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Nuclear rockets and the space challenge

The nuclear rocket can not only assure us of being first in the race to the near planets, but also, if developed early enough, can provide insurance for our U.S. program to put a man on the moon before 1970

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As has been pointed out frequently by NASA and other government officials, the Soviet Union has chosen the area of space exploration as the most visible form in which to demonstrate its technological strength. It is using this area of science to win the high technological position that we have held, and thereby to win the support of the world.

We have, as you know, made significant contributions to a scientific understanding of the space environment and to the practical applications of the satellite equipment that we have developed. Our work in these programs has been freely disseminated for the benefit of all. The Pioneer and Explorer series, Tiros, Echo, and Transit are important U.S. contributions in the areas of space sciences and space technology and are areas in which we have the lead.

It is an obvious fact, however, that in terms of manned space flight, we are behind. The Russians have larger vehicles, they have been developing heavy spacecraft, they have orbited a man, they have guided vehicles to an impact of the moon and to a position where they could photograph the back side of the moon. The second satellite they launched in November 1957 (before our *first* satellite), carried Laika, the dog, undoubtedly as part of their manned space-flight program. It was not until a year later, when NASA was established, that we initiated our Mercury program. The Russians must have planned their manned program at least five and a half years ago. Our manned program, and in fact our civilian space program, has been in existence for only three and a half years.

The Russians also started their program with the commanding lead offered by the large ICBM vehicles they had developed. We are still struggling with the small payloads provided by our smaller Atlas vehicle. Not until we have developed the Centaur vehicle will we even come close to Russian orbital payload capability, and not until we have Saturn will we have an orbiting capability greater than the one the Russians have demonstrated.

But obviously we cannot anticipate that the Russians will sit around idly twiddling their thumbs. They are too well motivated for that. We must assume that they will be trying for still greater achievements in space.

Where, then, do we direct our space efforts in trying to accept the challenge? Several approaches are possible. We could launch an all-out effort to achieve a manned lunar landing as early as possible in this decade in order to try to beat the Soviet Union in that mission (see page 20). Or, on the other hand, we may determine that we should devote our major emphasis to manned Mars and Venus missions and perform the manned lunar landing whenever that becomes possible, using the technology we develop for the planetary missions. A third alternative would call for carrying on with large lunar and planetary programs simultaneously.

Although it could not be done in this decade, perhaps we must aim our program for Mars and Venus. We may not beat the Soviet Union to manned lunar landings because of their head start, but we should be able to plan a program to beat them to the planets. Our program would, therefore, be a long-range one with the moon as a preliminary objective and the near planets as our ultimate objective. Under these circumstances, the nuclear rocket system would have to be our major propulsion development.

In fact, our nuclear rocket program is being conducted with the requirements of planetary missions in mind. I am convinced that our program will provide us with the nuclear rocket technology for planetary missions and that, with sufficient support, it will almost automatically provide us with the capability to perform the lunar-landing mission and with the technology required to provide for extensive manned lunar operations such as will be required, in time, when bases are established on the moon. We believe that we are ahead of the Russians in the development of nuclear propulsion systems and we therefore believe that we can beat them in the long-range space program. To indicate the importance of the nuclear rocket in such a long-term program, I would like to review the results of some of the vehicle analyses that we have conducted for Mars and lunar missions.

