of payload to study the properties of the planet.

The availability of power for the orbiting and landing capsules is one area that requires further development. Solar energy at Mars is only one-half the amount that is available at Earth. Therefore, solar cell panels that convert solar energy to electrical power become large in area although they are still feasible. However, on the surface of Mars with its limited available solar energy, other power systems must be provided. The AEC is now working with the NASA Jet Propulsion Laboratory to determine how nuclear radioisotope heated electric power systems could be incorporated into the orbiting spacecraft system and, most important, into the landing capsules. For these applications we may need several hundred watts of electrical power.

Radioisotope heated systems using thermoelectric conversion of the heat to electricity are not new. Four of these systems have already been used in Department of Defense space flight missions at powers of 3 watts and 25 watts. One of the three watt units is still operating in space after almost five years. The AEC is also developing such radioisotope power systems for the NASA Nimbus weather satellite and for the Apollo experiments that will be placed on the moon by our astronauts. In addition, the AEC is initiating the development of a 400 watt isotope power supply based on interest expressed by the DOD which may be of value in a wide variety of future space missions.

An important point in this connection is that the development of a particular system for a particular mission leads inevitably to the use of that system in other missions. This is one of the major justifications for initiating advanced developments that can

then be available for application in a wide variety of flights. For example, the 25 watt SNAP-19 radioisotope powered system is being developed by the AEC at the request of NASA for the Nimbus program which is scheduled to be launched in late 1967. During the course of this development, the AEC received an urgent request for a power supply required in a matter of months for another application. With minor modifications, the SNAP-19 system was made available to meet this high priority program need. In addition, discussions are now being held with DOD agencies that have expressed their interest in the SNAP-19 generators for the DoDGE-M satellite. This is a multi-purpose experimental satellite being studied by the DOD. [redacted]

Another important element of this total planetary exploration program plan is the requirement to conduct enough research in Earth orbit to assure that men and equipment can operate in space for periods of several hundred days which are the normal trip times for a round trip visit to Mars. The Gemini, MOL, and Apollo systems are a step in this direction. Gemini is providing and MOL and Apollo will provide much of the operating experience that will guide the large orbital laboratory design and that will determine the means to be used in the larger laboratories to conduct useful experiments in space that could be done more effectively there than in large, complex, and costly laboratories on the ground. These larger earth orbital laboratories will be required to provide the long periods in orbit - up to at least a year - needed to simulate a manned planetary mission. They will also be needed as orbital assembly and checkout stations for the large interplanetary

vehicles and as space science installations. These larger orbital laboratories would be manned by a crew of at least 6 to 12.

Such laboratories could eventually also be so arranged that they could also constitute an orbital test bed. In this way, advanced space systems could be brought to the laboratory, set up in the test bed, and development tests could be run under careful control without losing the opportunity for detailed in-test and post-test diagnostics. It is conceivable that entirely new systems that could not be developed by normal ground test methods and that could not be realistically conducted in unmanned flight tests could be developed in such space test beds. Such systems have been proposed at various times but they have been ruled out because of the difficulty of assuring their developability and reliability in space.

One such system is a nuclear reactor electric power supply that depends on boiling a metal working fluid in the reactor and then separating the vapor from the liquid - all in zero gravity - before using the vapor to drive a turboalternator that would generate large amounts of electric power. Orbital laboratory test beds would make the development of such systems possible and could open the way to advances in space technology not now considered feasible.

In addition, it is conceivable that follow-on extensions of such laboratories might permit production and fabrication in the space environment of superior products. For example, refractory metals must be fabricated (welded) in inert gas or preferably a vacuum atmosphere. The natural environment of space may provide an opportunity for large scale, high quality fabrication, of advanced materials.

An orbital laboratory operation of the growth magnitude I have described would be economically a more attractive system if a recoverable logistics vehicle or a cheap Earth-to-orbit launch vehicle were available to transport supplies, experiments, parts, etc. between the earth and orbit. Such an orbital laboratory operation would also require the availability of large amounts of electric power that could be provided most satisfactorily by nuclear energy systems that are under investigation. The early versions of these laboratories might need 10 kilowatts of electric power for which radioisotopes would still logically provide the heat energy required; however, instead of using direct conversion thermoelectric elements which have efficiency of only about 5 per cent, Brayton cycle gas turbine-alternator systems having efficiency of as high as 25 per cent are being developed and would be used. Strong interest has been expressed in these systems by various DOD agencies as well as by NASA. The AEC is now developing the technology of the isotope heat source and the special fuel and containment materials needed for such systems. NASA is developing the technology of the conversion equipment.

