National Aeronautics and
Space Administration
Langley Research Center
Langley Field, Virginia

May 19, 1961

Dr. Robert C. Seamans, Jr.
Associate Administrator
National Aeronautics and
Space Administration
1520 H St., N.W.
Washington 25, D. C.

Dear Dr. Seamans:

This will be a hurried non-edited and limited note to pass on a few remarks about rendezvous and large launch vehicles.

First, let me comment on the staff paper on rendezvous that was recently completed by Mr. Bernard Maggin. Bernie has done a fine job here and is to be commended. I share and back the viewpoints expressed almost completely. The main item not covered is the outlining of a specific and firm program on rendezvous, but this of course could not be covered without agreement throughout NASA. We have some definite ideas on what the program should be, and these will be forwarded as soon as some reproduction problems of the material are overcome.

With respect to launch vehicles, let me forthrightedly state that the situation is deplorable:

a. To be structurally sound the Saturn should undergo major structural modifications.

b. The S-IV is having serious setbacks which make it very doubtful that any time schedule involving S-IV can be met, and further there is no back-up to this S-IV stage in case it fails completely.

c. $H_2$, $O_2$ engines are not progressing nor developing as was so gloriously promised.

d. The F-1 engine is far from being developed.

e. There is no committed booster plan beyond Saturn C-1.

f. And even the existing but payload-limited launch vehicles, such as Atlas and Titan, which have had years of development and on which trememdous funds have been spent, are operationally poor.

In brief, our booster position is pathetic, but what is even worse, we have no jobs going on or even direct plans to remedy the situation. What should be done? It would appear that any consideration should include the following:

1. Give serious deliberation as to whether S-IV should have a back-up (whether propellant is RP, storable, or solid).

2. Firm up realistic and practical boosters that go beyond Saturn C-1 capabilities.

3. Establish parallel large booster programs involving solid rockets. The potentialities of large solids have been overlooked too long, and it may very well be that they can do Saturn jobs and beyond in a relatively easy manner.

In connection with these three items, let me also make this observation which I'm sure would sound naive to many. It would come as no surprise to me that we would now have a pretty good large booster if we had concentrated effort on the development of a very simple and reliable small booster, and that all we had to do to obtain various larger boosters was to "snap" these smaller boosters together in various arrangements, with no interconnections save necessary structural coupling members.

Now, let me revert back to rendezvous. I do not wish to argue which way, the "direct way" or the "rendezvous way", is the best. But 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, and that it be attacked vigorously. I would like, however, to make a few comments in connection with large booster desirability. For example, the argument is presented too freely and perhaps erroneously that the cost per pound in orbit is less through use of one big booster than by other means. Not enough attention is given to reliability and to probability of mission success. If the costs based on equal probability of mission success are compared, it may very well be that the cost per pound is larger by the big booster scheme. Charts of the type shown in the attached figure should be kept in mind. In this figure the probability of a mission success is plotted against number of mission attempts, for different probabilities of success for an individual attempt. Suppose that the probability of success of a big booster attempt is 0.4, and this low value may not be unrealistic (consider the Saturn S-I engines: I understand the probability of each engine functioning is 0.96; thus, the probability of all 8 engines operating is 0.72. This value pertai to engine only; the other components may add another factor of 0.72 bringing the probability down around 0.5. Now suppose, in addition, 6 - 8 - 10 or more engines had to be ignited aloft. Surely, if it is difficult to get 8 engines going on the ground, it is even more difficult while in fligh

Thus the 0.5 may even be cut in half, giving a fairly low overall probability.) After this long side comment, let's get back to the 0.4 value. If 2 attempts at this individual probability level are involved, then the attached figure shows a 0.64 probability for mission success. In contrast, now suppose another but slightly more costly mission scheme were used which had an individual probability of 0.64. Then only one attempt is necessary to accomplish the mission with the same probability of overall success as compared with two attempts for the previous case. The net cost is thus smaller for the more costly scheme.

