SELECTING THE WAY TO THE MOON: THE CHOICE OF THE LUNAR ORBITAL RENDEZVOUS MODE

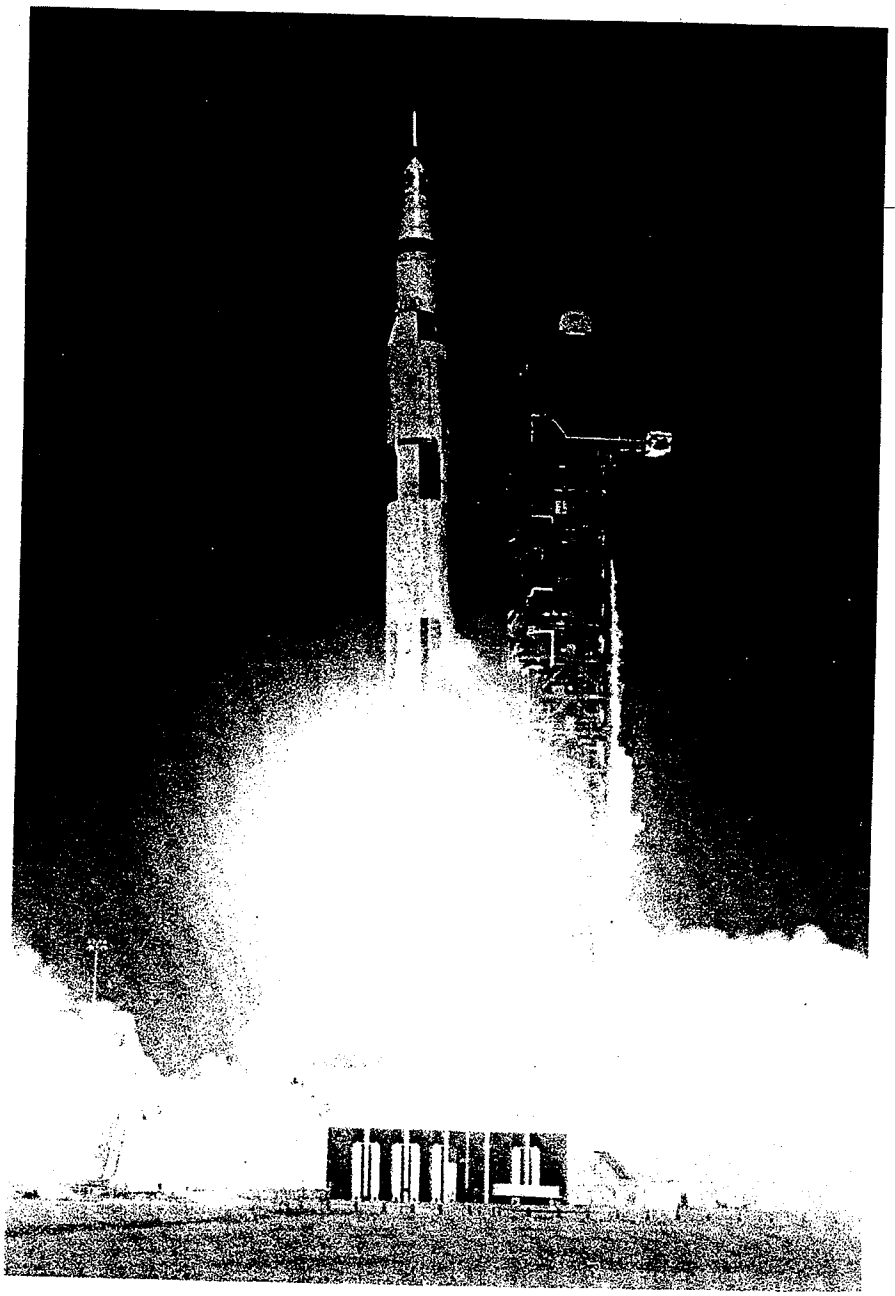
By JOHN M. LOGSDON

The success of Project Apollo in lofting men to the moon and returning them to earth has been hailed as one of the greatest technological accomplishments of western civilization. A myriad of scientific, technological, administrative, and economic factors combined to assure the success of Apollo. It would be difficult to single out any one factor as having contributed most to that triumph, but certainly one of the most significant would be the choice of the lunar orbital rendezvous (LOR) approach to accomplishing the manned moon mission "before the decade is out," as President John F. Kennedy vowed.

By now, the idea of separating the Apollo spacecraft into two sections as it orbits the moon and of using the lunar module, designed specifically for this one purpose, to transfer two astronauts from lunar orbit to the moon's surface and back to a rendezvous with the orbiting command and service modules seems familiar. It has been done three times, with a half-billion persons viewing it on television each time. But when President Kennedy on 25 May 1961 committed the nation to a lunar landing before 1970,[1] no one in a responsible position in the National Aeronautics and Space Administration (NASA) considered lunar orbital rendezvous the recommended approach to the first lunar mission.

By the time this mode was finally determined upon in July 1962 and the decision reaffirmed in November 1962, more than a million man-hours had been spent studying various ways of accomplishing the lunar mission. That these studies should have led to the selection of the lunar orbital mode would have surprised all but a few people who had examined the approach prior to 1961. These few people convinced of the merits of the lunar orbital plan initially had difficulty obtaining a full hearing from those responsible for planning the manned lunar mission, but they persisted in their efforts and ultimately persuaded the top officials of NASA that their plans were desirable. Even then, there was heated dialogue between NASA and the President's scientific advisors before the choice became final.