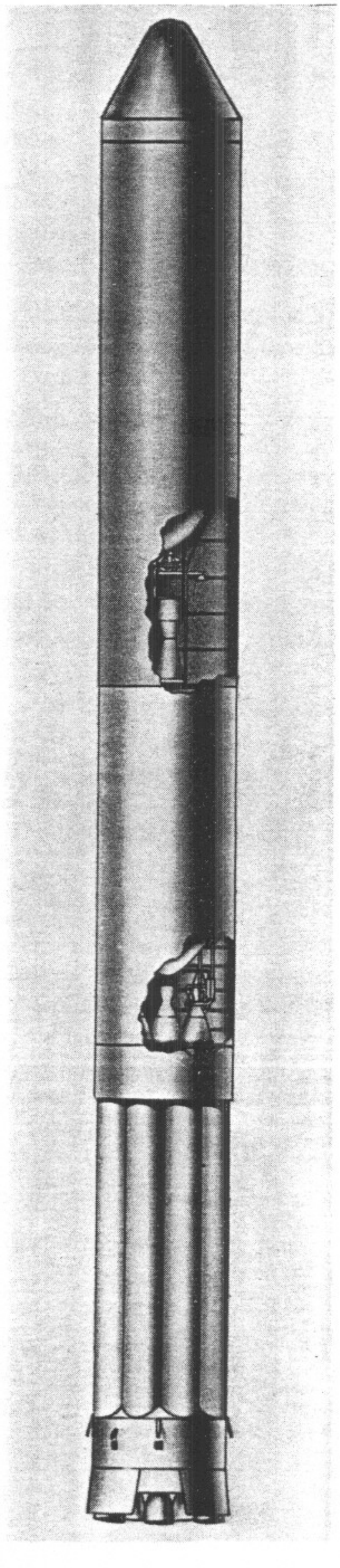
We Seem to be on the Right Track

Obviously we cannot at this time accurately and definitely specify the requirements of a manned Mars mission. However, we have made calculations to give us an indication of the types of systems that would be required for such missions. A detailed specification will require the accumulation of considerably more information on the space environment, the mechanics of flight to the planets, the technology of guidance, propulsion, and vehicle design, and the operation of both man and machine in space. Our calculations have indicated that the performance of the manned Martian mission with all-chemical combustion rocket systems would require the assembly in an earth orbit of a spacecraft weighing 9 to 10 million lb. Although this is theoretically conceivable, I believe that, from practical considerations, it is not feasible.

There is universal scientific agreement that the performance of this kind of a manned Mars mission will require the use of nuclear energy for propulsion. Although chemical combustion systems will still play a role in placing the necessary parts of the spacecraft into orbit and in performing the maneuver of landing on the planet from an orbit around Mars and then returning to the orbiting spacecraft, nuclear energy will provide the propulsive power for the major portion of the mission.

In comparison with the chemically-propelled spacecraft, a nuclear-rocket spacecraft would weigh 900,000 to 1,000,000 lb — one-tenth the size of the chemical vehicle. It (CONTINUED ON PAGE 94)

SATURN WITH NUCLEAR UPPER STAGE



Nuclear Rockets

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would probably have three stages propelled by engines having nuclear reactor thermal powers in the range from 1000 to 10,000 megawatts. It would still have to be assembled in the earth orbit. Two to four launch vehicles or launch freighters would be required to place in orbit all of the material, equipment, propellant, etc. that would be required for assembling the spacecraft. It is important to recognize that the launch freighters could be the vehicles that would perform the manned lunar-landing mission. In addition, the reactor power required for the planetary trip are in a range that could be used in vehicles for lunar-landing operations. The technology required for planetary missions would provide much of the equipment required for the performance of extensive lunar operations.

As noted above, it is generally agreed that the performance of planetary manned missions will require the use of nuclear energy systems. From a practical point of view, chemical systems could not do that job. Even if they could, analyses indicate that the cost saving of the nuclear rocket over the chemical rocket system, including the development costs, appear to be so great that the nuclear rocket would pay for itself on its first planetary mission.

In order to indicate how the required technology for the planetary mission could provide much of the equipment that would be required in extensive manned lunar operations, let's turn our attention now to some of the approaches that have been considered for landing men on the moon and the requirements of the various possible approaches. In defining the lunar-landing vehicle systems, we must first specify the payloads that are required to perform the mission. At the present time, estimates vary between 8000 and 15,000 lb as the weight of the manned capsule that must be returned to the earth after accomplishing the lunar-landing mission. In this discussion, let's consider vehicle systems that can return the high value, 15,000 lb, because I believe that, for a change, we ought not to restrict ourselves to marginal systems. We should have sufficient payload capability to insure ample margin for the inevitable increases in weight requirements that will result.

The Saturn vehicle now being developed is inadequate to provide such a capability unless several (more than six) are used to rendezvous in earth orbit and fuel or assemble the lunar chemical-combustion spacecraft. Although the development of orbital rendezvous is essential to our long-term space program (I indicated earlier that the planetary spacecraft will have to be assembled in an earth orbit), the rendezvous of such a large number of vehicles may not be practical within this decade.

The use of nuclear propulsion systems can reduce the number of Saturns required to rendezvous in orbit. A nuclear system can be used to propel the spacecraft assembled in orbit or a nuclear stage can be used as a third stage of the Saturn vehicle. The application of such nuclear stages could reduce the number of Saturn vehicles required to assemble or fuel the lunar spacecraft. The orbital payload of Saturn could be increased between 50 and 100% through the use of a nuclear third stage, thereby reducing the number of Saturns required for orbital freight delivery by one-third to one-half. In another approach for reducing the number of Saturns required, a nuclear rocket system would propel the spacecraft from the earth orbit to a lunar orbit and then return to the earth orbit. The optimum use of nuclear stages with the Saturn could reduce the number of Saturns required for the orbital rendezvous approach for lunar landings by a factor of at least two.

