The President's Science Advisory Committee, "Report of the Ad Hoc Panel on Man-in-Space," December 16, 1960, NASA Historical Reference Collection, History Office, NASA Headquarters, Washington, D.C.

[Editorial Note: When NASA submitted its 1962 fiscal budget request to the Bureau of the Budget in May 1960, President Eisenhower learned for the first time of the agency's plans for a lunar landing program. He asked Presidential Science Adviser George Kistiakowsky to study "the goals, the missions and the costs" of the manned spaceflight program that NASA had in mind. The six-man study was chaired by Brown University chemistry professor Donald Hornig and was presented to the president at a December 20, 1960, meeting. Eisenhower has been quoted as saying at this time that he was not willing to "hock his jewels" (referring to the decision by Spanish monarchs Ferdinand and Isabella to finance the initial expedition of Christopher Columbus) to send people to the Moon. The handwritten figures included in this report have been omitted. The bracketted arabic numbers refer to the page numbers of the original document.]

[1] REPORT OF THE AD HOC PANEL ON MAN-IN-SPACE

l. Introduction

We have been plunged into a race for the conquest of outer space. As a reason for this undertaking some look to the new and exciting scientific discoveries which are certain to be made. Others feel the challenge to transport man beyond frontiers he scarcely dared dream about until now. But at present the most impelling reason for our effort has been the international political situation which demands that we demonstrate our technological capabilities if we are to maintain our position of leadership. For all of these reasons we have embarked on a complex and costly adventure. It is the purpose of this report to clarify the goals, the missions and the costs of this effort in the foreseeable future, particularly with regard to the man-in-space program.

This report has been made possible by the complete cooperation of the National Aeronautics and Space Administration. Officials of the NASA presented a very impressive description of their detailed plans for development, utilization and costs of the Saturn vehicle. They also provided technical information on possible follow on vehicles, advanced propulsion techniques, and possible development and funding schedules, As far as we can tell, the NASA program is well thought through, and we believe that the mission, schedules and costs are as realistic as possible at this time. We had to project their plans beyond 1970, and such projections must be seen as only crude estimates.

[2] 2. The Man-in-Space Program

The initial American attempt to launch a manned capsule into orbital flight, Project Mercury, is already well advanced. It is a somewhat marginal effort, limited by the thrust of the Atlas booster. It has as its goal the launching of a one man capsule into orbit around the earth and its successful return to earth. The fact that the thrust of any available American booster is barely sufficient for the purpose means that it is difficult to achieve a high probability of a successful flight while also providing adequate safety for the Astronaut. Achieving reliability on both accounts will strain our capabilities. A difficult decision will soon be necessary as to when or whether a manned flight should be launched. The chief justification for pushing Project Mercury on the present time scale lies in the political desire either to be the first nation to send a man into orbit, or at least to be a close second.

The marginal capability cannot be changed substantially until the Saturn booster becomes available. The NASA program for utilizing Saturn involves the development of the so-called Apollo spacecraft. The Saturn rocket which is being developed now (C 1) should be capable of launching a spacecraft of about 19,000 lbs into a low earth orbit. The proposed Apollo spacecraft weight of 15,000 lbs is well within this limit and would enable orbital qualification flights of the Apollo spacecraft (some manned) about 1966-1968. Such a manned flight would occur after about 25 Saturn C1's have been tested and much depends on whether a demonstrated reliability can be attained in this rather small number of tests. The Apollo spacecraft, as presently envisioned, would carry three men who would exercise control from within the spacecraft and be able to return to earth within a fairly well defined area. The chief purpose of the early Apollo missions would be to gain experience in manned flight, to learn more of the problems encountered by crews under such new conditions and to aid in the development of a spacecraft for more ambitious missions.

The full capabilities of the Saturn booster cannot be utilized until a large hydrogen-oxygen second stage has been developed. The C2 Saturn, utilizing the new high-performance stage, is expected to enter the test phase about 1965 and may be available for manned flight (No. 17) in 1968 or 1969. There is again a question as to whether 16 flights will be enough to demonstrate sufficient reliability for its use in manned missions.

