CONCLUDING REMARKS BY DR. WERNHER VON BRAUN ABOUT MODE SELECTION FOR THE LUNAR LANDING PROGRAM GIVEN TO DR. JOSEPH F. SHEA, DEPUTY DIRECTOR (SYSTEMS) OFFICE OF MANNED SPACE FLIGHT

JUNE 7, 1962

In the previous six hours we presented to you the results of some of the many studies we at Marshall have prepared in connection with the Manned Lunar Landing Project. The purpose of all these studies was to identify potential technical problem areas, and to make sound and realistic scheduling estimates. All studies were aimed at assisting you in your final recommendation with respect to the mode to be chosen for the Manned Lunar Landing Project.

Our general conclusion is that all four modes investigated are technically feasible and could be implemented with enough time and money. We have, however, arrived at a definite list of preferences 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, the 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.

I shall give you the reasons behind this conclusion in just one minute.

But first I would like to reiterate once more that it is absolutely mandatory that we arrive at a definite mode decision within the next few weeks, preferably by the first of July, 1962. We are already losing time in our over-all program as a result of a lacking mode decision.

A typical example is the S-IVB contract. If the S-IVB stage is to serve not only as the third (escape) stage for the C-5, but also as the second stage for the C-1B needed in support of rendezvous tests, a flyable S-IVB will be needed at least one year earlier than if there was no C-1B at all. The impact of this question on facility planning, build-up of contractor level of effort, etc., should be obvious.

Furthermore, if we do not freeze the mode now, we cannot lay out a definite program with a schedule on which the budgets for FY-1964 and following can be based. Finally, if we do not make a clear-cut decision on the mode very soon, our chances of accomplishing the first lunar expedition in this decade will fade away rapidly.

I. WHY DO WE RECOMMEND LUNAR ORBIT RENDEZVOUS MODE PLUS C-5 ONE-WAY LOGISTICS VEHICLE?

a. We believe this program offers the highest confidence factor of successful accomplishment within this decade.

b. It offers an adequate performance margin. With storable propellants, both for the Service Module and Lunar Excursion Module, we should have a comfortable padding with respect to propulsion performance and weights. The performance margin could be further increased by initiation of a back-up development aimed at a High Energy Propulsion System for the Service Module and possibly the Lunar Excursion Module. Additional performance gains could be obtained if current proposals by Rocketdyne to increase the thrust and/or specific impulses of the F-1 and J-2 engines were implemented.

c. We agree with the Manned Spacecraft Center that the designs of a maneuverable hyperbolic re-entry vehicle and of a lunar landing vehicle constitute the two most critical tasks in producing a successful lunar spacecraft. A drastic separation of these two functions into two separate elements is bound to greatly simplify the development of the spacecraft system. Developmental cross-feed between results from simulated or actual landing tests, on the one hand, and re-entry tests, on the other, are minimized if no attempt is made to include the Command Module into the lunar landing process. The mechanical separation of the two functions would virtually permit completely parallel developments of the Command Module and the Lunar Excursion Module. While it may be difficult to accurately appraise this advantage in terms of months to be gained, we have no doubt whatsoever that such a procedure will indeed result in very substantial saving of time.

d. We believe that the combination of the Lunar Orbit Rendezvous Mode and a C-5 one-way Logistics Vehicle offers a great growth potential. After the first successful landing on the moon, demands for follow-on programs will essentially center on increased lunar surface mobility and increased material supplies for shelter, food, oxygen, scientific instrumentation, etc. It appears that the Lunar Excursion Module, when refilled with propellants brought down by the Logistics Vehicle, constitutes an ideal means for lunar surface transportation. First estimates indicate that in the 1/6 G gravitational field of the moon, the Lunar Excursion Module, when used as a lunar taxi, would have a radius of action of at least 40 miles from around the landing point of the Logistics Vehicle. It may well be that on the rocky and treacherous lunar terrain the Lunar Excursion Module will turn out to be a far more attractive type of a taxi than a wheeled or caterpillar vehicle.

e. We believe the Lunar Orbit Rendezvous Mode using a single C-5 offers a very good chance of ultimately growing into a C-5 direct capability. At this time we recommend against relying on the C-5 Direct Mode because of its need for a much lighter command module as well as a high energy landing and return propulsion system. While it may be unwise to count on the availability of such advanced equipment during this decade (this is why this mode was given a number 3 rating) it appears entirely within reach in the long haul.

