BELLCOMM, INC.
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SUBJECT: Requirements for an Improved ALSEP for the Lunar Exploration Program Case 232

DATE: June 23, 1967

FROM: P. J. Hickson

ABSTRACT

In this memorandum improvements to the Apollo Lunar Surface Experiments Package (ALSEP) are described which are desirable in order to make it a more effective and efficient scientific exploration tool for advanced lunar missions.

Following a brief description of the present ALSEP program is a discussion of those changes, mainly operational, which one would make in a minimum modification program. Next a new ALSEP program is described. The salient conclusion here is that the number of experiments one would like to do with a scientific emplaced station is not large. Hence a new ALSEP need not be very much larger than the present ALSEP, the main differences being an increase in experiment weight and in flexibility. This new ALSEP would also be useful as a test bed to check the feasibility of experiments for a future lunar-based inter-planetary observatory.

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MEMORANDUM FOR FILE

I. INTRODUCTION

In this memorandum the improvements to the Apollo Lunar Surface Experiments Package (ALSEP) are described which are required to make it a more effective and efficient scientific exploration tool for advanced lunar missions.

The presentation is considered in three sections. The first gives a brief description of the present ALSEP. This is followed by consideration of a "minimum" modification ALSEP. The final section describes a set of requirements for a new ALSEP if major redesign of the present ALSEP is permissible.

II. PRESENT ALSEP

The Apollo Lunar Surface Experiments Package (ALSEP) is a multi-disciplinary, man-deployed, fully automatic, programmed, commandable, emplaced scientific station. An ALSEP has a nominal life of from 1 to 2 years and it is planned to have 3 ALSEP's operating simultaneously on the lunar surface and to have continuous full time (day and night) data coverage through the 30 foot dishes of the MSFN. The ALSEP program provides three important capabilities:

(a) a space-frame is provided to which a wide variety of experiments from a number of scientific disciplines can be attached. The space frame provides a power source, power distribution system, digital programming, data transmission and command receiving, and a mechanical and thermal structure. The ALSEP program also provides 8 candidate experiments.

(b) operationally the ALSEP program allows sequential deployment of several copies of a particular experiment. A net of a given experiment operating simultaneously on the moon yields information on wide areas if the experiment separations are large.

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(c) alternate modes of operation of an ALSEP central station can be chosen by command. This provides ALSEP with the capability to do a limited number of special experiments, for example: periodic monitoring of lunar dust cover; measurement of thermal conductivity in a heat flow experiment; and an active seismic experiment.

The ALSEP parameters will now be briefly described. The total weight allocated for ALSEP is 233 lbs.*, of which 60 lbs. is outboard of the LM descent stage for the Radioisotope Thermoelectric Generator (RTG) fuel cask assembly and fuel capsule and the remaining 173 lbs. is in 2 compartments of the SEQ bay of the descent stage. The total volume of the compartments is 15 cubic feet. ALSEP has 60 lbs allotted for experiments, provides 56 watts (20 W for experiments), has a nominal data rate of 1060 bits/sec, about 30 experiments commands, and has been assigned $\sim$ 90 minutes for deployment at a distance of 100 meters from the landed LM. In contrast to this the total requirements of all 8 ALSEP candidate experiments are: 127 lbs, 40 watts, 60 commands, data rate of 1300 bits/sec, and at least 160 minutes for deployment. Thus, mainly because of the weight constraint, each ALSEP contains only 3 or 4 of the candidate experiments. In the allotted volume ALSEP could carry 7 of the 8 experiments.

ALSEP must be delivered to KSC 5 months before launch. All 4 ALSEP arrays, each containing a different mix of experiments, will be hard-wired assembled and flight qualified separately months before the first lunar flight. From a scientific point of view this lack of flexibility and modularity is less than optimum since it does not permit any change in the first 4 flight articles in response to our growing knowledge of the moon.

Following is a list of 8 ALSEP candidate experiments with the experiment numbers assigned by the Manned Space Flight Experiments Board.

S031 Passive Seismic Experiment (PSE)

S033 Active Seismic Experiment (ASE)

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*In addition to ALSEP an Apollo lunar landing spacecraft carries 27 lbs. of Apollo Lunar Hand Tools (ALHT) in the SEQ bay and 40 lbs of rock boxes, camera and film in the ascent stage or a total of 300 lbs of scientific equipment. This is a mission limit. The LM structural limit is 323 lbs, the difference being mostly in the ascent stage.

S037 Heat Flow Experiment (HFE)
(includes the Apollo Lunar Surface Drill, ALSD)

S058 Cold Cathode Ionization Gauge (CCGE)

S036 Suprathermal Ion Detector Experiment (SIDE)

S034 Lunar Surface Magnetometer (LSM)

S035 Charged Particle Lunar Environment Experiment (CPLEE)

S038 Solar Wind Spectrometer (SWS)

III. MINIMUM MODIFICATION ALSEP

In this section we consider changes to ALSEP which might be made in lieu of redesign. These improvements are then mainly changes in operations which permit maximum scientific utilization of the ALSEP capability.

