SUMMARY OF ARRAY E SYSTEM STUDY

ATM-913

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1.0 INTRODUCTION

This ATM is a brief summary of the salient points of the main Array E, F, G study document (ATM-889), to which reference should be made for more detailed information and rationale. It assumes a good background knowledge of the existing ALSEP systems. (NOTE: The main study was entitled "ELLSEP System Design Tradeoffs". The term 'ELLSEP' has been replaced by "ALSEP Arrays E, F, and G", corresponding to Apollos 17, 18 and 19 respectively.)

2.0 STUDY GUIDELINES

2.1 The objectives of the system design study were:

a. System reliability for a two year lunar mission. (In this context the system extended only as far as the experiment interface; experiment reliabilities were not included.)

b. Experiment interchangeability such that redesign and requalification will not be required for each experiment array.

c. Incorporate improvements suggested during the development of ALSEP

2.2 Constraints which limited the design considerations were:

a. Use of SNAP-27 power source (with possible use of SNAP-33 in the later Arrays).

b. Design for any five-experiment array, with maximum flexibility of selection of the five experiments up to a given minimum period before shipment.

c. No change to the normal downlink format of 10 bits/word, 64 words/frame, 1060 bps.

d. No change to uplink modulation or format, except perhaps 70 kHz subcarrier.

e. No major modifications to primary structure or thermal plate.

f. Same passive thermal control as used for Array D.

g. Use existing component design as much as possible to achieve reliability goal.

2.3 The design assumptions which were used were:

a. Dust Detector not included in any experiment array.

b. No LGE mechanical interface, e.g., ALHT will not be stored on pallets.

c. No passive experiment mechanical interface.

d. Deployment site within longitude $\pm 60^{\circ}$, latitude $\pm 25^{\circ}$.

e. Weight constraint of 155 lbs/compartment and 266 lbs total.

f. Experiment interchange desirable at BxA at or before 45 days prior to shipment.

g. No changes to LM interface from those defined for Array D.

h. Deployment between sun angles of 7° and 25°.

i. Reliability goals based on Central Station operation, i.e., from experiment interface on.

j. Candidate experiments to be:

Existing ALSEP Experiments

Passive Seismic
Lunar Surface Magnetometer
Heat Flow

New Experiments

Lunar Ejecta and Meteorites
Lunar Mass Spectrometer
Lunar Seismic Profiling

2.4 The mechanical and electrical interface requirements for the retained ALSEP experiments were based on the current design (Array D). Requirements for new experiments were preliminary, and the interfaces are amenable to some modification since the experiments are still in the development stage.

3.0 DESIGN APPROACH FOR CENTRAL STATION

The main emphasis was upon improving reliability and flexibility, but also, to the maximum practical extent, single failure points have been eliminated from the design of the Central Station. This has been accomplished by provision of dual-path redundancy, redundant components switchable by ground command, and astronaut back-up capabilities. Measures to improve uplink security have been examined and are recommended.

The following paragraphs outline the recommended system designs.

3.1 Uplink

The uplink provides all functions associated with the reception and processing of ground commands. The recommended configuration is shown in Figure 3.1. It represents a compromise between full redundancy and minimum redundancy concepts. Redundancy is provided for all active components; cross-strapping at intermediate points in the two chains is not recommended since there would be only a small theoretical gain in reliability, at the risk of introducing potential single points of failure. Both redundant signal paths are powered and operating continuously; the 3 db loss in signal strength due to splitting between the two receivers will not be sufficient to degrade the error rate significantly. The estimated two-year reliability for the uplink is 0.9894, and the practical goal has been set at 0.980.

3.1.1 Details of Uplink Components and Rationale

3.1.1.1 Antenna - The antenna radiating element is a highly reliable, passive component essentially unaffected by service life; a single unit similar to the antenna on Array D is therefore recommended. Although there will be no modifications to the antenna proper, considerable modifications to the mounting and aiming mechanisms are proposed. The mast will no longer double as a part of the pallet-carrying system, thereby removing any possibility of damage or jamming such that the antenna cannot be deployed. The aiming mechanism will be completely redesigned in order to make the settings easier and directly related to lunar latitude and longitude, with lower gear ratios for quicker setting. This new aiming mechanism will be smaller and it will be possible to stow it preset. In the event that the mechanism jams a new back-up feature will allow the worm gears to be disengaged and less accurate, manual settings to be made.