f. If and when at some later time a reliable nuclear third stage for Saturn C-5 emerges from the RIFT program, the performance margin for the C-5 Direct Mode will become quite comfortable.

g. Conversely, if the Advanced Saturn C-5 were dropped in favor of a Nova or C-8, it would completely upset all present plans for the implementation of the RIFT program. Contracts, both for the engines and the RIFT stage, have already been let and would probably have to be cancelled until a new program could be developed.

h. We conclude from our studies that an automatic pinpoint letdown on the lunar surface going through a circumlunar orbit and using a landing beacon is entirely possible. Whether this method should be limited to the C-5 Logistics Vehicle or be adopted as a secondary mode for the Lunar Excursion Module is a matter that should be carefully discussed with the Manned Spacecraft Center. It may well be that the demand for incorporation of an additional automatic landing capability in the Lunar Excursion Module buys more trouble than gains.

i. The Lunar Orbit Rendezvous Mode augmented by a C-5 Logistics Vehicle undoubtedly offers the cleanest managerial interfaces between the Manned Spacecraft Center, Marshall Space Flight Center, Launch Operations Center and all our contractors. While the precise effect of this may be hard to appraise, it is a commonly accepted fact that the number and the nature of technical and managerial interfaces are very major factors in conducting a complex program on a tight time schedule. There are already a frightening number of interfaces in existence in our Manned Lunar Landing Program. There are interfaces between the stages of the launch vehicles, between launch vehicles and spacecraft, between complete space vehicles and their ground equipment, between manned and automatic checkout, and in the managerial area between the Centers, the Washington Program Office, and the contractors. The plain result of too many interfaces is a continuous and disastrous erosion of the authority vested in the line organization and the need for more coordination meetings, integration groups, working panels, ad-hoc committees, etc. Every effort should therefore be made to reduce the number of technical and managerial interfaces to a bare minimum.

j. Compared with the C-5 Direct Mode or the Nova/C-8 Mode, the Lunar Orbit Rendezvous Mode offers the advantage that no existing contracts for stages (if we go to Nova) or spacecraft systems (if we go to C-5 Direct) have to be terminated; that the contractor structure in existence can be retained; that the contract negotiations presently going on can be finished under the existing set of ground rules; that the contractor build-up program (already in full swing) can be continued as planned; that facilities already authorized and under construction can be built as planned, etc.

k. We at the Marshall Space Flight Center readily admit that when first exposed to the proposal of the Lunar Orbit Rendezvous Mode we were a bit skeptical - particularly of the aspect of having the astronauts execute a complicated rendezvous maneuver at a distance of 240,000 miles from the earth where any rescue possibility appeared remote. In the meantime, however, we have spent a great deal of time and effort studying the four modes, and we have come to the conclusion that this particular disadvantage is far outweighed by the advantages listed above.

We understand that the Manned Spacecraft Center was also quite skeptical at first when John Houbolt of Langley advanced the proposal of the Lunar Orbit Rendezvous Mode, and that it took them quite a while to substantiate the feasibility of the method and finally endorse it.

Against this background it can, therefore, be concluded that the issue of "invented here" versus "not invented here" does not apply to

either the Manned Spacecraft Center or the Marshall Space Flight Center; that both Centers have actually embraced a scheme suggested by a third source. Undoubtedly, personnel of MSC and MSFC have by now conducted more detailed studies on all aspects of the four modes than any other group. Moreover, it is these two Centers to which the Office of Manned Space Flight would ultimately have to look to "deliver the goods". I consider it fortunate indeed for the Manned Lunar Landing Program that both Centers, after much soul searching, have come to identical conclusions. This should give the Office of Manned Space Flight some additional assurance that our recommendations should not be too far from the truth.

II. WHY DO WE NOT RECOMMEND THE EARTH ORBIT RENDEZVOUS MODE?

Let me point out again that we at the Marshall Space Flight Center consider the Earth Orbit Rendezvous Mode entirely feasible. Specifically, we found the Tanking Mode substantially superior to the Connecting Mode. Compared to the Lunar Orbit Rendezvous Mode, it even seems to offer a somewhat greater performance margin. This is true even if only the nominal two C-5's (tanker and manned lunar vehicle) are involved, but the performance margin could be further enlarged almost indefinitely by the use of additional tankers.