Additional factors which enter into big booster considerations include (1) are facilities available to construct them? (2) can they be moved about and transported? and (3) are launch sites practical and where will they be located? Although not specifically stated, one of the ideas I'm trying to bring out is that perhaps there is too much planning of projects that simply assume the existence of the type of booster needed, without asking honestly whether it really will be there, and at the right time.

I'll close now. Perhaps these thoughts may be of some use to you.

Sincerely yours,

John C. Houbolt
Associate Chief
Dynamic Loads Division

Encl.

JCH.fbm

NATIONAL
AERONAUTICS
AND SPACE
ADMINISTRATION

OFFICE OF THE ADMINISTRATOR
1520 H STREET NORTHWEST
WASHINGTON 25, D.C.
TELEPHONE: EXECUTIVE 3-3260 TWX: WA 733

IN REPLY REFER TO

61 JUN 5 AM 10:41

June 2, 1961

Mr. John C. Houbolt
Associate Chief
Dynamic Loads Division
Langley Research Center
National Aeronautics and
Space Administration
Langley Field, Virginia

Dear John:

Thank you for your comments in your letter of May 19, 1961. As you probably know, the problems that concern you are of concern to the whole agency and we have some intensive study programs under way at the present time that will provide us a base for decisions.

You also probably know by this time that the recent Presidential recommendations for increases in the space program budget included funding for the Air Force to accelerate a large solid motor development program and an increase in the NASA budget to accelerate the rendezvous docking program.

Sincerely,

B. L

Robert C. Seamans, Jr.
Associate Administrator

National Aeronautics and
Space Administration
Langley Research Center
Langley Air Force Base, Va.

November 15, 1961

Dr. Robert C. Seamans, Jr.
Associate Administrator
National Aeronautics and
Space Administration
1520 H Street, N.W.
Washington 25, D. C.

Dear Dr. Seamans:

Somewhat as a voice in the wilderness, I would like to pass on a few thoughts on matters that have been of deep concern to me over recent months. This concern may be phrased in terms of two questions: (1) If you were told that we can put men on the moon with safe return with a single C-3, its equivalent or something less, would you judge this statement with the critical skepticism that others have? (2) Is the establishment of a sound booster program really so difficult?

I would like to comment on both these questions, and more, would like to forward as attachments condensed versions of plans which embody ideas and suggestions which I believe are so fundamentally sound and important that we cannot afford to overlook them. You will recall I wrote to you on a previous occasion. I fully realize that contacting you in this manner is somewhat unorthodox; but the issues at stake are crucial enough to us all that an unusual course is warranted.

Since we have had only occasional and limited contact, and because you therefore probably do not know me very well, it is conceivable that after reading this you may feel that you are dealing with a crank. Do not be afraid of this. The thoughts expressed here may not be stated in as diplomatic a fashion as they might be, or as I would normally try to do, but this is by choice and at the moment is not important. The important point is that you hear the ideas directly, not after they have filtered through a score or more of other people, with the attendant risk that they may not even reach you.

Manned Lunar Landing Through Use of Lunar Orbit Rendezvous

The plan.- The first attachment outlines in brief the plan by which we may accomplish a manned lunar landing through use of a lunar rendezvous, and shows a number of schemes for doing this by means of a single C-3, its equivalent, or even something less. The basic ideas of the plan were presented before various NASA people well over a year ago, and were since repeated at numerous interlaboratory meetings. A lunar landing program utilizing rendezvous concepts was even suggested back in April. Essentially, it had three basic points: (1) the establishment of an early rendezvous program involving Mercury, (2) the specific inclusion of rendezvous in Apollo developments, and (3) the accomplishment of lunar landing through use of C-2's. It was indicated then that two C-2's could do the job, C-2 being referred to simply because NASA booster plans did not go beyond the C-2 at that time; it was mentioned, however, that with a C-3 the number of boosters required would be cut in half, specifically only one.

Regrettably, there was little interest shown in the idea - indeed, if any, it was negative.