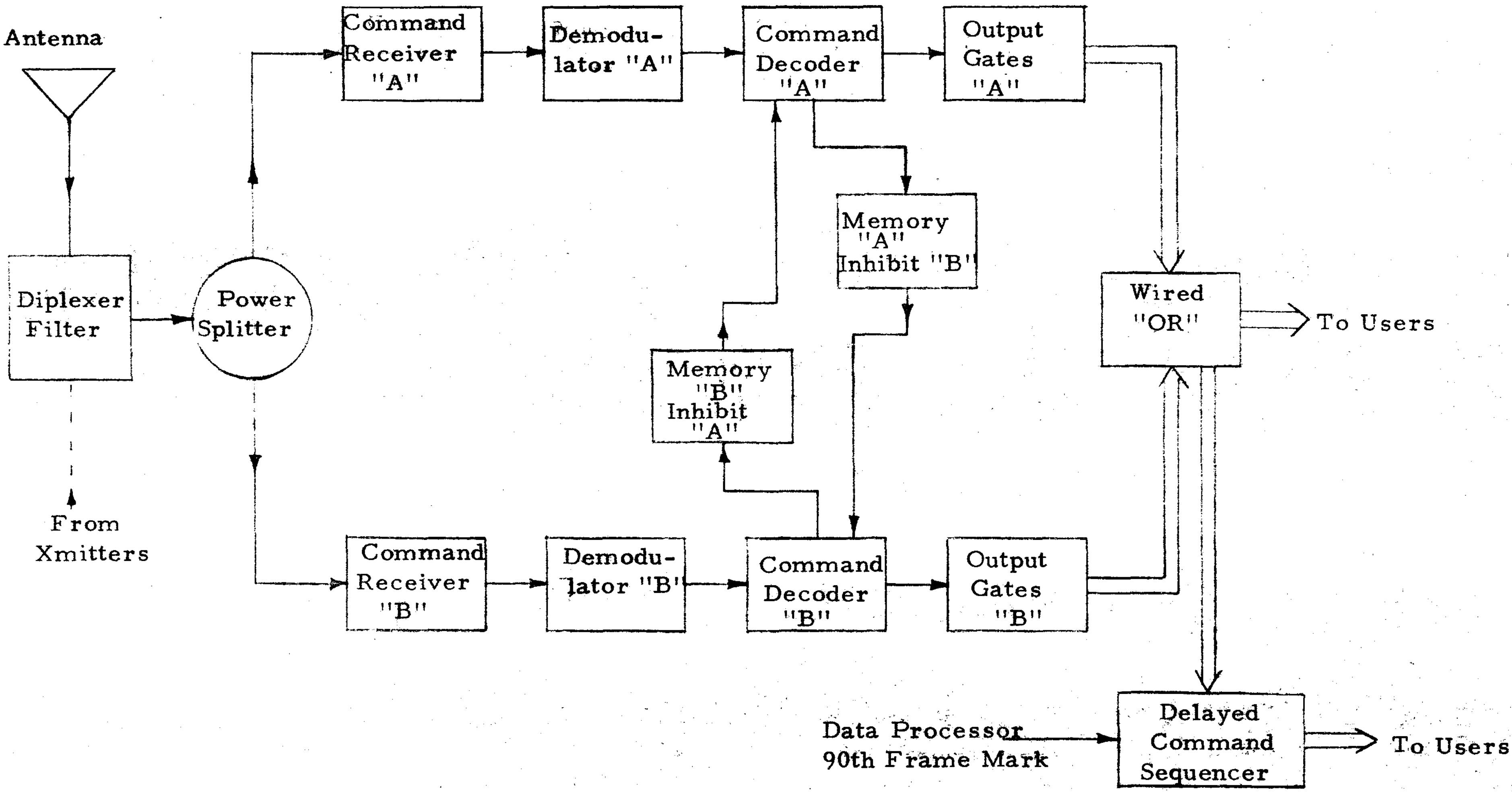


Figure 3-1. Block Diagram of Uplink Design

3.1.1.2 Diplexer Filter - The diplexer is another highly reliable, passive element; no modifications relative to Array D are proposed.

3.1.1.3 Power Splitter - This is a RF hybrid coupler, located within the dual receiver unit, which divides the input RF energy equally between the inputs to the two receivers; it is the same as in Array D. The splitter is passive and is predicted to be highly reliable.

3.1.1.4 Receivers - The receivers are to be the same as the receivers used in Array D. Although electrically distinct the two receivers are packaged as one unit with the Power Splitter. They have the ability to detect a 70 kHz subcarrier which is frequency modulating the main carrier and for the Array E, F and G systems it is recommended that this 70 kHz subcarrier option be implemented. The 1 kHz and 2 kHz bit signals will then phase-modulate the subcarrier, rather than the main carrier as they do in the earlier ALSEPs. This has three security advantages:

a. No interference with and by the earlier ALSEP's and therefore address codes may be used over again.

b. At low signal levels (< 96 dbm) the 70 kHz subcarrier system has a much better signal/noise ratio than the direct 1-2 kHz carrier modulation system. This will reduce the probability of bit errors.

c. The possibility of a beat between two carriers breaking through into the decoder and generating spurious responses is considerably reduced. Ground transmissions which are within specification can generate a 1-2 kHz beat, but not a 70 kHz beat.

3.1.1.5 Command Decoder - This consists of the Demodulator, Digital Decoder and Command Gates.

3.1.1.5.1 Demodulator - The demodulator is to be a completely new, redundant design giving a much improved performance but at the same time a lower parts count, smaller volume and higher reliability. It will be possible to package both new demodulators in the same volume as the single ALSEP demodulator.