The Saturn C2 is expected to lift about 40,000 lbs into low earth orbit and it is planned to utilize this capability to send up an "orbiting laboratory" capable of staying aloft for two weeks or more. It is our opinion that an [3] orbiting laboratory of this size could produce considerably more scientific information if it were wholly instrumented rather than manned. Alternatively, we believe that the valid scientific missions to be performed by a manned laboratory of this size could be accomplished using a much smaller unmanned instrumented spacecraft which would in turn require a smaller booster system. The large manned orbiting laboratory might be of value as a life sciences laboratory to acquire physiological and psychological data on humans, to study life support mechanisms, to perform biological studies, and to carry out engineering tests under gravity free conditions. In short, its major mission appears to be the preparation for further steps in the manned exploration of space.

To take such steps, the Apollo spacecraft may be launched into successively more elliptical orbits which carry it further and further from the earth, culminating about 1970 in a manned flight around the moon and back to the earth. The Apollo program in itself does not reach what might be considered to be the next major goal in manned space flight, i.e. manned landing on the moon. It does, however, appear to represent a logical approach to that goal in that it will develop spacecraft and crews for space flight and will enable us to gain experience in navigation and successful return from increasingly difficult trips. In the meantime it should be possible to obtain far more detailed information about the moon by unmanned spacecraft and lunar landing craft than the crew of the circumlunar flight could gain.

None of the boosters now planned for development are capable of landing on the moon with sufficient auxiliary equipment to return the crew safely to earth. To achieve this goal, a new program much larger than Saturn will be needed. It is likely to take one of three forms:

1. An all-chemical liquid-fueled rocket, the Nova, might be developed to take the trip directly. It would require a booster with about 6 times the thrust of the Saturn and utilizing either kerosene or hydrogen-oxygen. The upper stage of the Nova would require hydrogen-oxygen and at least one stage would probably be an existing stage from the Saturn development program.
2. If a suitable nuclear upper stage could be developed, the Nova vehicle could conceivably become a combination chemical-nuclear system. This system would still require the development of a first stage chemical booster with thrust of the same order of magnitude as that described for the all chemical system. If the nuclear development should be as successful as its proponents hope, it might open the way for future developments beyond the [4] possibilities envisioned for chemical rockets. However, a sound decision on the promise of nuclear rockets cannot be made until about 1963.
3. Rendezvous techniques, utilizing either Saturn C2 vehicles or some type of advanced Saturn vehicles, could be employed to lift into an earth orbit the hardware and fuel necessary to perform the manned lunar landing mission. In this system, a series of vehicles would be launched into a temporary earth orbit where they would rendezvous to enable fueling of the spacecraft and, if necessary, assembly of the component parts of the spacecraft. This spacecraft would then be used to transport the manned payload to the moon and thence back to Earth. These techniques will require considerable development, and are at present only in a preliminary study phase.

It is clear that any of the routes to land a man on the moon require a development much more ambitious than the present Saturn program. Not only must much bigger boosters probably be developed, but rockets and guidance mechanisms for the safe landing and then for return from moon to earth by means of additional rockets must be developed and tested. Nevertheless, it must be pointed out that this new, major step is implicit in undertaking the proposed manned Saturn program, for the first really big achievement of the man-in-space program would be the lunar landing.

The succeeding step, manned flight to the vicinity of Venus or Mars represents a problem and order of magnitude greater than that involved in the manned lunar landing. Not only does it appear to be insoluble in terms of chemical rockets, thus requiring the development of suitable nuclear rockets or nuclear-powered electric propulsion devices, but it also poses serious problems in terms of life support and radiation shielding for journeys requiring times ranging from many months to years.

