BELLCOMM, INC.

SUBJECT: Margin Allocation on Extended LM Lunar Missions - Case 232

DATE: June 9, 1967

FROM: N.W. Hinners

ABSTRACT

A discussion of Apollo lunar mission limitations has been undertaken, leading to suggested allocation of weight margin expected to be available for the extended or stretched LM (XLM). Of prime importance is the use of propellant to accomplish landings to within ∿100 meters of a predesignated lunar point. Next in priority is raising surface stay-time to 3 or 4 days with 6-8 EVA periods (two astronauts out simultaneously). Since XLM missions emphasize sampling, a minimum return lunar sample of 100 lbs (∿ 150 total returned payload) is desirable. It is prudent to increase descent scientific payload (ALSEP + LGE) by ∿125 lbs in order to accommodate a full complement of lunar experiments. The actual payload on a given mission will be affected by the specific site chosen.

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MEMORANDUM FOR FILE

I. INTRODUCTION

It is generally agreed that three to four Apollo lunar landing missions will, at best, present extremely limited opportunity to conduct extensive scientific investigations of the moon. Even so, they will be scientifically rewarding if they accomplish only sample return, for it is through analysis of such samples that we expect to learn the most significant facts regarding lunar geology. Additionally, one can expect that the short duration astronaut observations and the deployment of ALSEP packages will contribute valuable data. Perhaps more important, however, is the development, during the Apollo phase of lunar exploration, of the operational techniques necessary to conduct the scientific investigations. Once we have become confident in the conduct of operational techniques and sheer survival recedes as a prime concern, scientific objectives can be elevated in priority. The reader is referred to Reference 1 for a more detailed insight into the expected accomplishments of Apollo.

The question at hand is; how can we capitalize, during early SAAP lunar missions, on the capability developed on Apollo? On the one hand one can examine the deficiencies obvious in Apollo (short stay-time, low mobility, etc.) and ask for step-function increases which would seem reasonable at this time. Thus, we would be led to ask for two week surface missions with mobility aids yielding operational capability to $\sim$50 km from touchdown points. At the other pole is an acceptance of the status quo or a continuance of the Apollo missions. The former appears to be unreasonable for reasons of economy, schedules, and uncertainty in the progress of Apollo. The latter can be demonstrated to be undesirable as will be done below. The prime choice remaining, then, appears to be acceptance of the extended or stretched LM (XLM) concept in which Apollo system margins are utilized to obtain, for example, additional stay-time and payloads. How this margin is utilized is not unalterable. For example, there are trades available among stay-time, scientific payload to the moon, returned sample weight and landing site location. It is the purpose of this memorandum to delineate the desirable scientific attributes of XLM missions in order that the engineering studies of XLM may be made more realistic.

In the following we shall first discuss significant Apollo limitations and thence suggest the goals for XLM missions, all the while keeping in mind the magnitude of the Apollo margin which may become available.

II. APOLLO LIMITATIONS AND XLM GOALS

A. EVA Time

The most pressing Apollo limitation is extra-vehicular activity (EVA) time. It appears that the nominal Apollo missions will consist of 2 EVA periods of ∿3 hours each with two astronauts out simultaneously. A good fraction (∿ 1/3) of the first EVA periods will be taken up with operational tasks (Ref. 2) on every mission. Apollo Lunar Surface Experiments Package (ALSEP) deployment may take anywhere from 1/2 to 1 EVA period, the actual time depending heavily on the time taken by the active seismic and heat flow experiments. That leaves, at best, only 1 EVA period for the Lunar Geologic Experiment. This is too short a time to conduct a good examination of lunar surface features and to give proper attention to sample acquisition. E.M. Shoemaker Lunar Geologic Experiment (LGE) Principal Investigator, recently stated (personal communication) that somewhere between 3 and 5 EVA periods would be desirable for the LGE in the flat mare regions. More than that, however, he felt would be going after rapidly diminishing returns. We conclude, therefore, that even in a flat mare area, up to 6 (total) EVA periods could be efficiently utilized. As stated in B below, landing at a specific topographic feature would increase that to 8 EVA periods. Allowing 2 EVA periods per day leads to a desire for a 4 day XLM Mission.