We have spent more time and effort here at Marshall on studies of the Earth Orbit Rendezvous Mode (Tanking and Connecting Modes) than on any other mode. This is attested to by six big volumes describing all aspects of this mode. Nor do we think that in the light of our final recommendation - to adopt the Lunar Orbit Rendezvous Mode instead - this effort was in vain. Earth Orbit Rendezvous as a general operational procedure will undoubtedly play a major role in our over-all national space flight program, and the use of it is even mandatory in developing a Lunar Orbit Rendezvous capability.

The reasons why, in spite of these advantages, we moved it down to position number 2 on our totem pole are as follows:

a. We consider the Earth Orbit Rendezvous Mode more complex and costlier than Lunar Orbit Rendezvous. Moreover, lunar mission success with Earth Orbit Rendezvous requires two consecutive successful launches. If, for example, after a successful tanker launch, the manned lunar vehicle aborts during its ascent, or fails to get off the pad within a certain permissible period of time, the first (tanker) flight must also be written off as useless for the mission.

b. The interface problems arising between the Manned Spacecraft Center and the Marshall Space Flight Center, both in the technical and management areas, would be more difficult if the Earth Orbit Rendezvous Mode was adopted. For example, if the tanker as an unmanned vehicle was handled by MSFC, and the flight of the manned lunar vehicle was

conducted by the Manned Spacecraft Center, a managerial interface arises between target and chaser. On the other hand, if any one of the two Centers would take over the entire mission, it would probably bite off more than it could chew, with the result of even more difficult and unpleasant interface problems.

c. According to repeated statements by Bob Gilruth, the Apollo Command Module in its presently envisioned form is simply unsuited for lunar landing because of the poor visibility conditions and the undesirable supine position of the astronauts during landing.

III. WHY DO WE NOT RECOMMEND THE C-5 DIRECT MODE?

It is our conviction that the C-5 Direct Mode will ultimately become feasible - once we know more about hyperbolic re-entry, and once we have adequate high energy propulsion systems available that can be used conveniently and reliably on the surface of the moon. With the advent of a nuclear third stage for C-5, the margin for this capability will be substantially widened, of course.

a. Our main reason against recommending the C-5 Direct Mode is its marginal weight allowance for the spacecraft and the demand for high energy return propulsion, combined with the time factor, all of which would impose a very substantial additional burden on the Manned Spacecraft Center.

b. The Manned Spacecraft Center has spent a great deal of time and effort in determining realistic spacecraft weights. In the opinion of Bob Gilruth and Chuck Mathews, it would simply not be realistic to expect that a lunar spacecraft light enough to be used with the C-5 Direct Mode could be developed during this decade with an adequate degree of confidence.

c. The demand for a high energy return propulsion system, which is implicit in the C-5 Direct Mode, is considered undesirable by the Manned Spacecraft Center - at the present state-of-the-art at least - because this propulsion system must also double up as an extra-atmospheric abort propulsion system. For this purpose, MSC considers a propulsion system as simple and reliable as possible (storable and hypergolic propellants) as absolutely mandatory. We think the question of inherent reliability of storable versus high energy propulsion systems - and their usability in the lunar surface environment - can be argued, but as long as the requirement for "storables" stands, the C-5 Direct Mode is not feasible performance-wise.

d. NASA has already been saddled with one program (Centaur) where the margin between performance claims for launch vehicle and demands for payload weights were drawn too closely. We do not consider it prudent to repeat this mistake.

IV. WHY DO WE RECOMMEND AGAINST THE NOVA OR C-8 MODE?

It should be clearly understood that our recommendation against the Nova or C-8 Mode at this time refers solely to its use as a launch vehicle for the implementation of the President's commitment to put a man on the moon in this decade. We at Marshall feel very strongly that the Advanced Saturn C-5 is not the end of the line as far as major launch vehicles are concerned! Undoubtedly, as we shall be going about setting up a base on the moon and beginning with the manned exploration of the planets, there will be a great need for launch vehicles more powerful than the C-5. But for these purposes such a new vehicle could be conceived and developed on a more relaxed time schedule. It would be a true follow-on launch vehicle. All of our studies aimed at NASA's needs for a true manned interplanetary capability indicate that a launch vehicle substantially more powerful than one powered by eight F-1 engines would be required. Our recommendation, therefore, should be formulated as follows: "Let us take Nova or C-8 out of the race of putting an American on the moon in this decade, but let us develop a sound concept for a follow-on 'Supernova' launch vehicle".