Also (for the record), the scheme was presented before the Lundin Committee. It received only bare mention in the final report and was not discussed further (see comments below in section entitled "Grandiose Plans").

It was presented before the Heaton Committee, accepted as a good idea, then dropped, mainly on the irrelevant basis that it did not conform to the ground rules. I even argued against presenting the main plan considered by the Heaton Committee, largely because it would only bring harm to the rendezvous cause, and further argued that if the committee did not want to consider lunar rendezvous, at least they should make a strong recommendation that it looks promising enough that it deserves a separate treatment by itself - but to no avail. In fact, it was mentioned that if I felt sufficiently strong about the matter, I should make a minority report. This is essentially what I am doing.

We have given the plan to the presently meeting Golovin Committee on several occasions.

In a rehearsal of a talk on rendezvous for the recent Apollo Conference, I gave a brief reference to the plan, indicating the benefit derivable therefrom, knowing full well that the reviewing committee would ask me to withdraw any reference to this idea. As expected, this was the only item I was asked to delete.

The plan has been presented to the Space Task Group personnel several times, dating back to more than a year ago. The interest expressed has been completely negative.

Ground rules.- The greatest objection that has been raised about our lunar rendezvous plan is that it does not conform to the "ground rules". This to me is nonsense; the important question is, "Do we want to get to the moon or not?", and, if so, why do we have to restrict our thinking along a certain narrow channel. I feel very fortunate that I do not have to confine my thinking to arbitrarily set up ground rules which only serve to constrain and preclude possible equally good or perhaps better approaches. Too often thinking goes along the following vein: gound rules are set up, and then the question is tacitly asked, "Now, with these ground rules what does it take, or what is necessary to do the job?". A design begins and shortly it is realized that a booster system way beyond present plans is necessary. Then a scare factor is thrown in; the proponents of the plan suddenly become afraid of the growth problem or that perhaps they haven't computed so well, and so they make the system even larger as an "insurance" that no matter what happens the booster will be large enough to meet the contingency. Somehow, the fact is completely ignored that they are now dealing with a ponderous development that goes far beyond the state-of-the-art.

Why is there not more thinking along the following lines: Thus, with this given booster, or this one, is there anything we can do to do the job? In other words, why can't we also think along the lines of deriving a plan to fit a booster, rather than derive a booster to fit a plan?

Three ground rules in particular are worthy of mention: three men, direct landing, and storable return. These are very restrictive requirements. If two men can do the job, and if the use of only two men allows the job to be done, then why not do it this way? If relaxing the direct requirements allows the job to be done with a C-3, then why not relax it? Further, when a hard objective look is taken at the use of storables, then it is soon realized that perhaps they aren't so desirable or advantageous after all in comparison with some other fuels.

Grandiose plans, one-sided objections, and bias.- For some inexplicable reason, everyone seems to want to avoid simple schemes. The majority always seems to be thinking in terms of grandiose plans, giving all sort of arguments for long-range plans, etc. Why is there not more thinking in the direction of developing the simplest scheme possible? Figuratively, why not go buy a Chevrolet instead of a Cadillac? Surely a Chevrolet gets one from one place to another just as well as a Cadillac, and in many respects with marked advantages.

I have been appalled at the thinking of individuals and committees on these matters. For example, comments of the following type have been made: "Houbolt has a scheme that has a 50 percent chance of getting a man to the moon, and a 1 percent chance of getting him back." This comment was made by a Headquarters individual at 'high level who never really has taken the time to hear about the scheme, never has had the scheme explained to him fully, or possible even correctly, and yet he feels free to pass judgment on the work. I am bothered by stupidity of this type being displayed by individuals who are in a position to make decisions which affect not only the NASA, but the fate of the nation as well. I have even grown to be concerned about the merits of all the committees that have been considering the problem. Because of bias, the intent of the committee is destroyed even before it starts and, further, the outcome is usually obvious from the beginning. We knew what the Fleming Committee results would be before it started. After one day it was clear what decisions the Lundin Committee would reach. After a couple days it was obvious what the main decision of the Heaton Committee would be. In connection with the Lundin Committee, I would like to cite a specific example. Considered by this committee was one of the most hair-brained ideas I have ever heard, and yet it received one first place vote. In contrast, our lunar rendezvous scheme, which I am positive is a much more workable idea, received only bare mention in a negative vein, as was mentioned earlier. Thus, committees are no better than the bias of the men composing them. We might then ask, why are men who are not competent to judge ideas, allowed to judge them?