The ALSEP central station is sufficiently flexible that it can be wired to various mixes or arrays of experiments.* However, the first 4 arrays are being constructed in parallel and stored for later flight so that the science program for the first several landings is now virtually frozen and very little reaction to new data is permitted. This method of operation is efficient for the first few landings since these will essentially try each experiment once but subsequent arrays should be constructed sequentially to allow for the orderly buildup of scientific knowledge.

Some possible improvements to an ALSEP of this type are:

1. Delay assembly of a given ALSEP as long as feasible to provide maximum flexibility in the complement of each array. It is feasible to assemble the next ALSEP flight array after several days lunar operation of the last flight array. This requires:

   (a) maximum use of the data format patch panel to permit choice of the array complement that is dictated by the weight constraint and scientific objectives.

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*Each array then operates on a fixed program.

(b) plug-in stations for experiments stored in the LM ascent state or in other locations in the descent stage.

(c) qualifying several types of central station sun shields (the experiment tie-down pallet).

(d) reducing KSC storage and check-out time to less than six weeks before launch. Since ALSEP is buttoned up in the SLA 34 days before launch this allows only 1 week for check-out at KSC. This is feasible since KSC can monitor the ALSEP final systems test at the Bendix plant. Thus, Bendix would have about 6 weeks to wire an ALSEP and check it out.

2. Alter the lunar surface time-line to permit more choice of ALSEP deployment location and to allow more ALSEP functional operation before LM ascent. These are somewhat conflicting requirements but it is clear that ALSEP deployment should be delayed until after the initial geological survey is completed and the relation of that data to the deployment requirements of each experiment considered. Deployment at a greater distance from LM would of course allow a wider choice of location.

3. Add 25 lbs to experiment weight budget. This increase is all in the LM ascent stage. The weight would then be limited by the LM structure.

4. Add to the candidate experiment pool those experiments currently under development. Three important experiments in this category are the Tidal Gravimeter, the Micrometeoroid Detector and the Mass Spectrometer. The program should also include provision for minor alterations in the present experiments that would correct malfunctions discovered in lunar operation or improve their efficiency.

IV. NEW ALSEP

In this section we consider changes to ALSEP which might be made in a major rework of the ALSEP design while still retaining the single emplaced station single-deployment concept. For reasons similar to those discussed above the improvements would be made in the direction of achieving a highly flexible, completely modular, semi-permanent monitoring station, incorporating the latest generation experiments. Such a new ALSEP would be sized to handle about 8 experiments, and hence would

weigh about 350 lbs*, including 150 lbs of experiments, and occupy 20 to 30 cubic feet. This would require a power level of 120 watts, a data rate of 2000 bits per sec. and about 200 commands. At present this would also require LM structure improvements in the SEQ bay and additional volume allocation.

Some requirements for an ALSEP of this type are:

1. Rework the ALSEP central station so that it will have the following features:

   (a) accept any mix of plug-in experiment modules.

   (b) be reprogrammable from earth, allowing alteration of the data format in real time. This would permit real time assignment of experiment priorities in response to the quality of data being received.

   (c) have an extended life. This would require a transmit-only-important-data mode with remotely adjustable threshold levels on several experiments. In this way an old ALSEP could still provide data on, for example, free oscillations of the moon or large solar flares. ALSEP could store such data on tape for possible retrieval by command. This would obviate the need for continuous listening to permanent monitoring stations.

   (d) have a tape recorder.

   (e) have a constant per-centage-error digital data output. This requires a scheme such as digitizing the logarithm of the analogue signal so that the analogue-to-digital converter is not wasted on achieving dynamic range for the signal.

   (f) have closer thermal control. The accuracy and stability of the electronic circuits improves with closer thermal control and hence more precise measurements are possible.

   (g) be able to interface with remote experiments. It may become desirable to deploy satellite stations or make the ALSEP data transmission system available to an astronaut, hence the central station should be equiped with the appropriate RF link.

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*This weight does not include the 44 lbs of equipment in the ascent stage.

2. Add to the experiment pool. The experiments for a new ALSEP should be completely modular with a standard electrical interface (plug-in) and be able to operate at several appropriate data rates. The additional experiments listed here are those which yield specifically lunar data, as is the case for most ALSEP experiments, and are all, except for the heat flow experiment, in the 10 to 25 lb class, requiring about 3 to 7 watts operating powers and a storage volume of about 1 cubic foot. They are listed roughly in order of priority:*

(a) Mass spectrometer - measures the atomic-mass density of the neutral lunar atmosphere, which may be primordial or due to rocket exhaust or transient gaseous emission.

(b) Tidal gravimeter-measures tidal changes in the vector lunar g to 0.1% or better. Such precision is necessary because the elastic tidal effects are relatively smaller than those of the earth and is feasible because the microseismic lunar background is expected to be very low.

(c) Improved Passive Seismometer - improvements to the ALSEP seismometer might take the form of a longer period for the long period 3 axis seismometer, giving better free oscillation and surface wave data, and perhaps a satellite net of short period seismometers to improve the body wave data.

