MINUTES OF THE APOLLO SITE SELECTION BOARD MEETING

Held at

Kennedy Space Center

March 6, 1970

On March 6, 1970, the Apollo Site Selection Board met at Kennedy Space Center. The meeting agenda is shown in Attachment A and the attendees are listed in Attachment B.

Introduction

Capt. Scherer presented the current Board membership (see Attachment B) and presented a request by MSFC that they be given an additional Board seat to represent the Program Development side of Marshall. Dr. Petrone took the request under advisement. Capt. Scherer then reviewed the role of the ASSB, noting in particular that it might serve a broader purpose, as a mission review or mission definition board in addition to conducting its site selection function. Dr. Petrone said that he thinks that the mission review aspects are now well covered at other forums and that he would like to keep the ASSB focused on site selection related topics which, he agreed, covers a broad spectrum of subjects.

Apollo 11 and 12 Results

N. W. Hinners, Bellcomm, reviewed the salient results from the Apollo 11 and 12 sample analyses, with emphasis on relating them to the lunar science objectives as presented at prior ASSB meetings. The presentation can best be summarized with reference to Hinners' concluding chart shown in Figure 1 where the shading within a box connotes on a relative scale how far along we are towards accomplishing specific objectives.

Chronology: It is well established now that the rocks at the Apollo 11 site in Mare Tranquillitatis were molten ∿3.7 b.y. (billion years) ago and that a similar situation existed at the Mare Procellarum site of Apollo 12 $\gtrsim$2.7 b.y. ago. Thus we are well on the way to deciphering a sequence of and time span for mare filling and the remaining sites should enable us to obtain both younger and older material. About all one can say regarding the age of the mare basins and highlands is that they are older than 3.7 b.y. and younger than ∿4.6 b.y. This old age of 4.6 b.y., obtained for the Apollo 11 soil, is thought to represent the "age" of the moon although a lot of work must be done at future sites to ascertain just what happened 4.6 b.y. ago and why the soil retains evidence for that event. Lastly, work on the Apollo 11 samples shows that the surface is being churned or gardened at a rate such that the top six inches or so are completely mixed on a time scale of ~100 million years and that cratering events have shown no significant variation over the past half billion years.

Composition: We now have two good samples of mare material which indicate that lunar material has undergone major chemical fractionation, possibly in two steps. First, the material is extremely depleted in volatile elements relative to what one believes "primitive" solar system material ought to contain. This indicates a high temperature history for (all?) lunar material, possibly during the formation of the moon, and makes it unlikely that we will find primitive material anywhere on the moon. Second, the mare fill is most likely a product of in-situ chemical fractionation (differentiation) in the lunar interior in which case we have seen only a non-representative portion of the lunar interior. In the Apollo 11 soil, small pieces of exotic rock have been found which many investigators think may be samples of highland material and which may represent a rock created by a process similar to that which created mare rocks. The emphasis on future missions will thus be to obtain deep-seated samples and highlands material.

Processes: In most experimenters' minds there is little doubt that the igneous rocks found at the Apollo 11 and 12 sites were formed by a volcanic process in which internal heating of the moon is the prime energy source for melting the rocks. However, one cannot unequivocally rule out impact generated melting as a major lunar process. The role of meteoroid impact in generating the lunar soil is essentially undisputed and has resulted in the formation of a very fine soil with abundant particles of glass, the glass being, in general, simply a shock melted equivalent of the crystalline rocks. Before Apollo 11, there was widespread belief that lunar sinuous rilles resulted from water erosion. The finding that there is virtually no water in the rocks, and probably never was, is forcing a re-evaluation of that proposal.

Geophysics: The successful emplacement of seismometers on Apollo 11 and 12 has only whetted the appetite of geophysicists, especially since they are obtaining seismic signals unlike those seen on earth. The consensus is that one is seeing a complex absorption and reflection phenomenon through a highly fractured lunar surface layer. No heat flow measurement has yet been made, but the amount of radioactivity and variation thereof in the 11 and 12 samples assure us that it will be a significant experiment and potentially valuable in deciphering the lunar interior composition. The successful emplacement of the LR^3 on Apollo 11 goes a long way towards establishing the basis for accurate determination of the lunar ephemeris, moments of inertia and other orbital parameters. Emplacement of two more LR^3's at well selected sites will enable the investigators to conduct a thorough investigation of those lunar parameters. The finding of remnant magnetism on Apollo 11 rocks (indicating a small lunar field 3.7 b.y. ago) and of a small d.c. field at the Apollo 12 site have increased the significance of the magnetic experiments and serve to emphasize the need for other well placed instruments. There is no significant information on the lunar atmosphere yet on account of the failure of the pressure gauge on ALSEP, but we now know that the solar wind is impacting the surface directly. Analysis of solar wind incorporated in the lunar soil has already led to advances in understanding solar wind composition and may enable one to study the sun's history by studying lunar sites of varying age.