Perhaps the substance of this section might be summarized this way. Why is NOVA, with its ponderous ideas, whether in size, manufacturing, erection, site location, etc., simply just accepted, and why is a much less grandiose scheme involving rendezvous ostracized or put on the defensive?

<u>PERT chart folly</u>.- When one examines the various program schedules that have been advanced, he cannot help from being impressed by the optimism shown. The remarkable aspect is that the more remote the year, the bolder the schedule becomes. This is, in large measure, due to the PERT chart craze. It has become the vogue to subject practically everything to a PERT chart analysis, whether it means anything or not. Those who apply or make use of it seem to be overcome by a form of self-hypnosis, more or less accepting the point of view, "Because the PERT chart says so, it is so." Somehow, perhaps unfortunately, the year 1967 was mentioned as the target year for putting a man on the moon. The Fleming report through extensive PERT chart analysis then "proved" this could be done. One cannot help but get the feeling that if the year 1966 had been mentioned, then this would have been the date proven; likewise, if 1968 had been the year mentioned.

My quarrel is not with the basic theory of PERT chart analysis; I am fully aware of its usefulness, when properly applied. I have been nominally in charge of a facility development and know the merits, utility, and succinctness by which it is helpful in keeping a going job moving, uncovering bottlenecks, and so forth. But when it is used in the nature of a crystal ball, then I begin to object. Thus, when we scrutinize various schedules and programs, we have to be very careful to ask how realistic the plan really is. Often simple common sense tells us much more than all the machines in the world.

I make the above points because, as you will see, we have a very strong point to make about the possibility of coming up with a realistic schedule; the plan we offer is exceptionally clean and simple in vehicle and booster requirements relative to other plans.

Booster is pacing item.- In working out a paper schedule we have adopted the C-3 development schedule used by Fleming and Heaton, not necessarily because we feel the schedule is realistic, but simply to make a comparison on a parallel basis. But whether the date is right, or not, doesn't matter. Here, I just want to point out that for the lunar rendezvous scheme the C-3 booster is the pacing item. Thus, we can phrase our lunar landing date this way. We can put a man on the moon as soon as the C-3 is developed, and the number of C-3's required is very small. (In fact, as I mentioned earlier, I would not be surprised to have the plan criticized on the basis that it is not grandiose enough.)

Abort.- An item which perhaps deserves special mention is abort. People have leveled criticism, again erroneously and with no knowledge of the situation, that the lunar rendezvous scheme offers no abort possibilities. Along with our many technical studies we have also studied the abort problem quite thoroughly. We find that there is no problem in executing an abort maneuver at any point in the mission. In fact, a very striking result comes out, just the reverse of the impression many people try to create. When one compares, for example, the lunar rendezvous scheme with a direct approach, he finds that on every count the lunar rendezvous method offers a degree of safety and reliability far greater than that possible by the direct approach. These items are touched upon to a limited extent in the attached plan.

## Booster Program

My comments on a booster program will be relatively short, since the second attachment more or less speaks for itself. There are, however, a few points worthy of embellishment.