Here are our reasons for recommending to take Nova or C-8 out of the present Manned Lunar Landing Program:

a. As previously stated, the Apollo system in its present form is not landable on the moon. The spacecraft system would require substantial changes from the presently conceived configuration. The same argument is, of course, applicable to the Earth Orbit Rendezvous Mode.

b. With the S-II stage of the Advanced Saturn C-5 serving as a second stage of a C-8 (boosted by eight F-1 engines) we would have an undesirable, poorly staged, hybrid launch vehicle, with a payload capability far below the maximum obtainable with the same first stage. Performance-wise, with its escape capability of only 132,000 lbs. (in lieu of the 150,000 lbs. demanded) it would still be too marginal, without a high energy return propulsion system, to land the present Apollo Command Module on the surface of the moon.

c. Implementation of the Nova or C-8 program in addition to the Advanced Saturn C-5 would lead to two grossly underfunded and undermanaged programs with resulting abject failure of both. Implementation

of the Nova or C-8 program in lieu of the Advanced Saturn C-5 would have an absolutely disastrous impact on all our facility plans.

The rafter height of the Michoud plant is 40 feet. The diameter of the S-IC is 33 feet. As a result, most of the assembly operations for the S-IC booster of the C-5 can take place in a horizontal position. Only a relatively narrow high bay tower must be added to the main building for a few operations which must be carried out in a vertical position. A Nova or C-8 booster, however, has a diameter of approximately 50 feet. This means that the roof of a very substantial portion of the Michoud plant would have to be raised by 15 to 20 feet. Another alternative would be to build a very large high bay area where every operation involving cumbersome parts would be done in a vertical position. In either case the very serious question arises whether under these circumstances the Michoud plant was a good selection to begin with.

The foundation situation at Michoud is so poor that extensive pile driving is necessary. This did not bother us when we acquired the plant because the many thousands of piles on which it rests were driven twenty years ago by somebody else. But if we had to enter into a major pile driving operation now, the question would immediately arise as to whether we could not find other building sites where foundations could be prepared cheaper and faster.

Any tampering with the NASA commitment to utilize the Michoud plant, however, would also affect Chrysler's S-I program, for which tooling and plant preparation are already in full swing at Michoud. Raising the roof and driving thousands of piles in Michoud may turn out to be impossible while Chrysler is assembling S-I's in the same hangar.

In summary, the impact of a switch from C-5 to Nova/C-8 on the very concept of Michoud, would call for a careful and detailed study whose outcome with respect to continued desirability of the use of the Michoud plant appears quite doubtful. We consider it most likely that discontinuance of the C-5 plan in favor of Nova or C-8 would reopen the entire Michoud decision and would throw the entire program into turmoil with ensuing unpredictable delays. The construction of a new plant would take at least 2-1/2 years to beneficial occupancy and over 3 years to start of production.

d. At the Marshall Space Flight Center, construction of a static test stand for S-IC booster is well under way. In its present form this test stand cannot be used for the first stage of Nova or C-8. Studies indicate that as far as the noise level is concerned, there will probably be no objection to firing up eight F-1 engines at MSFC. However, the Marshall

test stand construction program would be greatly delayed, regardless of what approach we would take to accommodate Nova/C-8 stages. Detailed studies seem to indicate that the fastest course of action, if Nova or C-8 were adopted, would be to build

- a brand new eight F-1 booster test stand south of the present S-IC test stand, and

- convert the present S-IC test stand into an N-II test stand. (This latter conclusion is arrived at because the firing of an N-II stage at Santa Susanna is not possible for safety reasons, the S-II propellant load being considered the absolute maximum permissible.)