A study of the anomalous responses from ALSEP 1, and laboratory tests on the MSFN ALSEP, showed that modifications to the demodulator should have a very marked effect upon uplink security. The existing ALSEP demodulator phase-lock loop tracks any approximately 1 kHz signal component, genuine or otherwise, with a very short time constant (< 20 msec), and the threshold detector requires only three of the 1 kHz cycles to switch over and pass spurious NRZ data to the Digital Decoder. Short periods of loss of signal are ignored because the threshold signal does not immediately drop out. Since the receiver output noise, uplink off, contains far more 1 kHz than was expected the spurious response problem is quite marked. In the new demodulator the time constant of the 1 kHz phase-lock loop will be increased to one second (with a corresponding reduction in P. P. L bandwidth), and the threshold criterion will be that eight successive data bits have been received. (The 1 kHz signal is simply a phase reference and timing signal; the bit information exists in the in-phase or 180° out-of-phase condition of the 2 kHz component relative to the 1 kHz; it is most unlikely that 1 kHz and 2 kHz noise components will be systematically phase-related.) The threshold dropout criterion will be that a single bit fails to appear.

3.1.1.6 Digital Decoder - ALSEP has two digital decoders, but it is possible for single fault conditions to lock up both channels, block a number of commands or cause simultaneous operation of two commands. There also exist design features in the individual reset circuits which give a 1-in-8 chance of generating a spurious CVW following a genuine CVW, and a 1-in-64.8 chance of not transmitting a CVW following a genuinely commanded execution. These undesirable features have been studied in detail and will not recur in the redundant new digital decoders. Circuits to which particular attention has been paid are those which inhibit one channel when the other has detected its own address, and those which should legitimately generate a reset signal. Although the redesigned digital decoders will each contain two address detection gates and two address memories, plus other redundant circuitry necessary to remove potential single points of failure or to correct anomalous operation, the use of TI 54L low power logic elements wherever possible, and repackaging, will result in smaller volume, smaller parts count, lower power and higher reliability than for the existing circuits.

3.1.1.7 Command Decode Gates - The single set of command decode gates in ALSEP provides many potential single points of partial failure, i.e., loss of groups of commands or simultaneous operation of some commands. In the new system the Command Decoder Gates will be redundant, their outputs being paralleled by wired "OR"s onto the single command lines to experiments and Central Station components.

3.1.1.8 Delayed Command Sequencer - Although it is not in the uplink chain proper the Delayed Command Sequencer is included in the Command Decoder. It generates automatic commands, some on a one-time basis, others on a continuous periodic basis. In early ALSEPs the sequencer counter was advanced by one minute and 12-hour pulses from an external electromechanical timer. Array D replaced the electromechanical timer with a Resettable Solid State Timer (RSST) driven by one-minute and 18-hour pulses from a multivibrator and divider. The RSST included a Mission Termination Device. In Arrays E, F, G there will be no mission termination device, and a newly designed sequencer will be stepped by the 90th frame mark from the Data Processor, which occurs every 54 seconds. Only one Delayed Command Sequencer is proposed since it is primarily a back-up mode.

3.2 Downlink

The recommended downlink configuration is shown in Figure 3.2. Apart from the diplexer and antenna, which are common with the uplink, and the circulator switch, the system is fully redundant and has maximum cross-strapping of redundant components. Only one of each pair of redundant components will be powered at any time that the downlink is in operation, the selection being made via the uplink. Automatic switchover in the event of a failure is unnecessary. It is assumed that highly reliable cross-strapping circuits can be made without introducing potential single points of failure, in which case the overall downlink two-year reliability is predicted as 0.9821, with the practical reliability goal set at 0.974.

3.2.1 Details of Downlink Components and Rationale

3.2.1.1 Analog Multiplexer and Analog-to-Digital Converter

These circuits will in general be electrically and physically similar to those in Array D, with two modifications. As in Array D they will be packaged as one unit.

One modification will provide the recommended cross-strapping at the MUX/ADC interfaces. The necessary circuits will be incorporated onto the existing boards. The second modification is to provide serial ADC outputs, to eliminate the present 8 bit parallel data transfer to the Digital Data Processors.

No changes will be made to the ALSEP 90-channel analog data processor which will affect the analog signal interfaces. The sample rate will continue to be one channel per frame, the accuracy being in part a function of the characteristics of the flat cable signal path between experiment and Central Station. A study of all arrays of the known candidate experiments shows that at least three analog channels will be available for additional or substitution experiments. It is recommended that three analog channels be the standard constraint to be applied to any new experiments.