Booster design.- In the course of participating in meetings dealing with vehicle design, I have sometimes had to sit back completely awed and astonished at what I was seeing take place. I have seen the course of an entire meeting change because of an individual not connected with the meeting walking in, looking over shoulders, shaking his head in a negative sense, and then walking out without uttering a word. I have seen people agree on velocity increments, engine performance, and structural data, and after a booster design was made to these figures, have seen some of the people then derate the vehicle simply because they couldn't believe the numbers. I just cannot cater to proceedings of this type. The situation is very much akin to a civil engineer who knows full well that the material he is using will withstand 60,000 psi. He then applies a factor of safety of 2.5, makes a design, then after looking at the results, arbitrarily doubles the size of every member because he isn't quite sure that the design is strong enough. A case in point is the C-3. In my initial contacts with this vehicle, we were assured that it had a payload capability in the neighborhood of 110,000-120,000 lbs. Then it was derated. The value used by the Heaton Committee was 105,000 lbs. By the time the vehicle had reached the Golovin Committee, I was amazed to find that it had a capability of only 82,570 lbs. Perhaps the only comment that can be made to this is that if we can't do any better on making elementary computations of this type, then we deserve to be in the pathetic situation we are. I also wonder where we will stand after NOVA is derated similarly.

"Quantizing" bad.- One of the reasons our booster situation is in such a sad state is the lack of appropriate engines, more specifically the lack of an orderly stepping in engine sizes. Booster progress is virtually at a standstill because there are no engines available, just as engines were the major pacing item in the development of aircraft. Aside from the engines on our smaller boosters, and the H-1 being used on the C-1, the only engines we have in development are:

| Capability | Ratio |
|---|---|
| 15,000 | |
| | 13.3 |
| 200,000 | |
| | 7.5 |
| 1,500,000 | |

The attempt to make boosters out of this stock of engines, having very large ratios in capability, can only result in boosters of grotesque and unwieldy configurations, and which require many, many in-flight engine starts. What is needed are engines which step up in size at a lower ratio. Consideration of the staging of an "ideal" rocket system indicates that whether accelerating to orbit speed or to escape speed, the ratio of engine sizes needed is in the order of 3. Logically then we ought to have engines that step in capability by a factor of around 2, 3, or 4. An every-day analog that can be mentioned is outboard motors. There is a motor to serve nearly every need, and in the extreme cases the process of doubling up is even used.

Booster program.- In light of the preceding paragraph, and taking into account the engines under development, we should add the following two:

| | |
|---|---|
| 80,000 - 100,000 | $H_2 - O_2$ |
| 400,000 - 500,000 | $H_2 - O_2$ |

This would then give a line-up as follows:

| | |
|---|---|
| 15,000 | H/O |
| 80,000 - 100,000 | H/O |
| 200,000 | H/O |
| 400,000 - 500,000 | H/O |
| 1,500,000 | RP/O |

with the 15,000-lb. engine really not needed. This array (plus those mentioned immediately below) would allow the construction of almost all types of boosters conceivable. For example, a single 80,000-100,000 engine would take the place of the six L-115 engines being used on S-IV; not only is the arrangement of six engines on this vehicle bad, but these engines have very poor starting characteristics. The 400,000-500,000 would be used to replace the four J-2's on the S-II. Thus, C-3 would change from a messy 12-engined vehicle requiring 10 in-flight engine starts to a fairly simple 5-engine vehicle with only 3 in-flight engine starts.

In addition, the following engines should be included in a program:

| | | |
|---|---|---|
| | 1,000,000 - 1,500,000 lb. | Solid |
| | 5,000,000 | Solid |
| and/or | 5,000,000 | Storable |

The 1,000,000 - 1,500,000 lb. solid would in itself be a good building block and would probably work in nicely to extend the capabilities of vehicles, such as Titan. The 5,000,000 solid and/or storable would also be good building blocks and specifically would serve as alternate first-stage boosters for C-3, aiming at simplicity and reliability.

It may be said that there is nothing new here and that all of the above is obvious. Indeed, it seems so obvious that one wonders why such a program was not started 5 years ago. But the fact that it may be obvious doesn't help us; what is necessary is putting the obvious into effect. In this connection, there may be some who ask, "But are the plans optimum and the best?". This question is really not pertinent. There will never be an optimized booster or program. We might have an optimum booster for a given situation, but there is none that is optimum for all situations. To seek one, would just cause deliberation to string out indefinitely with little, if any, progress being made. The Dyna-Soar case is a good example of this.