(d) Improved Active Seismometer Experiment - the purpose of this type of experiment is to study the shallow sub-surface of the moon by detonating explosive charges and measuring the velocity and frequency spectrum of the resulting seismic disturbance at the lunar surface. In ALSEP the experiment deploys 4 mortar charges of less than 1/2 kilogram to distances of less than 1500 meters, has geophone detectors at a 100 meter separation and returns data on the lunar subsurface to depths of $\sim$ 150 meters. The experiment is performed after $\sim$ 5 months of ALSEP operation and requires a data rate of 10600 bits/sec. which ALSEP can provide through the 85 foot dishes of the DSN. Improvements in this experiment would probably tend toward a generalized, flexible and modular,

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*The reader may wish to add a Laser Corner Reflector Experiment to this list. This experiment is not listed because it is totally passive and self-contained.

system of charge deployment and of detector emplacement. More sensitive detectors, deployed at perhaps 10 km separations in sub-satellite fashion, would be desirable. Larger charges and means for deploying them should be provided, with a capability of firing them while the astronaut is still on the lunar surface.

(e) Advanced Heat Flow - since the NQR thermometer can measure absolute temperatures to better than $\pm$ 0.001 K°, is self-calibrating, and yields digital data, its use in the lunar heat flow experiment would improve the quality of data returned and simplify data analysis. This is especially true if the experiment probes were deployed in a deeper hole.

(f) RF, VLF Propagation experiment - besides providing lunar communications engineering data this experiment would yield useful scientific data on the electrical parameters of the lunar surface and near subsurface.

(g) Electric Field meter - the study of electric field fluctuations at the lunar surface would help in understanding the moon-solar wind interaction.

(h) Improved Magnetometer Experiment - should the moon prove to have a strong interaction with the solar wind, its detailed study over a wide frequency range (0 to 50 Hz) by a magnetometer net (antipodal pair preferred), especially if it is also capable of active sounding by use of an appropriate exciter, could yield the radial and azimuthal distribution of electric and magnetic parameters in the lunar interior.

3. Consider adding some platform experiments. From what we have said previously it seems clear that the total number of experiments one would like to perform in a lunar emplaced station, to gather <u>lunar</u> data, is not large. Hence the size of the new ALSEP need not be much larger than the present one. Therefore it may prove desirable and possible to take advantage of the moon as a stable, seismically quiet platform devoid of atmosphere to do solar and astronomical studies*. These experiments do not yield specifically lunar data but nevertheless are of high scientific interest and a new ALSEP program could be used

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*This application is in direct competition with similar earth-orbital mode experiments which could have potentially higher data rates but would require attitude control.

to test their feasibility for inclusion in a future lunar observatory. A list of these experiments would include the following list, as well as those experiments mentioned previously which do not prove to have a useful lunar return.* Most of these experiments could be made in a 20 lb size model. However, as a rule, the telescopes improve in quality with increasing size.

(a) Telescopes - (optical, UV, IR, X-ray, γ-ray, cosmic ray) - of these the optical telescope usually requires a high data rate. This may be achieved using a large receiving antenna, for example the present ALSEP could transmit 50,000 bits/sec. to a 210 foot dish, which would probably be an adequate rate even for an optical telescope.

(b) Solar constant experiment-high precision long-term monitoring of the solar electro-magnetic energy output, especially in the optical and UV regions, is of special interest since no other star is known to have an output as constant as that of our sun.

(c) Meteoroid flux detectors

(d) Solar charged particle spectrometer.

4. Optimum deployment of each experiment - Since these experiments are intended for a permanent station much more time and effort would be devoted to deployment and deployment would be delayed until an optimum compromise location is found.** It would then be desirable to provide the astronaut with a simple transporter, an LSSM or pull-cart, and the experiment cable arrangement should permit wide or adjustable separation of experiments. Such a deployment would probably take about 4 hours and be performed after the site is located. A longer time would be required if deep holes are drilled.

5. Maintain minimum time between array formation and flight. This is still necessary to take advantage of the landing site characteristics and it may even be desirable for the astronaut to choose the array while on the moon.

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*For example if the moon-solar wind interaction is not large the solar wind experiments will still provide useful monitoring of the solar wind but as a solar rather than lunar phenomenon.

**The deployment requirements for each experiment will probably conflict.

6. Make maximum use of the astronaut in deployment and adjustment of experiments. It is clear from the above that "automatic" deployment of the experiments would greatly complicate the array and would be difficult to accomplish satisfactorily. The astronaut should be utilized to choose gain settings and the like so that the experiments can be appropriately simplified.

V. SUMMARY

The present ALSEP program was briefly described. The description was followed by a discussion of those changes, mainly in operations, which one would make in a minimum modification program. Next a new ALSEP program was described. The salient conclusion here is that the number of experiments one would like to do with a scientific emplaced station is not large. Hence a new ALSEP would not be very much larger than the present ALSEP, the main differences being an increase in experiment weight and an increase in flexibility. This new ALSEP would also be useful as a test bed to check the feasibility of experiments for a future lunar based inter-planetary observatory.

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