B. Sites

The constraint applied to early Apollo to land only in relatively flat mare is apt to be a distinct drawback after the first few missions. On the initial landing it matters not at all and a second such mission can be justified assuming that one is at least looking at another mare. All our current ideas, however, lead us to believe that one mare is not significantly different from another be it with regard to age, composition or mode of origin.*

The next step up, then, is to land in a highland area and in or on specific topographic features in the mare. If that proves impossible, an attempt to land as near as possible to such features should be made. By as near as possible is meant within walking distance, for on XLM missions there is not enough margin

*It is even dubious how significant the difference is between circular and irregular mare.

available to carry mobility aids. As an essential goal then, and in view of the 1/2-1 km astronaut radius-of-operations one can expect, XLM missions should be targeted to land within 100 meters of predesignated points on the moon. Such operations will undoubtedly require use of margin in terms of fuel for redesignation during the descent phase. The ability to land near a feature could add, conservatively, a desire for 4 EVA periods per mission for specific examination of the feature and for traverse time. Assuming that only 2 EVA periods would then be used in "mare-type" investigations, a net addition of 2 EVA periods is envisioned.

C. Payload to Moon

The current authorized scientific payload to be taken to the moon (Ref.3) is 300 lbs, of which about 200 lbs is allotted to the ALSEP. The current ALSEP's however, are configured as two separate arrays consisting of different experiment mixes primarily for reasons of weight and power. A full complement of the available experiments or a full complement of lunar experiments would add about 75 lbs to overall descent payload*. Additional power (up to 100 watts from the current 56) plus changes to increase ALSEP flexibility might total another 25 lbs.

Additional geologic tools and/or sample return containers can be expected to require ∿25 lbs. Thus an overall increase of 125 lbs in scientific descent payload seems reasonable.

D. Ascent Payload

It is now planned (Ref. 3) to return 100 lbs of material to Earth from the Moon, including ∿50 lbs of lunar sample. (Sample containers weigh ∿27 lbs, tape, camera film, etc. make up the remainder.) Of prime importance to Apollo (Ref. 1) and more important to XLM missions, is the returned sample. The 50 lbs of Apollo sample appears small relative to the more than 110 Principal Investigators who desire sample. On the XLM mission there will be time to collect more and better samples and in view of the limited mobility, such missions will be primarily sampling missions. To estimate how much more sample is desirable is difficult. It is obvious that we cannot obtain, on these missions, the ∿500 lbs stated as a likely maximum (Ref. 4). It seems reasonable, and possible, however, to increase the return to 100 lbs. For this

*This subject will be treated in more detail in another memorandum it is suggested that one additional sample container be included for a nominal 25 lb increase and that the additional 25 be accommodated by better (denser) packing in each of three sample return containers (a useful astronaut function during the longer lunar stay).

E. Operational

The limited stay-time available on Apollo leads one to attempt to utilize as much of that time as possible for purely scientific endeavors. Since on XLM missions there will be a relaxation of the time pressures, we should attempt to develop techniques and operations which will be of use in the next phase of lunar exploration where more mobility will be available and astronauts range further from the LM. Several which come to mind are*:

1. Biologic exercising - having astronauts do increasingly difficult (metabolically) tasks such as climbing in and out of craters, up hills, etc.

2. Extended EVA - demonstrate lunar surface PLSS change which may be necessary for extending radius-of-operations and for obtaining continuous EVA periods up to 6-8 hours.

3. Rescue techniques - demonstrate ability of one astronaut to aid (rescue) another in simulated emergency situations.

4. Communications - test PLSS communications out of line-of-sight by having one astronaut enter nearby shallow crater or go behind nearby hill.

5. Dexterity - test (and use) the "hard" space-suit which promises greater dexterity and ease-of-motion on lunar surface.

Tasks 1 and 4 can be conducted during the course of conduct of the regular lunar surface exploration but 2, 3 and 5 would require time over and above that programmed for other activity. The amount is difficult to estimate but of the order of 1/2 an EVA period seems reasonable. No separate allowance is made for this in the total budget of 6 to 8 EVA periods although one should take this into account in estimating the time available for scientific endeavors.

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*The author is indebted to D.A. Beattie (NASA - MTL) for many of these suggestions.

III. SUMMARY

A discussion of Apollo lunar mission limitations has been undertaken leading to suggested allocation of weight margin expected to be available for the extended or stretched LM (XLM). Of prime importance is use of propellant to accomplish landings to within ∿100 meters of a predesignated lunar point. Next in priority is raising surface stay-time to 3 or 4 days with 6-8 EVA periods (two astronauts out simultaneously). Since XLM missions emphasize sampling, a minimum return lunar sample of 100 lbs (∿ 150 total returned payload) is desirable. It is prudent to increase descent scientific payload (ALSEP + LGE) by ∿125 lbs in order to accommodate a full complement of lunar experiments. The actual payload on a given mission will be affected by the specific site chosen.

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Attachment
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