This article, in addition to tracing the history of an important part of Project Apollo, is an account of how a major policy decision by a large government organization was reversed primarily through the efforts of a few individuals within that organization. It is also a case study of organization response to the stimulus of a challenging goal imposed on the organization as the result of external events. The



Mission possible. The Saturn booster carrying the Apollo 11 spacecraft lifts off from Cape Kennedy, 16 July 1969. (NASA photos).

article is based largely upon NASA and other documents, as well as interviews not previously published.[2]

Even before the decision to select a manned lunar landing mission as the central feature of an accelerated space program by President Kennedy in May 1961, NASA planning for such a mission had been accelerated. In early 1961, a NASA task force headed by George Low, then in charge of manned flight programs in NASA's headquarters, Washington (now NASA's deputy administrator), reported to the agency's associate administrator and general manager, Robert C. Seamans (now secretary of the Air Force), that "no invention or breakthrough is believed to be required to insure the overall feasibility of safe manned lunar flight." This conclusion held, Low's report stated, for both approaches to the lunar landing under consideration. One approach involved a single launch of spacecraft directly from the earth to the lunar surface (the direct-ascent approach). The other approach would use several launches to place portions of a spacecraft into a lunar trajectory (the earth orbital rendezvous (EOR) approach).[3] The Low committee's report was a qualitative, somewhat preliminary assessment of the feasibility of a lunar mission.[4]

Then, on 12 April 1961 Yuri Gagarin, in Vostok I, became the first man to orbit the earth. By 2 May Seamans saw "an immediate need for a comprehensive and well-founded study to establish program plans and supporting resources necessary to accomplish the manned lunar landing mission." He established an ad hoc task group to determine "a feasible and complete approach" to such a mission with a target date for the first landing of 1967.[5] This task group was chaired by William Fleming of Seamans' office and it came to be known as the Fleming committee.

The Fleming Committee interpreted its instructions to prepare plans for a "feasible" mission as meaning it should select "the approach which appeared to offer the greatest assurance of success based on existing experience, technology, and knowledge."[6] This interpretation influenced the group to concentrate its efforts on studying the direct-ascent approach to the mission, since it appeared that development of the extremely large vehicle required for this approach could be patterned on experience gained from developing Saturn-class boosters. The basic assumption appeared to be that it was always possible to "build something bigger and make it work."[7]

To accomplish its task, the Fleming Committee had to develop a plan relating some 1,800 discrete elements. After several computer runs and three major reviews of program schedules developed thereby, the committee established that it was indeed feasible to accomplish the lunar mission using the direct-ascent approach by July 1967.[8]

The program developed by the Fleming Committee called for manned earth-orbital flights using the previously-planned Saturn C-1 booster with a 1.5 million-pound thrust first stage beginning in late 1964, circumlunar flights using a new booster called the Saturn C-3 beginning in late 1965, and lunar landing flights using a new, very large booster called the Nova by mid-1967. The C-3 was to have two engines with 1.5 million pounds thrust each (designated the F-1) in the first stage. Its upper stages were to use liquid hydrogen as fuel. The Nova was to have eight F-1 engines clustered in the first stage, and be capable of boosting 160,000 pounds to lunar-escape velocity. The estimated weight of the spacecraft required for the lunar landing mission including lunar landing and take-off stages was 150,000 pounds. The total cost of the program including manned flights and the unmanned flights in direct support of the lunar mission was estimated at $11.683 billion.

Even though there was a general assumption that direct ascent was the simplest and best approach, NASA officials would not select it as the primary mode for the lunar landing without first looking at other possibilities. In order to examine "numerous other approaches to accomplishment of the manned lunar landing mission, some suggested by contractors, some by the military, and some by individuals within NASA," on 25 May Dr. Seamans organized a group to "assess a wide variety of ways for executing a manned lunar landing."[9] This group was chaired by Bruce Lundin, now Director of NASA's Lewis Research Center, Cleveland, Ohio.

The Lundin Committee was briefed by the proponents of various methods of earth and lunar-orbital rendezvous and of lunar-surface rendezvous. This last approach, developed primarily at Caltech's Jet Propulsion Laboratory, involved using a series of Saturn vehicles to launch a lunar-return spacecraft and fuel for its rockets to the lunar surface. All these payloads would land within 45 feet of one another on the moon and then the return spacecraft would be automatically fueled and checked out. Only then would a man be launched to the moon; after landing, he would perform experiments and walk to the waiting spacecraft for his return to earth.