Report on GLEP+ February 6-7 Meeting

A. J. Calio presented the results of a meeting of the Group for Lunar Exploration Planning (and other invited scientists including ALSEP PIs, the Lunar Panel of the LPMB, and "remote sensors") held at MSC on February 6 and 7. The objective of the meeting was to re-evaluate the site mission assignments in view of the deletion of Apollo 20 from the Program. The starting point was the site assignments approved at the ASSB in October of 1969 as shown in Column 1 of Figure 2.

At the GLEP meeting there was a consensus that Fra Mauro was indeed a good site for Apollo 13. There was sentiment expressed, however, that for Apollo 14 one of the sites which would potentially provide "deep-seated" lunar material might be preferable to Littrow. Candidates for such a site included Davy Crater Chain, Rima Bode II and Hyginus. A substantial majority of participants agreed that Littrow should remain as the site for Apollo 14. The arguments in favor of one of the deep sample sites were persuasive enough that, combined with a recently expressed ambiguity in the interpretation of Censorinus (possibly Nectaris basin throw out), participants agreed to rate Davy as preferable to Censorinus on Apollo 15. On account of the necessary reliance upon Apollo 13 photography to obtain satisfactory coverage of the desired landing points, the agreed-to option included the pair Davy/Censorinus with the understanding that Davy has higher priority if one can land at a point such that both the highlands and craters are accessible to the astronauts. It was noted by Calio that Davy is preferable to both Hyginus and Rima Bode II on account of its multiple objectives (upland fill, highlands, and deep-seated material) as contrasted with the more singular objective of deep-seated samples at Hyginus and Rima Bode II.

Consideration of J-mission sites at the GLEP+ meeting presented more of a problem for it had been established that one mission would have to drop out on account of the Apollo 20 deletion. All the sites were discussed, pro and con, with a consensus for the sequence shown in Column 2 of Figure 2. In that list Tycho was selected as the site to drop in the prime sequence on account of the apparently overwhelming operational problems involved in conducting the mission. Tycho was left as an alternate to the Descartes site, however, since it was realized that more photography is necessary (to be obtained on Apollo 13) before one can make a final decision. Discussion of Hadley focused on the opinion that a mission oriented primarily towards the rille might be unwise for two reasons: first it appears that slumping of wall material into the bottom has covered up any signs of erosion which might have been observable when it was formed and second, the lack of water in the Apollo 11 and 12 samples makes it unlikely that any form of water erosion was involved in the rille formation. The group thus decided that it would be better to reposition the landing site to where it had been about a year ago and to have multiple objectives including the crater Hadley C, the rille, and the Apennine front.

MSC recommended a site assignment as shown in Column 3 of Figure 2. This follows the GLEP+ list with the exception that they would delete Tycho from any further consideration on account of the operational difficulties and would switch the relative positions of Copernicus and Marius Hills. The rationale for the switch was:

1. The Marius Hills has been a prime rover mission and the rover may not be ready in time to meet the Marius Hills launch window. Copernicus would make a better walking mission in MSC's opinion;

2. The traverse instrumentation cannot be ready for an Apollo 16 launch date but could be for the Apollo 18 date and it is preferable to have that instrumentation available at the Marius Hills;

3. We may learn enough on missions 13-15 to obviate the need to go to the Marius Hills at all; and

4. Marius Hills is too complex a site for a first rover mission.

<u>Discussion</u>

Dr. Petrone noted that it was only necessary at this time to make the Apollo 14 decision. Since there has been a favorable concensus (GLEP+, MSC, ASSB) on Littrow for that mission, the decision was made to assign it to Apollo 14. It was again noted that we do not have the information necessary to make the decision on Davy or Censorinus for Apollo 15. Dr. Petrone accepted a philosophy of keeping the pair under consideration for Apollo 15 with Davy being of higher scientific priority assuming that the landing point is within astronaut walking range of both the highlands and craters. In view of the time needed to process and analyze the Apollo 13 photography and the leadtime needed before Apollo 15, it was agreed that the Apollo 15 decision should be made about two to three months after the Apollo 13 launch.

In the discussion of the J-mission sequence, Dr. Petrone noted that for some time now NASA has been advertising the Marius Hills as the prime and first rover mission. To change it now requires a good reason. Points brought up regarding the MSC position on the switch were:

1. We're as apt to learn enough from 13-15 to make us change our mind about Copernicus;

2. Copernicus is not a good walking mission site considering the latest walking constraints (buddy-system) and that the MSC preferred landing point (2 km diameter circle) is about 5 km from the central peaks.