The later versions of these orbital laboratories will undoubtedly grow in power requirements to at least the 30 kilowatts that is the initial development target of the SNAP-8 nuclear reactor-mercury Rankine turboalternator system. With continued support and with technical success in the program, this electric power system should be available in time for such a large laboratory operation. However, its growth version will also be needed if significant orbital test, research, and fabrication operations

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that are being used now. However, if nuclear propulsion is to be used, then this weight could be reduced by at least 40 per cent and, if a high enough rocket specific impulse is achieved, perhaps in half to about 500,000 pounds. Two, or at most three, Saturn V launches with assembly in orbit would be required to perform such a nuclear propelled flyby; if the Saturn V were uprated to a payload in earth orbit of half a million pounds by strapping solid rockets to the basic vehicle, then it may be possible to do the mission with a single Saturn V launch.

The use of nuclear rocket propulsion for such a mission presents no technical problems. The success that we have had in the joint AEC-NASA program to develop nuclear rockets over the past two years demonstrates the high performance that can be achieved with these systems, their high reliability, the high degree of understanding we have about them, and, in general, the high level of confidence with which mission commitments can now be made to their use in the space program. I believe that commitments can and should now be made to use nuclear rockets wherever payload weights greater than those of the basic Saturn V vehicle will be required beyond earth orbital missions. These would include direct flight lunar landing missions, planetary flyby missions, and the planetary landing missions. It certainly appears a much wiser long term investment to apply this advanced system as early as possible to derive the benefits of this new technology than to make new investments to stretch the older technology.

Since May of 1964, our nuclear rocket program has successfully tested six nuclear rocket reactors and one total breadboard engine. The maximum operating time at full power on a single reactor was achieved in the breadboard engine when that system was run for almost 30 minutes at full power with an altitude equivalent specific impulse of over 750 seconds compared to the 425 to 440 seconds which is the maximum achieved on chemical rocket systems. The total integrated operating time on all of these reactor-engine systems has been $4\frac{1}{4}$ hours. Every single test was successful and met or exceeded its test objectives. This test record leads us to the obvious conclusion that nuclear rockets offer high reliability in addition to extremely high performance with logical and well understood development program requirements. No other advanced propulsion system is as well proven out in development at this time; it is highly improbable that any other one can be available in the time period when manned operations in space may require them. Nuclear rockets provide a major advance in this country's capabilities to explore space and to be a leader in space technology and "in the application thereof to the conduct of peaceful activities...".

Beyond the flyby or eccentric orbit missions, would come the manned planetary landing missions. These would require extremely large and heavy spacecraft systems with large space propulsion energy requirements. It is important to recognize that manned planetary mission planning involves understanding the atmospheric conditions and surface conditions of the planets;

it gets involved with interesting possibilities of playing what I might call "space billiards" to make the missions easier (lower energy requirements) and perhaps to make such missions more valuable. Because the earth and the other planets - for example Mars - do not move in circular orbits around the Sun, different amounts of energy are required to do a Mars mission at different opportunities. As a result, the weight of the total interplanetary nuclear rocket propelled spacecraft system that would have to be assembled in earth orbit for a Mars mission could vary from 1.5 million to almost 5 million pounds. This variation could be reduced to 1.5 to 2.5 million pounds if the route to Mars, or returning from Mars, were designed to pass close to Venus. This space billiard shot would take advantage of the fact that the mass of Venus exerts a gravitation attraction on the spacecraft system that adds or subtracts velocity and can change the direction of flight.

It is interesting to point out that for other missions, the large mass of the planet Jupiter can turn spacecraft almost anywhere in the solar system. For example, a probe at the Sun can be accomplished by launching outward to Jupiter and using that planet to put enough "English" on the shot to turn the spacecraft around and have it hit the Sun.