The Mississippi Test Facility is still a "cow pasture that NASA doesn't even own yet", and cannot compete with any test stand availability dates in Huntsville. Developments of basic utilities (roads, water, power, sewage, canals, rail spur, etc.) at MTF will require well over a year, and all scheduling studies indicate that whatever we build at MTF is about 18 months behind comparable facilities built in Huntsville. MTF should, therefore, be considered an acceptance firing and product improvement site for Michoud products rather than a basic development site.

e. In view of the fact that the S-II stage is not powerful enough for the Apollo direct flight mission profile, a second stage powered by eight or nine J-2's or two M-1's is needed. Such a stage would again be on the order of 40 to 50 feet in diameter. No studies have been made as to whether it could be built in the Downey/Seal Beach complex. It is certain, however, that its static testing in Santa Susanna is impossible. As a result, we would have to take an entirely new look at the NAA contract.

f. I have already mentioned the disruptive effect a cancellation of the C-5 would have on the RIFT program.

g. One of the strongest arguments against replacement of the Advanced Saturn C-5 by Nova or C-8 is that such a decision would topple our entire contractor structure. It should be remembered that the temporary uncertainty about the relatively minor question of whether NAA should assemble at Seal Beach or Eglin cost us a delay of almost half a year. I think it should not take much imagination to realize what would happen if we were to tell Boeing, NAA and Douglas that the C-5 was out; that we are going to build a booster with eight F-1 engines, a second stage with eight or nine J-2's or maybe two M-1 engines; and that the entire problem of manufacturing and testing facilities must be re-evaluated.

We already have several thousands of men actually at work on these three stages and many of them have been dislocated from their home plants in implementation of our present C-5 program. Rather than leaving these thousands of men suspended (although supported by NASA dollars) in a state of uncertainty over an extended period of new systems analysis, program implementation studies, budget reshuffles, site selection procedures, etc., it may indeed turn out to be wiser to just terminate the existing contracts and advise the contractors that we will call them back once we have a new program plan laid out for them. We have no doubt that the termination costs incurring to NASA by doing this would easily amount to several hundred million dollars.

I have asked a selected group of key Marshall executives for their appraisal, in terms of delay of the first orbital launch, if the C-5 was to be discontinued and replaced by a Nova or C-8. The estimates of these men (whose duties it would be to implement the new program) varied between 14 and 24 months with an average estimate of an over-all delay of 19 months.

h. In appraising the total loss to NASA, it should also not be overlooked that we are supporting engine development teams at various contractor plants at the rate of many tens of millions of dollars per year for every stage of C-1 and C-5. If the exact definition of the stages were delayed by switching to Nova/C-8, these engine development teams would have to be held on the NASA payroll for just that much longer, in order to assure proper engine/stage integration.

i. More than twelve months of past extensive effort at the Marshall Space Flight Center to analyze and define the Advanced Saturn C-5 system in a great deal of engineering detail would have to be written off as a flat loss, if we abandoned the C-5 now. This item alone, aside from the time irretrievably lost, represents an expenditure of over one hundred million dollars.

j. The unavoidable uncertainty in many areas created by a switch to Nova or C-8 (Can we retain present C-5 contractors? Where are the new fabrication sites? Where are we going to static test? etc.) may easily lead to delays even well in excess of the estimates given above. For in view of the political pressures invariably exerted on NASA in connection with facility siting decisions, it is quite likely that even the NASA Administrator himself will find himself frequently unable to make binding decisions without demandin from OMSF an extensive re-appraisal of a multitude of issues related with siting. There was ample evidence of this during the past year.

k. For all the reasons quoted above, the Marshall Space Flight Cent considers a discontinuation of the Advanced Saturn C-5 in favor of Nova or C- as the worst of the four proposed modes for implementation of the manned lun landing project. We at Marshall would consider a decision in favor of this mo to be tantamount with giving up the race to put a man on the moon in this deca

IN SUMMARY I THEREFORE RECOMMEND THAT:

a. The Lunar Orbit Rendezvous Mode be adopted.

b. A development of an unmanned, fully automatic, one-way C-5 Logistics Vehicle be undertaken in support of the lunar expedition.

c. The C-1 program as established today be retained and that, in accordance with progress made in S-IVB development, the C-1 be gradually replaced by the C-1B.

d. A C-1B program be officially established and approved with adequate funding.

e. The development of high energy propulsion systems be initiated as a back-up for the Service Module and possibly the Lunar Excursion Module.

f. Supplements to present development contracts to Rocketdyne on the F-1 and J-2 engines be let to increase thrust and/or specific impulse.

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