Direct-Flight Approach

Another approach considered by many to offer higher probability of achieving a manned lunar landing at the earliest possible time is the direct-flight approach, in which a vehicle would take off from the earth and carry the manned spacecraft directly to the moon. The vehicle for such an application could be an all-chemical vehicle or a vehicle combining chemical and nuclear stages. A rocket using all liquid-propellant-chemical-combustion stages would require a takeoff thrust of 10.5 million lb and probably six stages to return a 15,000-lb capsule from the moon. The first stage would be made up of a cluster of seven 1.5 million-lb-thrust F-1 engines now being developed for NASA. All other stages could use hydrogen-oxygen propellants. The use of solid-propellant rocket engines in the first stage would require the development of significantly more thrust than the 10.5 million lb of the liquid-rocket system.

The combination of nuclear stages and chemical stages can provide major reductions in the thrust and vehicle weight required to perform the manned lunar-landing mission. The use of a nuclear third stage using a 4000-megawatt reactor would result in a vehicle having a takeoff thrust of 4.5 million lb rather than the 10.5 million lb of the all-chemical rocket. The first-stage propulsion system would be made up of a cluster of three F-1 engines. The remaining chemical stages of the five-stage vehicle would use hydrogen-oxygen propellants. Still lighter vehicles could result from the use of stages having higher reactor powers. The reactor powers required for all of these lunar missions are in the same range as would be provided if we develop systems intended for planetary missions.

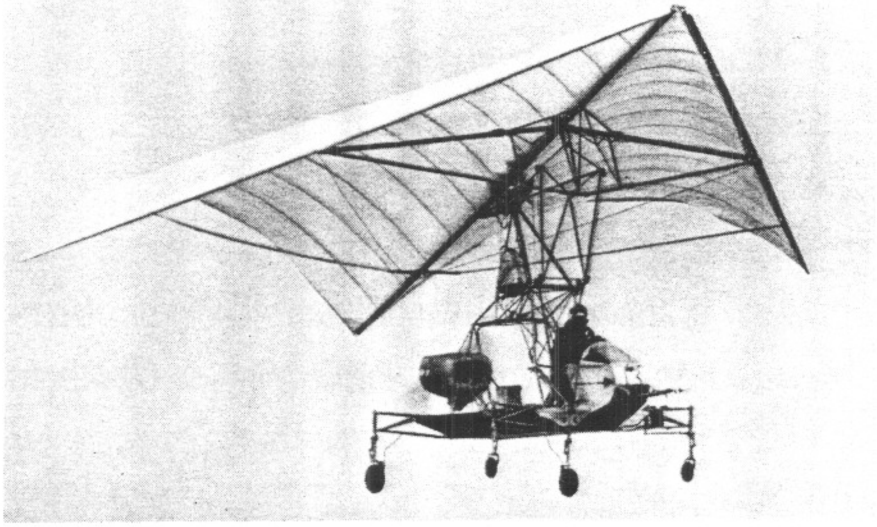
To summarize this space-mission discussion, the use of nuclear stages is required to permit the execution of manned planetary missions. Vehicles developed for the lunar missions could provide the freighter service required to deliver the planetary spacecraft into the earth orbit. The use of nuclear stages can reduce the weight of the lunar-landing vehicles by a half to two-thirds. If orbital rendezvous is to be used for the lunar mission, the application of nuclear stages could reduce the number of freighter vehicles required to deliver the necessary material into the earth orbit.

We must recognize, however, that success in the nuclear rocket program is not yet assured. We are developing a new and advanced technology. Our work to date has been very encouraging. In describing this work, I am in the position of trying to discuss, in an unclassified manner, a subject that depends heavily on classified information. For that reason, I will not be able to go into the details of technology or of the results we have obtained to date.

We have tested three research reactor devices with gaseous hydrogen as a propellant and water as the pressure shell and nozzle coolant. These tests provided us with necessary information on our design techniques and with an improved understanding of materials operating at conditions similar to those that will be encountered in nuclear rocket systems. This Kiwi-A series of tests was remarkedly successful, particularly for a point so early in the development of a new system.