It may be helpful if I described the conduct of a manned Mars mission starting from Earth orbit in 1982. Such a timing should be technologically possible if decisions were made to proceed towards such a goal. The total spacecraft made up of

the Mars Mission Module, the Mars Excursion Module, and the Earth Return Module and the necessary midcourse and orbital maneuvering propulsion might weigh 300,000 to 350,000 pounds. The three stages of nuclear rockets required to propel the spacecraft out of Earth orbit, decelerate it into the Mars orbit, and depart from the Mars orbit would weigh almost another 2 million pounds if space billiards or planetary English is not relied upon. If Venus swingby is used, then the total initial system weight in Earth orbit would be almost 1.8 million pounds instead of 2.3 million pounds. If the orbital payload capability of Saturn V were increased to about 500,000 pounds (its present designed capability is 250,000 pounds), then this entire system could be placed in orbit using 6 uprated Saturn V launches and could be assembled in the orbital laboratory assembly station. A preferable approach would probably require the development of a post-Saturn launch vehicle having an orbital payload of at least a million pounds to reduce orbital assembly operations.

In any case, the three stages of the space vehicle assembled in Earth orbit would use the same nuclear rocket engine having a thrust of 200,000 to 250,000 pounds and a specific impulse of about 800 to 850 seconds. The orbital departure stage would use a cluster of two or three nuclear propulsion modules while the other two stages would each use a single propulsion module.

The first stage would fire for about 30 minutes (as I pointed out earlier such operating times have already been achieved in ground tests) and would accelerate the spacecraft to a velocity of approximately 40,000 feet per second relative to Earth. As it escapes the Earth's gravitational field, the spacecraft slows somewhat and joins the family of planets in our solar system racing around the sun. With its carefully planned trajectory, the spacecraft will "catch-up" to Mars and be "caught-up" by the Martian gravitational field. As Mars is approached, a gradual increase in velocity relative to Mars will occur until a value over 20,000 feet per second is reached when the spacecraft comes to its closest approach to the surface of Mars. Then, the second nuclear rocket stage would slow down the spacecraft until it achieves Mars orbital velocity of about 10,000 feet per second. This part of the trip to Mars would take about 220 days. Six or perhaps seven of a ten man crew would be landed on the surface of Mars in the chemically propelled Mars Excursion Module (MEM). After about 30 or 40 days of exploration, they would return to the orbiting spacecraft for the 200 day trip back to Earth.

This kind of a mission certainly sounds difficult, and it is. However, with a properly planned total program, including the necessary attention to the development of the required technology in addition to carrying out the necessary precursor missions, some of which I have briefly discussed, this mission should be no harder to do in the early part of the decade of the 80's than is the lunar landing mission in

this decade. This is the broad outline of one total program plan that I believe can be established. It is not, however, an approved space program plan.

Before closing, I would like to emphasize that the national character of the space program demands its continued emphasis. It is playing an important role in the DOD through unmanned satellite applications. Officers of the Air Force, the Navy, and the Army are directly involved in NASA's program. In the AEC, military officers are also directly assigned to development projects applicable to NASA and DOD missions. About 140 universities are involved in the NASA University program. Over 400,000 people and over 20,000 companies throughout the country are working in the program. The program has an international character too as reflected by the 64 countries participating in various ways in it. The effects of space exploration are felt everywhere. Though I don't know the specific areas with which you are involved, I feel sure your work has been or will be affected by space operations and space technology.

Obviously, a strong space capability is not enough for this country if it is to effectively carry out its responsibilities at home and throughout the world. It must be strong and advanced in all fields. It must be militarily strong, it must be scientifically advanced and searching; it must be economically sound. None of our people must be deprived of the essentials of good living and opportunity - the opportunity for education, equal

opportunity for productive and challenging work, for good homes, for pleasant surroundings. This kind of a total image is not easy to establish. All of these national requirements add up to heavy demands on our resources that must be properly balanced.

In this balance, we would certainly anticipate that the capability that has been established for space exploration will be effectively utilized and expanded to assure our strong position. In receiving the Robert H. Goddard Trophy earlier this year, President Johnson said, "...so long as I am in public office, I am going to do everything within my power and my capability to prevent us from falling behind...The whole Nation now understands the true significance of America's space efforts. The story of man's advancement down through the ages is, of course, the story of his victories over the forces of nature. The health and comfort he enjoys, the leisure he possesses, the abundance of food he eats, all of these are the result of his unending determination to probe the secrets of the world around him.

"In 1958 when we introduced the legislation to create the National Aeronautics and Space Administration, I said in the Senate at that time, 'I believe that the development of the space age will bring the beginning of the longest and greatest boom of abundance and prosperity in the history of man.'

"Time is bringing out that belief. The future belongs to those of faith, daring, and vision...".