3. The topography at Copernicus is rougher than at Marius Hills making it less desirable as a first rover mission.

4. The proposed Principal Investigators for the traverse instrumentation have not identified specific site dependent objectives so one cannot make a better case for one site or the other;

5. Marius Hills on 16 would allow more frontside photographic coverage early which might be of use for later missions.

6. Keeping Marius Hills in the 16 slot would keep the pressure on the rover development.

7. Keeping Marius Hills on 16 would force the continuation of detailed traverse planning.

Participants agreed that there is validity to all points raised, pro and con. Perhaps most significant is the realization that the arguments about relative science merit are based largely upon educated speculation and hypotheses. Dr. Petrone stated that pressure must be kept on the rover development regardless of the specific 16 site and that mission planning must proceed on traverse utilization. Since it was not necessary to make a decision at the ASSB meeting, Dr. Petrone stated that he would take the matter of the Marius Hills-Copernicus trade and the J-mission assignments under advisement and make a decision in the next couple of weeks. However, he requested the following:

1. Compare the relative merits of the Marius Hills and Copernicus as walking missions (Action: MSC, Calio).

2. Investigate the other sites as potential walking missions for Apollo 16 (Action: MSC, Calio).

Discussion of Tycho re-affirmed the MSC feeling that Tycho is difficult operationally. Dr. Petrone re-iterated the desire of the scientists to explore Tycho and asked that it remain in the list of candidate sites. Realizing that it is a difficult site, he tentatively positioned it as an alternate to Hadley-Apennine on Apollo 19. As such, it causes no large amount of effort now but will keep it alive.

A summary of the tentative position of the ASSB regarding site assignments is shown in Column 4 of Figure 2.

Regarding the site selection review process, Dr. Petrone said that we need to eliminate the constant re-education of new participants since such has been time consuming and disorganizing in the past. He would like the site selection rationale documented in a NASA publication. In response, A. J. Calio said that S&AD is preparing a Site Data Book which will contain facts and photography on all sites. N. W. Hinners noted that he is working on a write-up of the science rationale. Calio and Hinners indicated that they would coordinate those efforts.

Assessment of Proposed Mission Sequences

F. Bennett, MSC, reported the results of the study on the effects of lunar dust during terminal descent. It was concluded that, within the error of the analyses, the differences in visibility between the Apollo 11 and 12 missions could be explained by differences in engine thrust (~20% of the effect) and sun angle (~80% of the effect). It was noted that undeterminable differences in soil mechanics properties at the two sites might also account for the differences. Bennett recommended that studies continue on dust scattering properties, effects of variation of cohesion, particle size distribution, albedo and sun angle on visibility obscuration, and on the role of gas diffusion through the soil as it aids soil erosion. The summary comment was that there is no apparent way to avoid dust on future landings but that a software change is expected to enable essentially "blind" landings.

Next, Bennett summarized the Apollo 11 and 12 descent profiles below 500 feet and compared them with the nominal automatic altitude-time history. Althought there were deviations from the nominal (both Apollo 11 and 12 took longer below 500 feet) sufficient margin existed such that an allowance of two minutes below 500 feet is still considered valid.

M. Cassetti, MSC, reported on deltas to the LM/CSM payload capability. Revisions in the DPS ΔV budget included removing the ΔV allowance for the engine valve malfunctions (+120 lbs LM payload), adding ΔV for the early low level sensor anomaly (-400 lbs payload), removing the 99.999% probability of propellent non-depletion, and adding a 20 second abort pad (these last two cancelled each other on the ΔV budget). On SPS, Cassetti noted that lower midcourse correction ΔV and a revised LM reserve/contingency budget resulted in a gain of ~200 lbs.

A summary of the J-mission weight status indicated a current CSM inert weight (less payload) of 24,900 lbs with projected growth to 25,450 (control weight is 25,000). The LM (full propellent loads but less payload) is currently 35,131 with projected growth to 35,331 (35,350 control weight). Consideration of current CSM science payloads (~830 lbs) and LM science payload including the rover (~850 lbs) led MSC to recommend 850 lbs control weight on each and 1000 lbs for a limit weight. For certain proposed schedules and landing sites (Figure 3) the launch vehicle requirements exceed the APO control weight of 106,500 lbs. MSC proposes to get around the problem by tailoring launch environment (temperature, wind, etc.) requirements to a specific monthly schedule rather than using yearly envelope as is now done. In many cases one requires a 90 nm orbit to gain performance. Such is true in enough cases that MSC recommended that the 90 nm orbit become standard. MSC and MSFC were asked to submit a written recommendation to that effect to Headquarters (Action: MSFC, Speer and MSC, McDivitt). Any launch vehicle payload deficiencies remaining after the above improvements would be accomplished either by reducing the launch window or by using a non-free return trajectory.