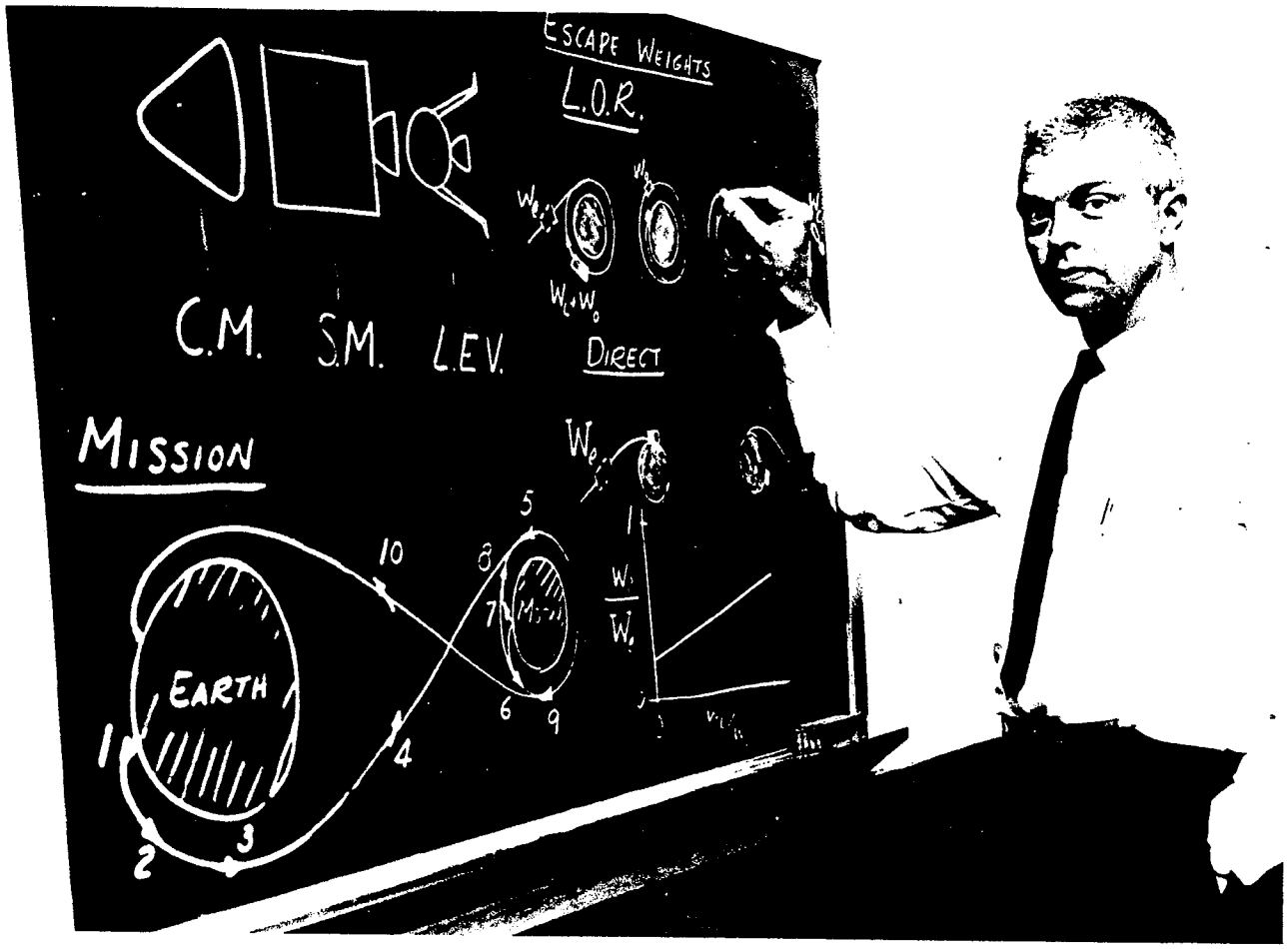
Each member of the committee ranked the various mission approaches considered by the group in order of preference. The earth orbital rendezvous using Saturn C-3s was a clear preference of the Lundin Committee. They estimated that the use of such a mission plan could place men on the moon in August of 1967. The lunar orbital rendezvous approach was the first choice of no one on the committee; for most it was a third of fourth choice.[10]

The Lundin Committee efforts were a qualitative "quick look," with no attempt at ascertaining detailed funding or schedule estimates. On 20 June 1961, Dr. Seamans established a new task group to establish in more detail program plans and supporting resources necessary to accomplish the manned lunar landing mission by the use of earth orbital rendezvous techniques, using the Saturn C-3 vehicle, with a target date of 1967. This group was to be chaired by Colonel Donald H. Heaton, USAF, in NASA Headquarters.[11]

The Heaton Committee was composed of 20 specialists, drawn almost equally from NASA Headquarters and field centers. The group used the scheduling framework set by the Fleming study for launch vehicle and spacecraft development and construction of facilities. By building rendezvous missions from these schedules, the committee was able to arrive at its major conclusion, that earth-orbital rendezvous offered the earliest possibility for a successful manned lunar landing.[12]

In addition to plans using a Saturn C-3 configuration with two engines in the first stage, the committee examined a mission plan based on a four engine first stage, which they designated the Saturn C-4. The Heaton Committee believed that the dates for the availability of the C-3 contained in the Fleming report were too optimistic. This meant, said the committee, that "the operational launch vehicle is the pacing item for the rendezvous approach," and the "the C-4 should offer a higher probability of an earlier successful manned lunar landing than the C-3."[13]

To the Department of Defense (DOD) and NASA planners who prepared the recommendations for an acceleration of the U.S. space program, the manned lunar landing mission has not been seen as an isolated development, but rather as the focal point for a vigorous and broadly-based national space program involv-



John Houbolt has been widely acclaimed as the originator of the lunar orbital rendezvous scheme, but this article contends several people originated the concept which Houbolt strongly promoted.

ing both NASA and Air Force activities. They believed that the Soviet lead over the United States in space achievements was only secondarily due to the Soviet advantage in booster capability. Primarily, they thought, effective central planning had enabled the Soviet Union to be highly successful in space. What the United States needed, they believed, was a carefully-planned *national* space program aimed at a few clear goals and intended to develop a preeminent capability for space operations, both civilian and military.[14]

As part of this approach to the space program, NASA and DOD space planners, especially NASA's Robert Seamans and Assistant Secretary of Defense and Deputy Director of Research and Engineering John Rubel, agreed on the need for study aimed at developing a detailed national launch vehicle program. On 7 July 1961 Seamans outlined for NASA Administrator James Webb the type of study anticipated. The goals of the study were "to determine the large launch vehicle configurations and operational procedures which will best meet the needs of the DOD and NASA." These needs were:

1. "Early successful landing of manned spacecraft on the moon and return to earth."
2. "Manned scientific missions. . . ."
3. "Utilization . . . for advanced military missions."
4. "Increased reliability and economy achieved by multiple use of vehicle components, vehicle stages, and complete launch vehicles."[15]

The same day, Webb wrote Secretary of Defense Robert McNamara, asking him to concur in authorizing the study. The NASA Administrator left no doubt as to the scale of effort he thought involved: "The planning effort for which these arrangements are contemplated is of great and perhaps unprecedented scope. It is destined to serve as a basis for the successful execution of research and development in succeeding years, will call for the utilization of vast resources on which our future national posture is so dependent."[16] McNamara replied immediately, concurring with the proposed plans for the study and agreeing with Webb as to its importance.[17]

The study was organized as a joint NASA-DOD effort, called the Large Launch Vehicle Planning Group (LLVPG). Its director was Nicholas Golovin, who was a mathematician and physicist also experienced in technical management. Golovin had worked for NASA earlier, and his attempts to use the mathematical and statistical techniques of operations research and systems analysis to raise reliability standards in Project Mercury had brought him into conflict with the more empirically-oriented engineers at NASA's Space Task Group.[18] The LLVPG came to be called by many the Golovin Committee.