3. Unmanned Programs Related to Man-in-Space

A great part of the unmanned program for the scientific exploration of space is a necessary prerequisite to manned flight. The programs which are now planned fall in the following general categories:

1. The general scientific exploration of space. This will take place in a continuing series of flights. This program has been moving along well and has been marked by solid scientific achievement; it could probably be carried on to a high state of advancement using launch vehicles no larger than Centaur (an Atlas with hydrogen-oxygen upper stage).
2. [5] A rough landing on the moon, with television recording of the impact and with a surviving seismometer to make measurements on the lunar surface, may be made in 1962 or 1963 using an AtlasAgenaB vehicle.
3. The Centaur rocket, which should make its first flight in 1961, will make it possible to fly instruments past Venus and Mars, making closeup scientific observations for a short time, in 1962 or 1964. It may even be possible to land a 10 lbs instrument capsule through their atmospheres.
4. The Centaur should also make it possible to soft land 190 lbs of scientific gear on the surface of

the moon (1964-1966) and to make surface observations from a very close orbit about the moon, including photography comparable to satellite photography of the earth (Samos).

5. The Saturn C 2 will be the first vehicle which can carry an adequately instrumented spacecraft, weighing perhaps 325 lbs, into an orbit about Venus or Mars, and to land a 225 lbs capsule through their atmosphere, giving us direct atmospheric and surface measurements for the first time in about 1967 or 1968. It may then be possible to obtain definite evidence regarding life on Mars. Although such studies can be started with the Saturn C 1 in 1965 or 1966, they really require the C2 to give reasonable instrument weights.
6. A roving automatic vehicle equipped with television and other sensing instruments to make observations on the surface of the moon can first be landed with the C2 in about 1967, and is included in present NASA plans.
7. It should also be possible to soft land objects on the moon which is large enough to send a capsule back to earth with a few pound sample of the surface of the moon. This also requires the C2 and could be tried begin¾g in about 1968.
8. No booster smaller than the C2 can carry scientific instruments to the vicinity of Mercury or Jupiter. This, too, should be possible around 1968 to 1970.
9. For unmanned scientific investigations with roving vehicles on the planets, or for more ambitious instrumented missions out of the plane of the elliptic, even the Saturn C 2 does not provide sufficient payload-carrying capability.

[6] 4. Relation between Manned and Unmanned Space Exploration

Certainly among the major reasons for attending the manned exploration of space are emotional compulsions and national aspirations. These are not subjects which can be discussed on technical grounds. However, it can be asked whether the presence of a man adds to the variety or quality of the observations which can be made from unmanned vehicles, in short whether there is a scientific justification to include man in space vehicles.

It is said that an astronaut's judgment, decision-making capability and resourcefulness can increase the probability of successful accomplishment of a space mission and expand the variety and quality of observations performed. On the other hand, man's senses can be satisfactorily duplicated at remote locations by the use of available instrumentation and advances in the state of the art are continually increasing the ability to transmit information back to a central receiving point. With such an instrumented system, the decisions requiring man's mental capabilities can be performed by many men in a normal environment and with the aid of elaborate computational aids, where necessary.

The following considerations seem pertinent:

1. Information from unmanned flights is a necessary prerequisite to manned flight.
2. The degree of reliability that can be accepted in the entire mechanism is very much less for unmanned than for manned vehicles. As the systems become more complex this may make a decisive difference in what one dares to undertake at any given time.
3. From a purely scientific point of view it should be noted that unmanned flights to a given objective can be undertaken much earlier. Hence repeated observations, changes of objectives and the learning by experience are more feasible.

It seems, therefore, to us at the present time that man-in-space cannot be justified on purely scientific grounds, although more thought may show that there are situations for which this is not true. On the other hand, it may be argued that much of the motivation and drive for the scientific exploration of space is derived from the dream of man's getting into space himself.

[7] 5. Cost of the NASA Man-in-Space Program

The NASA man-in-space program, exclusive of the Mercury Project, revolves around the use of the Saturn and Nova vehicles. Development of the Saturn is far enough along that its characteristics are fairly well known, and the costs of its development and use can be predicted with reasonable accuracy. The Nova, required for direct manned operations on the moon, is based on the use of the 1.5 million lbs thrust engine, six of which would probably power the first stage. The character of the vehicle as a whole cannot be clearly determined until the characteristics of this engine are understood. However, the present tentative designs of the Nova configuration are probably adequate to support the very rough cost analysis presented here.