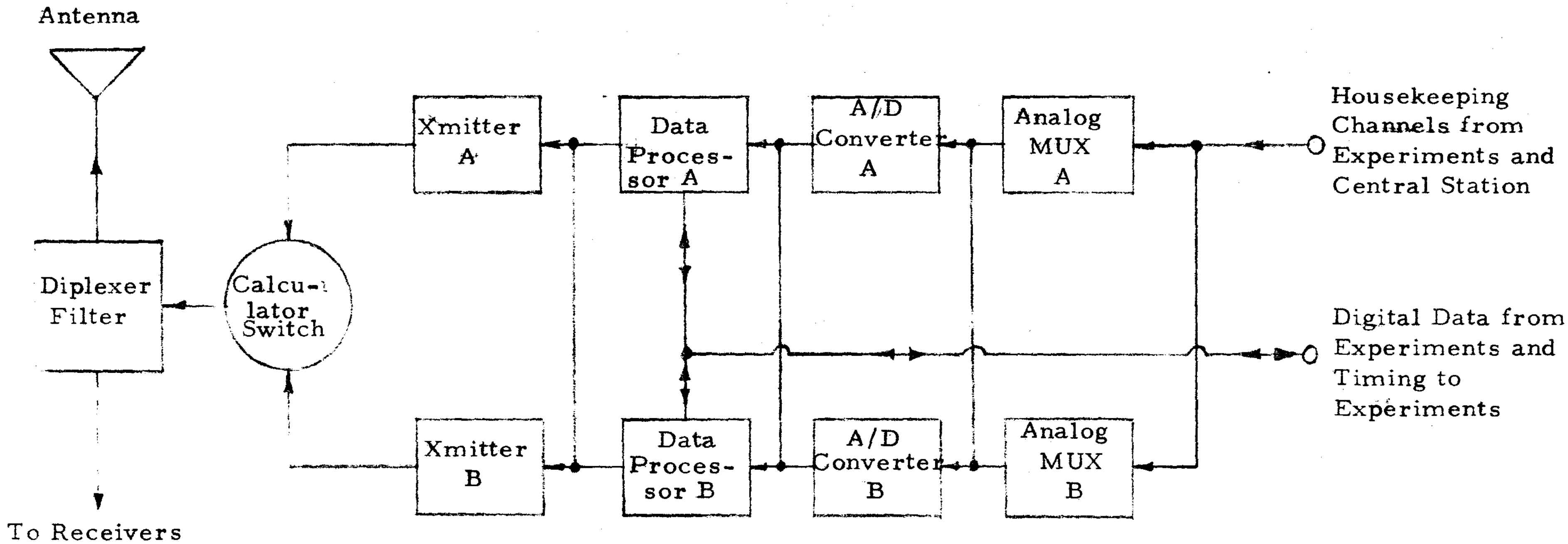


Figure 3-2. Recommended Downlink Design with Full Cross-Strapping

3.2.1.2 Digital Data Processor (DDP)

A new Digital Data Processor design is recommended, mainly to meet the required improvements in flexibility and experiment substitution, but also because there will be improvements in reliability. The new design features are:

a. Redundant Frame Counters. The purpose of the frame counter is to insert the frame count into Word 3 of the downlink T/M frame. It takes no part in the main timing and control functions of the DDP and if it failed it would still be possible, with difficulty and inconvenience, to extract complete information from the downlink. The ALSEP's up to and including Array D have only one frame counter, and the inclusion of a redundant circuit is not by itself sufficient reason to modify the DDP. However, since the DDP is to be modified for other reasons it is a fairly straightforward matter to incorporate two frame counters.

b. Reduction in the number of timing and control signals supplied to the new experiments, from six to four. Arrays E, F, G will still supply all six signals to the old ALSEP experiments as required, but Data Gate and Even Frame will not be available to the new experiments. This will simplify the presently unnecessarily complex decommutation problem. The standard signals available to any experiment will be: 90th Frame Mark, Frame Mark, Shift Pulse, Data Demand. (High Data Rate will be provided for any single experiment.)

c. Shifting of data serially into the DDP from the A- to -D Converter. This was discussed in Paragraph 3.2.1.1 above.

d. Use of 54L or 9040 series logic elements, as appropriate. This will reduce parts count, power consumption, volume and cost, and will increase reliability.

e. Increased flexibility of T/M frame word assignment by the use of a detachable patching connector. The fixed part of the connector will be external to the DDP, and by wiring the free half appropriately it will be possible to allocate any piece of scientific, housekeeping or CVW data to any telemetry frame slot. The necessary volume for the connector will be provided by the reduction in volume of the DDP circuits. Within practical limitations data will be sampled at regular intervals, but this will not be possible if complete flexibility of experiment arrays is to be maintained. In some cases it may be necessary for the experiments with less than five words per frame to buffer their data so that they may be sampled at regular intervals and then fed into the T/M frame at irregular intervals. In general, the known new experiments each require five words or less, except that for its short period of operation the LSP experiment utilizes the whole frame at a higher than normal data rage. Any as yet unspecified new experiments which require more than five words per frame may create a problem which will then have to be resolved on the basis of scientific priority.

3.2.1.3 Transmitters

The redundant transmitters will be exactly as in Arrays A2 and D.

3.2.1.4 Circulator Switch

This unit connects one or the other of the two transmitters to the Diplexer Filter and Antenna. It will be exactly as used in Arrays A2 and D.

3.2.1.5 Diplexer Filter and Antenna

These are common with the uplink and have already been discussed, in Paragraphs 3.1.1.2 and 3.1.1.1, respectively.

3.3 Power Subsystem

The main components of the Power Subsystem are the Radioisotope Thermoelectric Generator (RTG), the RTG Shorting Switch, the Power Conditioning Unit (PCU), and the Power Distribution Unit (PDU). The recommended configuration is shown in Figure 3.3. Full redundancy is provided for all the major components except the RTG primary power source and the Shorting Switch. The estimated two year reliability is 0.9818, with a practical goal of 0.980.