In the analyses performed by the LLVPG, 16 possible vehicle configurations and three basic mission models —direct ascent, earth orbital rendezvous, and lunar orbital rendezvous— were considered. Despite these analyses and the extensive efforts of the LLVPG, the group reached the end of the study with a relatively large number of critical questions unresolved. A primary reason for this was NASA-Air Force rivalry, with each desiring its own booster program. As a result,

the LLVPG recommendations were something of a compromise and did not provide the basis for development of an integrated national launch vehicle program, based on a "building block" concept, as had been hoped. The committee did conclude that the rendezvous technique would be the quickest way to achieve a manned-lunar landing and that the Saturn C-4 vehicle with four F-1 engines in the first stage, four of five smaller engines using hydrogen fuel, designated J-2 in the second stage, and one J-2 engine in the third stage should be used in the rendezvous approach.[19]

When D. Brainerd Holmes, NASA's Associate Administrator for Manned Space Flight, officially assumed responsibility for the manned lunar landing program on 1 November 1961 his first priority was the creation of an effective management team with effective working relationships with the Marshall Space Flight Center in Huntsville, Alabama, and the Manned Spacecraft Center in Houston, Texas, where most of the program hardward and technical details would be supervised. Closely connected to this undertaking was the resolution of several outstanding technical questions, most importantly the choice of a specific configuration for the advanced Saturn booster and the final choice of a mission plan for the manned-lunar flight. The first of these was resolved within a few weeks; the choice of mission mode became an extended and contentious process, with the final decision not ratified until late 1962.

At Holmes' request, Milton W. Rosen, newly-named Director of Launch Vehicles and Propulsion in the Office of Manned Space Flight, on 6 November 1961 formed a working group to prepare recommendations for a large launch vehicle program related specifically to achieving the manned lunar landing, in contrast to the joint NASA-DOD character of the Golovin Committee.[20] The group spent more time examining rendezvous techniques than on any other subject. They concluded that "space rendezvous presents the possibility of accomplishing the initial manned lunar landing mission earlier than by any other means . . ." and that "the preferred rendezvous mode is the single rendezvous in earth orbit."[21]

This conclusion was similar to the one that had led the Heaton and Golovin Committees to recommend the development of the Saturn C-4 in the belief that it could accomplish the earth orbital mission with only one rendezvous. But the Rosen Committee study indicated that the weight-lifting capability of the C-4 would be too limited to accomplish the mission with a single rendezvous, or at best it would be marginal. Rosen and his associates convinced Werner von Braun that this conclusion was probably correct.[22] The group was also aware that a larger vehicle gave better assurance of accomplishing the mission by lunar rendezvous, should that approach be followed. Accordingly, they recommended that "to exploit the possibility of accomplishing the first manned lunar landing by rendezvous, an intermediate vehicle with five F-1 engines in the first stage and four of five J-2 engines in the second stage and one J-2 in the third stage should be developed." The fifth engine could be added to the first stage without changing the basic dimensions of the C-2.[23] The Nova was considered too complex to develop in the time available.

NASA announced on 15 December that the first stage of the advanced Saturn booster, then called the C-5 would be built by the Boeing Company at the Michoud Plant; that the stage would consist of five engines was decided on 21 December 1961 at the first meeting of the Manned Space Flight Management Council.[24] Holmes submitted a preliminary project development plan for the advanced Saturn to Seamans on 11 January calling for a vehicle which would "by two launches, inject enough payload into earth orbit to accomplish the desired mission with one rendezvous."[25] The development program was approved and the final configuration of the advanced Saturn C-5 announced on 25 January.

With the establishment of the Saturn C-5 configuration, only one major element of the lunar mission flight hardware was still undefined. The contract for the command and service modules of the Apollo spacecraft had been awarded to North American Aviation on 28 November 1961, but no contract for the lunar landing and takeoff module had been let, since the design of this module was intimately related to the mode selected for the mission.

Throughout 1961, as the studies of the manned lunar landing progressed, the NASA position on the preferable mode for the lunar flight had gradually shifted away from direct ascent to some form of earth orbital rendezvous. In late 1961, there were indications that earth orbital rendezvous had displaced direct ascent as the primary mode. But this was far from a unanimous position within the NASA organization, and the mode choice was the subject of intensive study beginning in early 1962. By the time a few months had passed, these studies led to the selection of lunar orbital rendezvous as NASA's "way to the moon."