Proposed Launch Opportunity Plan

Since the content of this segment of the agenda had been discussed by Dr. Petrone and MSC the day before the ASSB meeting, only a summary was given. McDivitt first spoke to the question of the back-up site philosophy and noted that keeping a back-up or recycle site for a mission entails too much work, presents an astronaut training problem, and if used results in a science loss. This led to a recommendation (accepted) to drop further work on back-up sites. Therefore, the object is to now concentrate on the prime site and T-0 launches. In order to maximize the launch opportunities for a given site, a look is being taken at extending the launch window to three months (110 days on hypergolics). Results of that study should be available in May.

To increase the prospects of a successful launch, MSC investigated T-24 and T+24 opportunities. A T-24 launch entails a change in the mission profile to "eat-up" extra time either in translunar coast or in lunar orbit. The extended flight time leads to a projected shortage of consumables (H_2) which could be solved by a later loading of H_2 (at T-20 hrs), by reducing power drain during TLC, and by restricting activities during the extra time in lunar orbit. SHe pressure margins also become critical in certain cases but a series of potential fixes indicate that it is not an insurmountable problem. The prime problem of a T+24 launch concerns visibility at the higher sun angle at landing (18°-27°), in particular can the crew see well enough to quickly recognize the landing site early in the visibility phase and well enough to avoid obstacles at landing? Although studies so far are incomplete on the T+24 visibility, the opinion was expressed that the visibility would be degraded but would be acceptable for landing. The prime concern was that one is apt to lose the capability for the pin-point landing at certain sites which do not have obvious, easily distinguished landmarks.

The agreed upon position for the opportunities for the Apollo 13 mission was:

First month	T-0 only
Second month	T-24, T-0, T+24

Site Leadtime Reduction Task Group Report

C. Perrine, MSC, reminded the ASSB that in October, 1969, the Task Group reported that a standard mode-of-operation leadtime for site selection was six months. A re-evaluation of that earlier work indicates that there are four critical paths (Figure 4) of seven months, thus making it impossible for the results of one mission to influence the site of the next mission (the time available for that reaction is only ~four months). Dr. Petrone agreed with the recommendation that the sites be selected by T-7 months and that the Task Group effort be considered completed.

Status Report on Lunar Surface Exploration Capability

This part of the ASSB meeting consisted primarily of informal discussions. Dr. Petrone noted that the object of the game is to extend mission capability but that in the traverse planning exercises (MSC, U.S.G.S., Bellcomm) there does not appear to be consistency in assumed capability (BTU rates, rover speeds, etc.). Col. McDivitt said that MSC has recognized this problem and will provide an official document with planning numbers.

Mr. Calio, MSC, discussed the role of the mission scientists (scientist-astronauts) in S&AD. He said that the system is working well and urged that they become the focal point for science input at MSC (now scattered among S&AD, ASPO, E&D, FCOD).

Discussion of the J-mission traverses again brought out the fact that so far Principal Investigators have not identified specific site-dependent objectives. Mr. Calio was given the action item to coordinate such a plan.

Status Report on Orbital and Surface Science

Capt. Scherer showed the current surface and orbital experiments assignments (Figures 5-7). Of particular note was the fact that the proposed traverse science instruments (seismic profiling, gravimeter, electrical properties) will not be available for Apollo 16 and most of them not until 18 and 19. Regarding the orbital experiments, Capt. Scherer noted that it has been possible to integrate the subsatellite into the SIM on Apollo 16 and that incorporation of the electromagnetic experiment on Apollo 19 precludes carrying the pan camera on 19 (a volume problem). He further stated that the two electromagnetic experiments (sounding radar and EM Sounder A) are being studied by a task group and the Principal Investigators in an attempt to make a single combined experiment. At this time such an integration appears desirable and feasible.

Summary of Action Items

1. Consider MSFC request for an additional seat on the ASSB (R. A. Petrone/MA).

2. Compare the relative merits of the Marius Hills and Copernicus as walking missions (A. J. Calio/MSC).

3. Investigate the other sites as potential walking missions for Apollo 16 (A. J. Calio/MSC).

4. Submit a written recommendation to Headquarters concerning use of a 90 nm earth orbit (J. A. McDivitt/MSC and F. A. Speer/MSFC).

5. Provide an official document providing consistent planning numbers for surface mission planning (J. A. McDivitt/MSC).

6. Establish site-dependent objectives for J-mission traverse science (A. J. Calio/MSC).

7. Document the lunar sites and site selection rationale (N. W. Hinners/Bellcomm and A. J. Calio/MSC).