3.3.1 Details of Power Subsystem Components and Rationale

3.3.1.1 RTG

The RTG which will be used for Array E (Apollo 17) will be the SNAP-27 unit as used with previous ALSEP. General Electric is developing a SNAP-33 unit which will be permanently fueled and which will have a higher power output (140 vs 68 watts EOM) at a higher voltage (30 volts vs 16 volts), but this unit will not be available in time for Apollo 17. SNAP-33 has obvious advantages; the SNAP-27 fueling operation would be completely eliminated (removing several potential single points of failure), night power margins would cease to be a problem, and the higher output voltage would allow considerable simplification of the PCU. SNAP-33 will be seriously considered for later Arrays if it becomes available.

3.3.1.2 Shorting Switch

This will be a considerably modified unit. The ALSEP push-button will be replaced by a simpler, resettable knife-type switch. The easy reset capability is desirable in the event that the astronauts have to return to the LM before completing system deployment. The connectors in the RTG/Shorting Switch/Automatic Switch chain will be designed so that in the event of a Shorting Switch failure the astronaut may easily remove the shorting plug and reconnect the RTG cable directly, bypassing the failure. The ammeter needle will be painted a flamboyant orange color to improve readability.

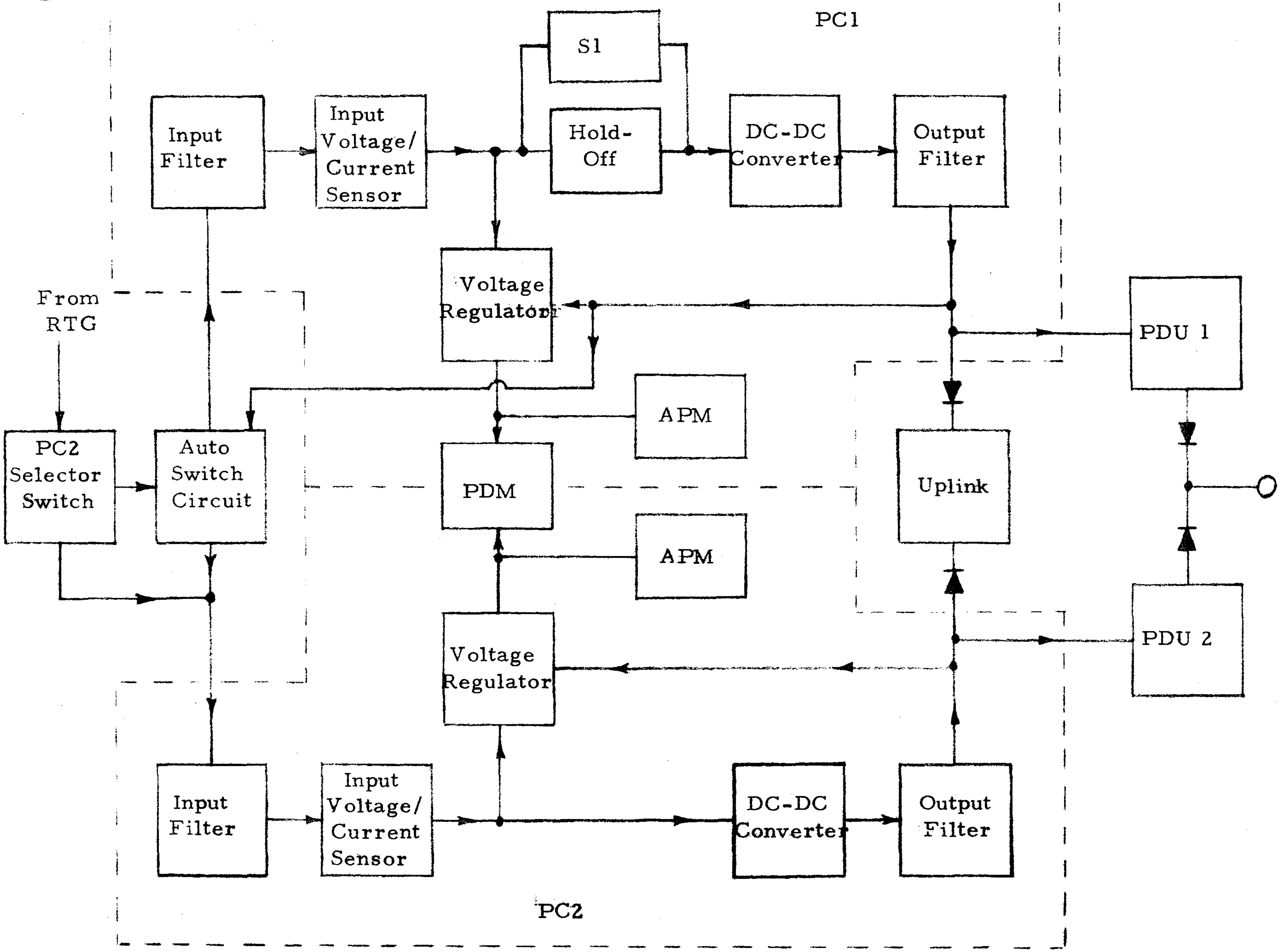


Figure 3-3. Power Subsystem with Redundant PC's and PDU's and Diode Isolation

3.3.1.3 Astronaut PC2 Selector Switch

In the current ALSEP system the failure of PC1 to operate upon deployment is a single point failure. In the starting condition only the switchover capacitor will not be charged up, the automatic change-over to PC2 will not occur, and there will be no uplink to command the change. In the new system the Astronaut PC2 Select Switch can if necessary apply the RTG power directly to PC2, bypassing the preset "PC1 Select" condition. When uplink-downlink has been confirmed the astronaut will open the PC2 Select Switch, which will reapply power to PC1 and may start PC1. If PC1 has failed, (or the changeover period exceeds 300 milliseconds), switchover to PC2 will then be automatic. The 'PCU 2 Select' astronaut switch has a second purpose in that it eliminates a potential single point of failure due to open relay contacts in the automatic or commanded switching circuit, provided of course that the fault occurs and is detected before or during the time that the astronaut is on the lunar surface. The launch, landing and deployment phases are the most likely times for the fault to occur.

3.3.1.4 Power Conditioning Unit (PCU)

The PCU will be modified and repackaged relative to the ALSEP/Array D units. Single points of failure will be eliminated, reliability will be improved and the day-night temperature swing of the thermal plate will be reduced by a new circuit, Automatic Power Management (APM). One APM will be associated with each redundant PCU and will be switched with the PCU. The APM will distribute reserve power as a function of thermal plate temperature; above 80°F power will be dumped externally; below 60°F the internal heaters will be on; between 60°F and 80°F will be a hysteresis region to reduce the number of switching cycles. The APM may be switched off by an over-riding uplink command, causing the system to revert to passive thermal control.