A criticism that undoubtedly will be leveled at the above suggestions is that I'm not being realistic in that there is just not enough money around to do all these things. If this is the situation, then the answer is simply that's why we have Webb and his staff. That's why he was chosen to head the organization, this is one of his major functions, to ask the question, do we want to do a job or not?, and, if so, then to find out where the gaps or holes are, and then to go about doing what is necessary to fill the gaps to make sure the job gets done, Further, the load doesn't have to be carried by the NASA alone. The Air Force and NASA can work together and share the load, and I'm sure that if this is done, the necessary money can be found. Even if some project, say, for example, the 5,000,000-lb. storable engine has to be dropped for some reason after it gets started; no harm will be done. This happens every day. On the contrary, some good, some new knowledge, will have been uncovered, even if it turns out to be the discovery of the next obstacle which prevents such a booster from being built.

<u>Nuclear booster and booster size</u>.- Although not mentioned in the previous section, work on nuclear engines should, of course, continue. Any progress made here will integrate very nicely into the booster plans indicated in the attachment.

As regards booster size, the following comment is offered. Excluding for the moment NOVA type vehicles, we should strive for boosters which make use of the engines mentioned in the preceding section and which are the biggest that can be made and yet still be commensurate with existing test-stand sites and with the use of launch sites that are composed of an array of assembly buildings and multiple launch pads. The idea behind launch sites of this type is an excellent one. It keeps real estate demands to a minimum, allows for ease in vehicle assembly and check-out, and greatly eases the launch rate problem. Thus, C-3 or C-4 should be designed accordingly. We would then have a nice work-horse type vehicle having relative ease of handling, and which would permit a lunar landing mission, as indicated earlier in the lunar rendezvous write-up section. From my point of view, I would much rather confine my spending to a single versatile launch site of the type mentioned, save money in real estate acquisition and launch site development necessary for the huge vehicles, and put the money saved into an engine development program.

## Concluding Remarks

It is one thing to gripe, another to offer constructive criticism. Thus, in making a few final remarks I would like to offer what I feel would be a sound integrated overall program. I think we should:

1. Get a manned rendezvous experiment going with the Mark II Mercury.

2. Firm up the engine program suggested in this letter and attachment, converting the booster to these engines as soon as possible.

3. Establish the concept of using a C-3 and lunar rendezvous to accomplish the manned lunar landing as a firm program.

Naturally, in discussing matters of the type touched upon herein, one cannot make comments without having them smack somewhat against NOVA. I want to assure you, however, I'm not trying to say NOVA should not be built. I'm simply trying to establish that our scheme deserves a parallel front-line position. As a matter of fact, because the lunar rendezvous approach is easier, quicker, less costly, requires less development, less new sites and facilities, it would appear more appropriate to say that this is the way to go, and that we will use NOVA as a follow on. Give us the go-ahead, and a C-3, and we will put men on the moon in very short order - and we don't need any Houston empire to do it.

In closing, Dr. Seamans, let me say that should you desire to discuss the points covered in this letter in more detail, I would welcome the opportunity to come up to Headquarters to discuss them with you.

Respectfully yours,

John C. Houbolt

JCH.fbm

Encls.

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.

## 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 under-managed 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-1 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 <u>average</u> estimate of an over-all delay of <u>19 months</u>.

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 demanding 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 Center considers a discontinuation of the Advanced Saturn C-5 in favor of Nova or C-8 as the <u>worst</u> of the four proposed modes for implementation of the manned lunar landing project. <u>We at Marshall would consider a decision in favor of this mode to be tantamount with giving up the race to put a man on the moon in this decade even before we started.</u>

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.

Wernher von Braun

Wernher von Braun, Director
George C. Marshall Space Flight Center