The key concept of the lunar orbital rendezvous approach was not a new one; in fact, the idea had first been suggested by Russian rocket theoretician Yuri Konratyuk as early as 1916. When a spacecraft reached another celestial body, he wrote, "the entire vehicle need only be reduced so that it moves uniformly in a circle as near as possible to the body on which the landing is to be made. The inactive part [the landing craft] separates from it, carrying the amount of the active agent [fuel] necessary for landing the inactive part and for subsequently rejoining the remainder of the vehicle."[26] Writing in 1948, H. E. Ross, a member of the British Interplanetary Society, described in some detail the essential features of the lunar orbit rendezvous concepts.[27]

None of this early theoretical work was known to a group of engineers at NASA's Langley Research Center in tidewater Virginia as they began in 1959 to examine method of going to the moon. This group included Clint Brown, head of Langley's Theoretical Mechanics Division, and his associates, William Michael, John Bird, Ralph Stone, Art Vogeley and Max Kurbjun. Although Brown's supervisors at Langley thought an orbiting space station should be the next major NASA manned flight program, they had allowed Brown to form a Lunar Trajectory Group. As part of its work, Brown's group examined the "Weight Advantages of Use of a Parking Orbit for Lunar Soft Landing Mission"—the title of a May 1960 paper by William Michael which contained perhaps the first written discussion within NASA of the lunar orbit rendezvous concept. Michael pointed out the "considerable savings in fuel weight" resulting from leaving "that portion of the weight in parking orbit which is not essential for the lunar landing part of the mission (i.e., the fuel for return from parking orbit to earth, re-entry heat shield, etc.)." This weight saving, Michael pointed out, "must be compared with the additional complications involved in requiring a rendezvous with the components left in the parking orbit."[28]

Brown and his associates thought they had hit upon a new and exciting idea in lunar rendezvous. They were surprised and a little disappointed to find that they were not the only inventors of the idea when in February 1960 they were briefed on the plans for a "manned, modular multipurpose space vehicle" developed by Vought Astronautics of Dallas, Texas.

A Vought study team had since 1958 been developing concepts for manned space missions, aiming at a lunar landing by 1969, and its plans were based on landing on the moon in a separate two-man module and later rendezvous in lunar orbit.[29] So thoroughly had Vought examined the benefits of lunar rendezvous that the people at Langley considered giving up their own studies, which appeared to be duplications of work already done. As a result, they did little work for several months, but eventually did resume their attempt to develop a detailed mission plan employing lunar orbital rendezvous concept.[30]

Bird, Vogeley, and Kurbjun were also members of a Langley committee concerned with the rendezvous problems associated with the development of an orbiting space station. At an August 1960 meeting of this committee, the discussion turned to the various ways of performing a lunar landing mission. Chairman of the rendezvous committee was a Langley engineer from a competing division within the center named John Houbolt, who previously had not been intimately involved in the lunar rendezvous studies. Houbolt recalls that when he heard the approach described by those who had been working on the approach with Clint Brown, "It became clear that LOR offered a chain reaction of simplifications. I said, 'Oh my God, this is it. This is fantastic! If there is any idea we mush push, it is this one.' "[31]

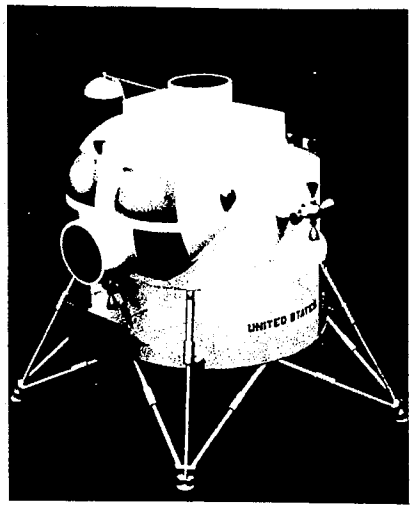
In the next year and a half, Houbolt did indeed push hard for the LOR concept. He became an unabashed and dedicated propagandist for the scheme, and it was his persistence that stimulated the top NASA officials to take a close look at it in early 1962. But Houbolt was not, as he has been portrayed by *Life* and *The New York Times*, among others, the "person who developed the concept of lunar orbit rendezvous."[32] Credit for originating the scheme cannot be given to any one individual.

Houbolt presented the approach at almost every opportunity throughout 1961. On 19 May believing that rendezvous was not being seriously considered in the accelerated NASA planning, Houbolt wrote Associate Administrator Seamans directly (thereby circumventing several layers of organizational channels), claiming that because "of the lag in launch vehicle developments, it would appear that the only way that will be available to us in the next few years is the rendezvous way. For this very reason I feel it mandatory that rendezvous be as much in future plans as any item . . .[33]

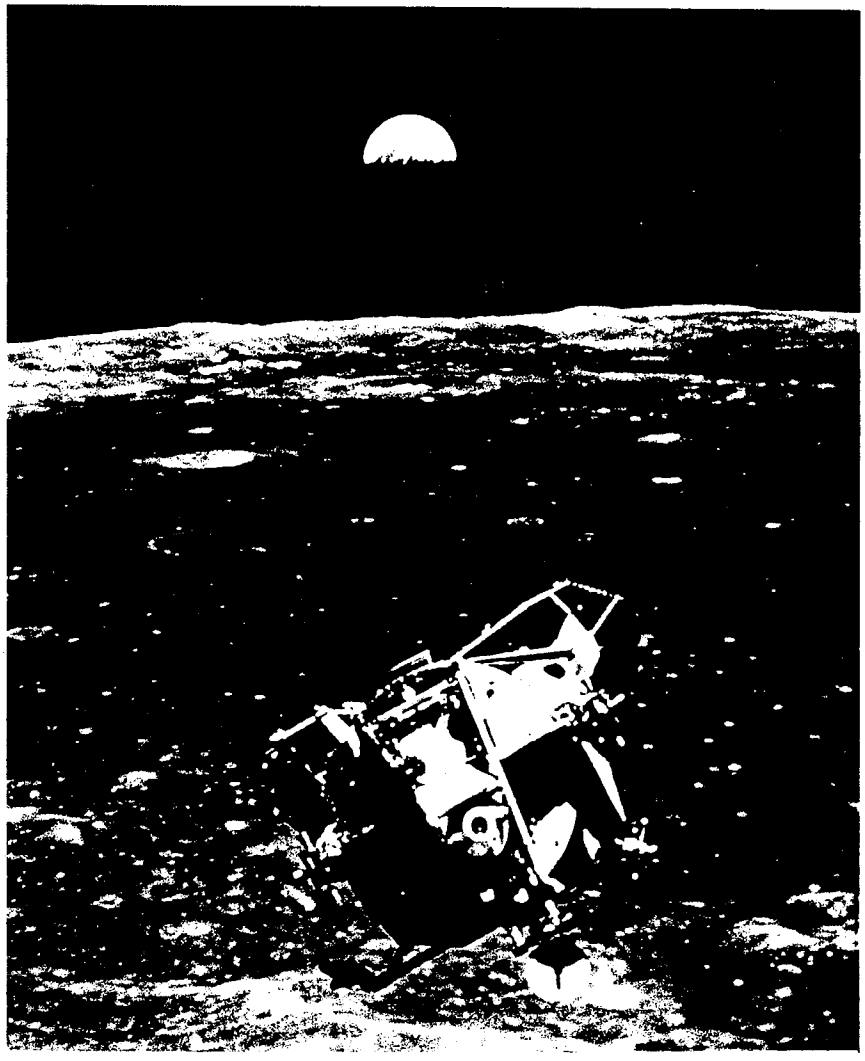
This may have been one impetus for Seamans' formation of the Lundin Committee. Houbolt outlined the lunar rendezvous plan to the Lundin Committee, and was upset at the low ranking given it by the committee. Houbolt also served as a member of the Heaton Committee and unsuccessfully tried to persuade the group to broaden its ground rules, which limited its considerations to earth-orbital techniques, to examine lunar orbital rendezvous.[34]