The modifications to remove the potential single points of failure are:

a. Redundant input and output filters, with output isolation diodes. (The diodes require a power penalty, and the PCU output voltages must be set about 0.7 volts higher.)

b. Redundant input voltage/current sensing circuits.

c. Automatic switching from PC1 to PC2 for open +5 and -12 volt lines. (In ALSEP only an open +12 volt line will cause switching.) An open +29 volt line will not cause switching since the uplink will still be available for a commanded switchover.

A modification which will improve reliability and reduce complexity is the deletion of the ALSEP +15 and -6 volt supplies.

General PCU performance will be improved by:

a. Use of single capacitors in the redundant output filters to reduce ripple.

b. Use of the RTG terminal voltage to activate the transfer relay, and the use of latching in the input switching circuit. This reduces line transients and gives more reliable switching.

c. Modification of the voltage regulators by adding roll-off circuits, increasing the gain and changing the temperature coefficient.

Complete repackaging of the PCU is necessary to provide room for all the circuit improvements without violating the existing ALSEP PCU form factor. The APM's are to be packaged with the PCU as this has significant thermal advantages.

Reserve power status will be monitored by four analog T/M channels per PC/PDU (i. e. eight channels in all) at approximately even intervals in the 54 second, 90 frame cycle.

3.3.1.5 Power Distribution Unit (PDU)

Array E, F, G will have redundant PDU which will be switched with the associated PCU, as shown in Figure 3.3. (Cross-strapping at the PCU/PDU interface would increase flexibility, but it would also introduce a potential single point of failure and is not recommended.) The PCU design will follow the general lines of the ALSEP PDU design, including ripple-off, but with the following modifications:

a. Redundant power switching and fusing to the experiments and the redundant downlink components.

b. Use of latching Teledyne relays in TO5 cans in place of the existing standby power relays - this provides the volume required for the new circuits and uses considerably less power than the possible alternative of transistor switching.

c. Fuse protection of uplink power lines and all unprotected non-essential circuits.

d. General elimination of potential single points of failure, particularly by failures of relay contacts.

e. Command over-ride of the single ripple-off sequencer by a series relay circuit. (Automatic ripple-on was considered but is not recommended.)

f. Complete repackaging so as to contain the PDU modifications within the existing ALSEP form factor, but with a 50% increase in weight.

g. The status of the redundant component power-switching relays will be multiplexed onto one or two analog channels to provide positive redundancy status information.

3.3.2 System Power Requirements

A study of the power requirements of the possible experiment arrays, assuming that the SNAP 27 is used and that PSE is always present, shows that all are feasible. However, in the two most critical cases (including Array F, Apollo 18) the predicted power reserve at night will be small and it might become necessary to switch one or more experiments into standby in order to maintain adequate thermal control. If the SNAP 33 RTG is available there will be no power problems.