The Kiwi-B series of reactor tests to be initiated later this year will include tests with liquid hydrogen as a propellant and as a coolant of all critical parts. Some of the areas requiring further evaluation in these Kiwi-B tests are the structural characteristics of the materials that will be utilized in flight reactor systems and the control characteristics and dynamics of operating reactors with liquid hydrogen as the propellant. The Kiwi-B series should lead to the development of reactors that will be used in the flight test of the first nuclear rocket system.

Both NASA and the AEC have agreed that it is essential that flight



Flex Wing Up for Testing

The flex wing conceived by F. M. Rogallo of NASA-Langley for such jobs as recovering large rocket boosters, e.g., the Saturn first stage, gets tested in experimental form by Ryan's Aerospace Div. with this rig. Ryan is studying the engineering of the flex wing for NASA-Marshall and the Army's Transportation Research Command. The wing appears useful powered or unpowered, for manned and unmanned vehicles, at speeds up to the supersonic and at altitudes up to 200,000 ft.

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tests be conducted on a nuclear rocket system so that, at an early time, its operation in the flight environment can be evaluated and demonstrated. In addition, such flight tests will enhance our technological stature. We have had four contractors study the various approaches for flight testing. All these contractors recommend that the first flight tests should be conducted with a nuclear stage boosted by stages of the Saturn vehicle on a ballistic trajectory from Cape Canaveral. Such a flight-test approach could lead to the development of a Saturn vehicle with a nuclear third stage. Such a vehicle could provide 50 to 100% more orbital payload than can the all-chemical Saturn vehicle and two to three times the escape payload of the all-chemical Saturn.

Although we may not be able to overtake the Russians in the race for the moon, I must repeat that I believe we are ahead in the race for manned exploration of the planets. The work we have done to date on the nuclear rocket gives us the lead in that area. The planetary mission will not be performed unless nuclear rocket development is successful. Our long-term lead in space therefore requires that we treat the nuclear program with a strong sense of urgency, and that we support it accordingly. I am confident that we can develop the systems that we will need for such planetary missions. We must insure that we retain our lead in this area.

Use of Brute Force

I have thus far been discussing a program in which our manned space program would aim at Mars and Venus as our primary objective, with the moon mission as a secondary or preliminary objective. In this case, the nuclear rocket propulsion system will have to be our major propulsion development effort. However, if the manned lunar landing is, in the immediate future, to be given top national priority, and is to be pursued with all possible vigor in order to beat the Soviet Union on that particular mission, systems using the most developed state of art will have to be relied upon as the primary vehicle approach in achieving the mission. With such a national urgency placed upon our being first to the moon, we would be forced to use the surest technical approaches even if they are brute force, unsophisticated systems lacking in growth potential. Because of the comparatively large amount of experience with them, chemical-combustion rockets would certainly be chosen for this primary vehicle approach.

However, with such high national priority, backup or alternate approaches will have to be included in the program planning to fill the gap if insoluble difficulties are encountered in the primary vehicle approach. The cost of such backup development would be trivial when compared with the cost of performing the first manned lunar landing, which has been variously estimated at $15 to $40 billion. The development of the nuclear rocket as an alternate for the lunar landing is entirely consistent with its primary role in space—insuring that we will be the leaders in the race to the near planets. The power levels required for lunar and planetary missions are essentially the same. If our nuclear technology is developed sufficiently rapidly, and slippages due to technical difficulties arise in the large chemical systems, it may eventually be determined that nuclear stages should be substituted for chemical systems in lunar mission vehicles.

We must recognize that we cannot with assurance say that we will beat the Russians to the moon with any system because we do not know their time scale. In addition, because we have less experience with them, nuclear systems for lunar missions may lag the chemical systems. The nuclear-system development would provide an alternate approach for the lunar mission without jeopardizing our ability to lead in a manned race to the planets. As I have indicated earlier, the similarities between nuclear reactor engines for planetary and lunar missions are sufficiently great that the development of the nuclear rocket as a lunar-landing backup would still insure its availability for the planetary missions.

As I have said before, all nations face the same natural laws in performing these difficult space missions. The only differences that arise in the accomplishment of such missions are related to the national determination to do the mission. In this competition for survival, we must show our determination to win. The program will be costly; it will require the hard and sincere labor of our best people. But, since this is a survival competition, we have no alternative. We may lose in the premilinaries, but we must win in the long-term main events. ♦♦