Objections to the lunar orbital technique at this time were centered around the necessity of performing a rendezvous in lunar orbit, 240,000 miles from the earth, after takeoff from the lunar surface. At a time when no space rendezvous had been performed and there was no clear idea of just how difficult or easy rendezvous would be, such a proposal made those who looked at it understandably wary.

Houbolt, still believing that the LOR



First model of the lunar module prepared by its builder, Grumman Aircraft, in 1962.



Mission accomplished. Lunar module, "Eagle," about to rendezvous in orbit around the moon with command module, "Columbia," after first manned landing on the moon.

concept had not received the consideration it deserved, wrote a second letter outside of channels directly to Seamans on 15 November 1961. In a cover note he urged Seamans "to read every word of this letter. I am convinced that man will first set foot on the moon through the use of ideas akin to those expressed herein." The nine-page letter argued vigorously in favor of the lunar rendezvous plan and criticized NASA's booster program. Houbolt complained that "for some unexplicable reason everyone seems to want to avoid simple schemes. The majority always seems to be thinking in terms of grandiose plans. . . . Figuratively, why not go buy a Chevrolet instead of a Cadillac?" Houbolt attached to his letter a two-volume presentation of the lunar-rendezvous approach, which he said was "easier, quicker, less costly, requires less development, less sites and facilities. . . . Give us the go-ahead, and a C-3, and we will put man on the moon in very short order. .. ."[35]

Houbolt's letter apprarently did have a challenging effect on NASA's thinking. Seamans forwarded it to Brainerd Holmes who asked his staff for comments. On 5 December George Low told Holmes that "I agree that the 'bug' approach may yet be the best way of getting to the moon and back."[36]

Low, with close ties to the former Space Task Group (which had become the core staff of the Manned Spacecraft Center, which moved to Houston by mid-1962) was, at least in part, reflecting the views of Center Director Robert Gilruth and his associates, who were finding the idea of having a portion of the Apollo spacecraft specifically designed for lunar landing increasingly attractive. One of Gilruth's main apprehensions about the direct-ascent method was the difficulty of landing the large spacecraft on the lunar surface with its heavy reentry heat shield and the propulsion unit fueled for the trip back to earth. The lunar rendezvous approach left both of these heavy items in lunar orbit and landed only a separate module on the moon. Gilruth was aware of the work of Houbolt and his associates on the other side of Langley Field, and by the end of 1961, on the basis of further studies by his own staff, had become convinced that the lunar-rendezvous approach was the way to proceed, since it offered the safest way to perform the most difficult portion of the mission, landing on the lunar surface. He would have the responsibility for getting the Apollo crew on and then off the lunar surface to return to earth.

By the end of 1961, a situation had developed in which von Braun and his Huntsville team favored earth orbital rendezvous, while Robert Gilruth and his staff at the Manned Spacecraft Center favored the lunar orbital rendezvous approach. This divergence in views presented Holmes with a difficult management problem, since the two major centers responsible for executing the program had strongly-held and opposing views. The effective implementation of the program required that these views be reconciled in some way. Holmes adopted two techniques for attempting to select the mission mode. He organized a top-level Management Council to provide a forum for establishing clear understandings on matters affecting more than one center, and he assigned the responsibility in headquarters for conducting and coordinating further studies of the mission mode to the Office of Systems Engineering in the Office of Manned Space Flight. This Group was headed by a newly-hired aggressive young engineer, Joseph Shea.

Until a final choice of the mission mode was made, Holmes established earth orbital rendezvous as the "working mode." NASA's early 1962 presentations to Congress in defense of its budget were based on a mission plan using earth orbital rendezvous.

The situation at this time was summarized by a memorandum prepared by Shea after his first visits to Marshall and the Manned Spacecraft Centers (MSC) in mid-January, 1962:

> Most of the MSC people seem enthusiastic about LOR. However, I don't feel they have a good understanding of the rendezvous problem, and their weight estimates for the LOR operation seem quite optimistic.
>
> Their [Marshall's] version of EOR is quite different from the MSC version. In essence, each Center has its equipment doing most of the work, and completely ignores the capability of the other's hardware.
>
> MSFC has not paid any attention to LOR and was not in a good position to comment on the mode. Their instinctive reaction, however, was negative.[40]

Throughout the spring of 1962, although discussion of the mode choice intensified, no consensus within NASA on the best choice seemed imminent. Then, in April, a team from the Manned Spacecraft Center traveled to Huntsville to brief von Braun and his top staff on their latest studies of the lunar rendezvous mode. By now the Houston people were firmly convinced that this mode was the best approach. They realized that if von Braun could be persuaded that they were correct, NASA headquarters could hardly make any other choice. After a three-hour presentation, von Braun seemed to be moving towards agreement with the lunar rendezvous approach.[38]

The three "basic attractive features of lunar rendezvous" stressed in these briefings were high-payload efficiency, minimum constraints on design of the lunar lander, and the smallest size for the lunar lander.[39] The last two advantages were related to Gilruth's belief in the difficulty of landing on the lunar surface.