3.4 Experiment Interchangeability - Central Station/Experiment Electrical Interface

In paragraph 3.2.1.2(e) it was noted that full flexibility of T/M word assignment will be available by means of a detachable connector. In Paragraph 3.2.1.2(b) the standard timing functions for the new experiments were listed; there will be sufficient fan-out for all four signals to be available to all experiments. The standard conductor allocation for experiment/Central Station interfaces is given in Table 1. Forty pins will be sufficient for all old and new candidate experiments except PSE, which is in any case always present. In the case of the remaining ALSEP experiments a modification will be necessary; irrespective of the number of lines actually required and the current plug-pin allocation, it will be necessary to fit a 40 pin plug at the C/S end of the cable. The complement of experiment connectors on the primary C/S structure will be as follows:

a. Two PSE sensor connectors (always used).

b. LSP geophone connector - mounted only if LSP selected (LSP electronics will be in Central Station).

c. LSP RF connector - mounted only if LSP selected.

d. Three standard (flat cable) 40-pin connectors.

e. One standard 40 pin astronaut mating connector, with provision for a second if required.

TABLE 1

CONDUCTOR ALLOCATION FOR STANDARD EXPERIMENT INTERFACES

Pin Number	Function
1 through 10	Command Signals 1 through 10
11	Signal Ground
12	Analog Channel 1
13	Analog Channel 2
14	Analog Channel 3
15	Signal Ground
16	90th Frame Mark
17	Frame Mark
18	Data Demand
19	Digital Data
20	Shift Clock
21	Signal Ground
22	Spare 1
23	Spare 2
24	Spare 3
25	Spare 4
26	Chassis Ground
27	Survival Power
28	Power Return
29	Survival Power
30	Power Return
31	Operating Power
32	Power Return
33	Operating Power
34	Power Return
35	Operating Power
36	Power Return
37	Operating Power
38	Power Return
39	Operating Power
40	Power Return

Flexibility of experiment interchange will be provided by rewiring the connections between the internal C/S terminal boards and the Central Station experiment connectors. This can be accomplished in about seven weeks, including verification testing, without disturbing the main harness and with the incidental advantage that unused connectors can be left unwired, thereby reducing heat leaks to a minimum.

3.5 Command Summary

The new command word allocation will be the same as for ALSEP wherever similar commands exist. ALSEP commands which have no application in Arrays E, F and G will of course be eliminated and new commands which are required irrespective of the experiment array will be allocated early in the program, (e.g., Central Station functions, and PSE). The final complete list including specific experiment commands cannot be determined until the particular experiment array has been decided.

A preliminary analysis of all the known experiment arrays has shown that there should be at least nine spare commands, even in the worst case. If a new, as yet unspecified experiment is required to be substituted for any one of the current candidates then it can use at least thirteen commands. Above thirteen it might be necessary to incorporate a separate decoder into the experiment so as to fan out combinations of the thirteen commands into many more commands. (Note that only ten lines of the standard C/S - experiment interface are specifically allocated to commands. If the four spares are also available for commands the number rises to fourteen.

3.6 Auxiliary Test Connector

In order to facilitate testing and to provide limited fault isolation it is recommended that a number of test connections be made accessible from outside the thermal barrier. The test connections which are essential are:

a. PC1 and PC2 reserve power analogs - Monitor.

b. +12 volt sense line - this is carried over from ALSEP and is necessary for correct turn-on and turn-off of the Central Station - Monitor.

c. External "PC1 Select" command. This ensures selection of PC1 on C/S power-down, so that the subsequent turn-on is performed with the correct status.

Desirable test connections, which may eventually have to have their ultimate value traded against weight, space, safety, reliability and EMI considerations, are:

a. Uplink 1-2 KHz Audio Monitor and Break-in. To allow monitoring of both receiver/demodulator interfaces, or direct injection of audio into the decoders.

b. Uplink NRZ and Clock In/Out. Monitoring, and injection of test signals via break-ins in each uplink chain.

c. Downlink Split-Phase Modulation and Clock - Monitoring, and direct injection to transmitters via break-ins in each of the redundant channels.

d. Delayed Command Sequencer - Monitoring of the critical functions.

e. PC1 and PC2 Output Voltage - Monitor.

The lines for the essential function test points must be brought out through the thermal barrier and terminated in connections which will be accessible at all times, including thermal/vacuum testing. Up to six spare pins are available on an existing power connector, J22. Unrepresentative heat loss into the test cable will be compensated by a suitable guard heater.

The desirable fault-isolation test points could be provided by a connector mounted to a recess in the thermal plate, under the masked area of the radiator where it would have the least effect upon thermal balance. Normally the connector would be terminated by a mating half with appropriate shorting links, etc., and the recess would be covered by a plate.

All test lines will be permanently wired into the harness, and isolation protection of all lines will be provided.