This analysis is based on the rule-of-thumb principle, generally supported by past experience, that the cost of a program of this nature, including development, flight test and use, should be approximately proportional to the dry weight of the booster vehicle and payload on which the program is based. The dry weight of the Nova vehicle is about six times that of the Saturn vehicle, and accordingly a factor of six should be applied to the costs of the two programs. It is pointed out, however, by the NASA that there is some reason to believe that a somewhat smaller factor might be appropriate. There is a good deal of basic engineering that will carry over from Saturn to Nova, and certain of the Nova stages may already have been developed for Saturn. Such considerations are doubtless valid, but they could not justify the use of a factor smaller than four. In the analysis that follows two values of the multiplicative factor are used: four, representing the lower bound on what might be achieved, and six, representing a reasonably conservative estimate.

It is further assumed that the time span required for the development and exploitation of the capabilities of the Nova are the same as that for Saturn. It is assumed, however, that the Nova development follows that of Saturn by seven years. Thus, by 1968 Nova is in a state of development corresponding to that of Saturn in 1961.

With these assumptions in mind, the method of arriving at the yearly costs given in the figure can be stated.

1. The known and estimated costs for the development and use of Saturn are plotted on the curve so labeled in Figure 1. The costs following 1970 are not NASA estimates, but are predicated on the likelihood of some continuing use for this vehicle.
2. [8]The "Saturn" curve is now displaced to the right by seven years, and the ordinate multiplied by the factors four and six. This produces the solid sections of the curves labeled "Nova" in Figure 1. The dashed lefthand tails of the Nova curves represent pure estimate and have only reasonableness to recommend them.
3. The "Saturn" and "Nova" curves have been added year by year to produce the composite curves of Figure 2. These are taken to represent rough bounds on the cost of the NASA man-in-space program.
4. The integrated areas under the curves represent the total expenditures for the period 1961 through 1975. As indicated on the figures, the total Saturn program costs 8 billion (1961) dollars up to 1975. The Nova program over the same time period comes to 25.5 billion on the lower estimate and 38 billion on the higher estimate. (It will be noted that these totals are not four and six times, respectively, the total Saturn cost. This is because the Nova costs were integrated only out to 1975, when the first manned lunar landing might be achieved. The Saturn costs, on the other hand, were integrated over the entire estimated program.) Figure 2 gives the total composite expenditure to 1975 as 33.5 billion for the lower estimate and 46 billion for the higher.

The cutoff at 1975 is arbitrary and might be misleading. During the five or ten year period preceding this date new developments will be under way to implement new programs for the post 1975 era. It does not seem possible at this time to estimate the incremental costs associated with these programs.

Present indications suggest that alternative methods, described elsewhere in this report, of accomplishing the manned lunar landing mission, could not be expected to alter substantially the overall cost of mission as analyzed here on the basis of Nova.

In the event that additional flight testing is required to achieve adequate reliability in these programs, it seems likely that the program would be stretched out in time. Thus probably the annual expenditures would not change appreciably, although the integrated expenditure would increase accordingly.

6. Conclusions

1. The first major goal of the man-in-space program is to orbit a man about the earth. It will cost about 350 million dollars.
2. [9] The next goal, of an intermediate nature, is the manned circumnavigation of the moon. It will cost about 8 billion dollars.
3. The second major goal, landing on the moon, can only be achieved about 1975 after an additional national expenditure in the vicinity of 26 to 38 billion dollars.
4. The Saturn program is a necessary intermediate step toward manned lunar landing but must be followed by a much bigger development before manned lunar landing is possible.
5. The unmanned program is a necessary prerequisite to a manned program. Even if there were no manned program, the unmanned program might yield as much scientific knowledge and on this basis would be justified in its own right.
6. Even if there were no man-in-space program, Saturn C2 is still a minimum vehicle for closeup instrumented study of Venus and Mars, for unmanned trips to more distant planets, and for putting roving vehicles on the surface of the moon.
7. Manned trips to the vicinity of Venus or Mars are not yet foreseeable. . . .

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