Another form of the direct ascent approach, this one using the Saturn C-5 as the booster, came under consideration in early May. Such an approach had been studied for some time at the Ames and Lewis Research centers. Its feasibility was based on reducing the escape weight of the lunar spacecraft and propulsion system by using light-weight hydrogen-oxygen cryogenic fuel in the lunar landing and lunar takeoff propulsion stages and possibly by using a two-man crew for the mission, rather than a three-man crew. This approach had been suggested several times to the spacecraft managers in Houston, but had been rejected primarily because there had been no experience in storing and handling cryogenic fuels on long-term space flights, and it was not known whether such use was feasible. The C-5 direct flight approach was at this time favored by North American, the Apollo spacecraft contractor. For one thing, the adoption of such an approach meant that North American would build the whole spacecraft, rather than split the job with another contractor. Shea recorded that "conversations with Al Eggers . . . at Ames, and many other people, indicate that a direct flight lunar landing mission may be possible on a C-5 vehicle. Although Houston has rejected this approach in the past, there seems to be sufficient smoke here to warrant a detailed investigation."[40]

Perhaps the most crucial of the meetings to discuss the mode choice was held 7 June in Huntsville, when the Marshall personnel who had been studying various models for several years presented their findings to Shea. To the surprise of most of those present, Wernher Von Braun announced that his staff had concluded that all four modes investigated were technically feasible, but that they would rank them in the following order: (1) Lunar Orbit Rendezvous Mode, with the strong recommendation (to make up for the limited growth potential of this mode) to initiate, simultaneously, development

of an unmanned, fully automatic, one-way C-5 logistics vehicle; (2) Earth Orbit Rendezvous Mode (Tanking Mode); (3) C-5 Direct Mode with minimum-size Command Module and High Energy Return; (4) Nova or C-8 Mode.

The recommendation of the lunar orbit mode was a reversal of Marshall's long-standing preference for the earth orbital rendezvous approach, and Von Braun attributed the shift to three factors: (1) the LOR mode appeared most likely to be accomplished within the decade; (2) it offered adequate performance margin; (3) the designs of a maneuverable hyperbolic reentry vehicle and a lunar landing vehicle constituted the two most critical tasks in producing a lunar spacecraft and separating these two functions into two separate elements was bound to greatly simplify development of the spacecraft system; (4) the LOR Mode augmented by a C-5 Logistics Vehicle clearly offered the cleanest managerial interfaces between the Manned Spacecraft Center, Marshall Space Flight Center, Launch Operations Center and all the contractors on the project.

Von Braun noted that the staff at Marshall Space Flight Center initially was skeptical of the LOR Mode, particularly of the aspect of having the astronauts execute a complicated rendezvous maneuver 240,000 miles from Earth, but they had come to the conclusion that this disadvantage was far outweighed by the several advantages of the mode. He added that he understood that the Manned Spacecraft Center also was skeptical of the LOR Mode when it was first proposed. Von Braun concluded his remarks, on the note that both centers had actually embraced a scheme suggested by a third source. He said he considered it fortunate for the Manned Lunar Landing Program that both centers, after much soul searching, had come to the same conclusion and favored the LOR Mode. "This would give the Office of Manned Space Flight some additional assurance that our recommendations should not be too far from the truth," he said.[41]

With Von Braun's acceptance of the lunar orbital rendezvous mode, the decision to select it as the primary approach to the lunar mission was all but made, at least at the level of NASA's technical planning. By 16 June the Office of Systems Engineering had prepared a rough draft of the "Manned Lunar Landing Mode Comparison" in which the arguments for and against each mode were compiled and compared.[42]

In addition to the technical and managerial advantages of the lunar rendezvous mode, this comparison estimated that the lunar mission hardware, using that mode would cost $9.2 billion, as compared to $10.6 billion for the earth rendezvous and direct flight modes, and that the first lunar landing using the lunar rendezvous mode was possible in July 1968, six months earlier than with the earth rendezvous approach and eight months earlier than with the direct flight approach.[43]

On 22 June 1962 the Manned Space Flight Management Council met to make what Brainerd Holmes described as a "most important" decision—mission mode selection. Shea presented the results of the study on mission mode selection to the Council. After extended discussion, the Council unanimously concluded that "the manned lunar program should adopt LOR, with the C-5 launch vehicle as the mission mode for lunar exploration."[44]

In a memo over Seamans' signature with concurrances by Dryden and Webb, Holmes was informed on 10 July: "We have carefully reviewed the recommendations of your office and of the Management Council concerning changes in the primary mode previously approved for the manned lunar landing program. We are in basic agreement with the conclusions of the Management Council and with your recommendations. In view of the above, and to provide any clarification needed, your office is authorized to proceed as follows: 1. Adopt lunar orbit rendezvous (LOR) as the prime mission mode for our first manned lunar exploration.[45]

The decision was publicly announced the next day at a news conference, in which Webb, Seamans, Holmes, and Shea answered reporters' questions. Webb stressed that the decision was not yet final (for reasons discussed below) and that NASA would be conducting "other studies that have been indicated as a result of our work here in NASA, of our consultation with the Department of Defense authorities, of our consultation with Dr. Wiesner [Kennedy's scientific adviser) and his panel of scientists . . . and with others who have been brought in as consultants in connection with this matter." Seamans gave credit to John Houbolt for his advocacy of the lunar rendezvous mode. Holmes sounded a rather more definite note than Webb, noting the "there is a balance between studying a program . . . and finally implementing it. There comes a point in time, and I think the point in time is now, when one must make a decision as how to proceed, at least as to the prime mode."[46]

To the men directly involved in running the lunar landing program, the decision on how to proceed had been made. But that decision was challenged by others, outside of NASA, and was not finally made firm for several months. The primary opposition came from the highest-level governmental advisory body for science, the President's Science Advisory Committee (PSAC). By the time NASA announced the selection of lunar orbital rendezvous as the primary mode on 11 July, PSAC was on record with the agency and with the President as unanimously opposed to the choice of that approach rather than earth orbital rendezvous. The reasons for PSAC's opposition were complex. One was the belief that the choice of lunar rendezvous was based only on finding the earliest and least expensive way to a lunar landing, and that the contribution of an earth rendezvous approach to the total civilian and military space effort had been neglected in rejecting earth rendezvous. Another was a conviction that non-technical factors, especially these related to internal NASA politics and the intercenter rivalry, had been decisive. A third was the belief of a key PSAC staff member, Nicholas Golovin, (who had chaired the LLVPG and who had left NASA shortly after Brainerd Holmes assumed director of Project Apollo) that NASA's top management had not done an adequate technical analysis of the mode possibilities, and thus had made a choice based on insufficient or incomplete information.

Even after the July choice of lunar rendezvous, NASA continued to study the other approaches to the mission, primarily in order to provide enough justification for its choice to reverse the PSAC judgement that the choice had been incorrect. Although these studies confirmed the lunar orbital rendezvous selection, PSAC and especially Nicholas Golovin and Jerome Wiesner never were convinced. The dispute finally subsided in November, when Webb apparently indicated an intention to resign if the agency choice were not upheld by the President. The NASA-PSAC differences broke into public in the form of a vigorous debate between Wiesner and NASA officials in front of the President as he was visiting the Huntsville space center.[47] On 7 November 1962, NASA announced that it was affirming the tentative decision to choose the lunar rendezvous mode, and that it had chosen Grumman Air-

craft Engineering Corp. to build the lunar module. Thus, the final major segment of the Apollo-Saturn system was assigned to a contractor, and, as Webb had said in the July news conference announcing the tentative LOR decision, NASA had been able finally "to line up the forces, point them in the same direction, and get in motion now with the final stages of the lunar exploration.[48] Webb, a few weeks later, wrote the President, summarizing "the action taken and the reasons therefore." He told the President that "despite the very extensive study efforts, . . . we are dealing with a matter that cannot be conclusively proved before the fact, and in the final analysis the decision has been based upon the judgement of our most competent engineers and scientists who evaluated the studies and are experienced in this field."[49]

The planning of the period from early 1961 until late 1962 provided the basis from which NASA was able to "drive forward vigorously," in Webb's words,[50] towards a manned lunar landing. This planning was energized by a goal set at the highest levels of government, a goal which had effects permeating the total space capability of the nation. In response to the challenge set by the goal of landing Americans on the moon "before the decade is out," some of America's finest resources were focused in planning an enterprise of unprecedented and fascinating complexity. The choice of the lunar orbital rendezvous approach was perhaps the central decision of that enterprise, and as such it must rank as one of the most important choices in the history of technology.

References

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2. This article is extracted from a longer paper selected by the National Space Club as a recipient of the Robert H. Goddard Historical Essay Award for 1969. I wish to thank the NASA Historian, Eugene Emme, former NASA Historian for Manned Space Flight William Putnam, and Manned Spacecraft Center Historian James Grimwood for their assistance in the research for this paper.

3. NASA, Lunar Landing Working Group, "A Plan for Manned Lunar Landing," 7 February 1961. This and other unpublished material cited are located in the NASA Historical Archives, Washington, D.C., or the Manned Spacecraft Center Historical Archives, Houston, Texas.

4. NASA's post-mercury manned circumlunar manned mission called "Apollo" had just been announced in July 1960. Subsequent studies of the lunar-landing mission had been initiated in October to design modular components, with costed projections, compatible with the circumlunar mission for which studies had been authorized.

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6. Comments by William Fleming on earlier draft of this article.

7. Interview with Fleming, 6 August 1968.

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16. Letter from James Webb to Robert McNamara, 7 July 1961.

17. Letter from Robert McNamara to James Webb, 7 July 1961.

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21. Memorandum from Milton W. Rosen to Brainerd Holmes, "Recommendations for NASA Manned Space Flight Vehicle Program," and attached "Report of the Combined Working Group on Vehicles for Manned Space Flight," 20 November 1961.

22. Interview with Milton W. Rosen, 7 August 1968.

23. Rosen memorandum and attached report, 20 November 1961, *op. cit.*

24. Minutes of Management Council meeting, 21 December 1961.

25. "Advanced Saturn Preliminary Project Development Plan," undated.

26. Quoted in NASA, *Pioneers of Rocket Technology: Selected Works,* NASA Technical Translation F-9285, November 1965, p. 151.

27. H. E. Ross, "Orbital Bases," *Journal of the British Interplaintary Society,* VIII, 1 (1949), pp. 5-7.

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31. *Life,* 23 March 1969, p. 22.

32. *New York Times,* 17 July 1969, p. 35 and the *Life* article cited in the previous footnote make this mistake.

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44. Minutes of Management Council meeting, 22 June 1962.

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47. *Time,* 21 September 1962, p. 22.

48. NASA, *Lunar Orbit Rendezvous, op. cit.,* p. 7.

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