3.7 Structural Design

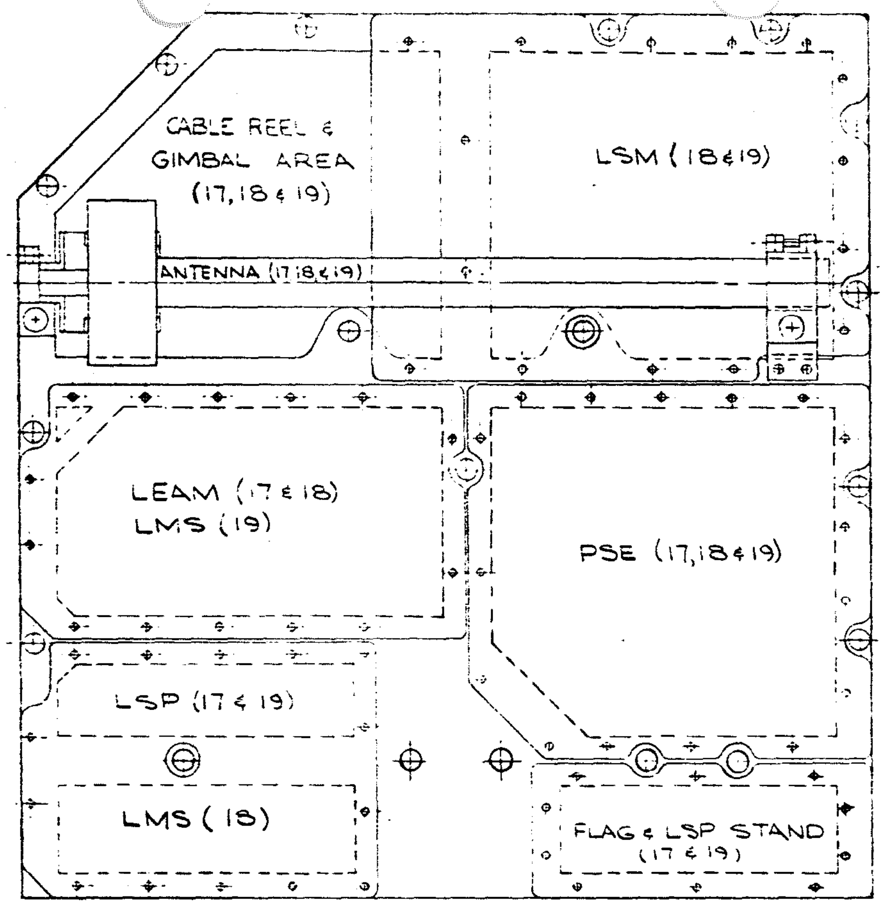
3.7.1 Subpackage 2

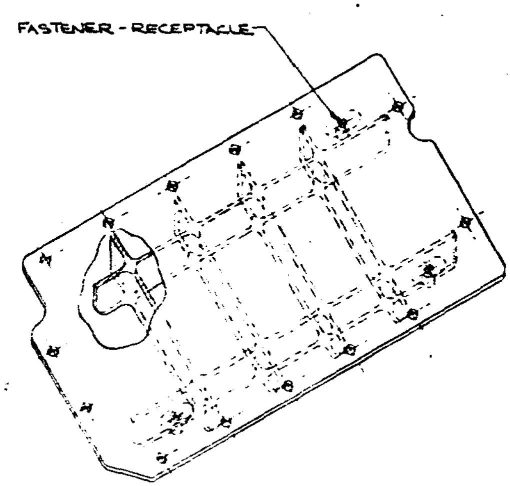
This subpackage carries the RTG, ALSD carrier (if HFE is in the array), astronaut tools and normally one experiment, with space available if required for the antenna mast, gimbal and mount, or carry bar. The experiment will normally be the HFE, but in one array the LMS is substituted. Dependent upon array configuration up to two experiments may be accommodated. In general, the Subpackage 2 design is very similar to that of Array D but the RTG and experiment(s) will be mounted upon standard subpallets. If SNAP-33 is used for the later Arrays the RTG position will be clear for further experiments, but with the disadvantage that the astronaut must make all connections to the Central Station.

3.7.2 Subpackage 1

The primary structure (containing the C/S electronics) will be similar to that of Array D, but a new sunshield design is recommended in order to obtain the required experiment flexibility. The new design is an I-beam and channel-section framework which will be identical in all flight models and all experiment arrays (see Figure 3.4). In order to mount four experiments it will be necessary to extend the sunshield 3-1/2 inches beyond the edge of the primary structure, with consequent passive thermal control effects (see Paragraph 3.8). The framework will have a bottom skin, but the top will be open to accept the experiment subpallets. A given subpallet will always be located in the same position but will have various bolt-hole patterns for accepting different experiment mounting brackets. This means that in qualifying the structure at the system level only the worst case array needs to be tested.

The upper flanges of the framework members will contain floating fastener receptacles for retaining the experiment subpallets; the subpallets will be stiffened on the underside by members fitting into the 1.5 inch framework cavities, leaving a flush upper surface. In the case of the PSE the framework cavity and a special pallet design will allow the PSE stool to be mounted integrally with the experiment. By incorporating damping gaskets between the subpallets and the framework, and adjusting the torque of the locking screws, it will be possible to 'tune' the dynamic environment of the experiments.





TYPICAL SUB PALLET CONSTRUCTION

Figure 3-4

Subpackage 1 Sunshield

The sunshield-to-primary structure fastener pattern will be the same as in ALSEP, but a worst-case structural analysis has shown that the loads in five, perhaps six, of the fasteners are so small as to justify their removal, thereby reducing astronaut workload and the number of potential single points of failure. Guide cups are no longer necessary since the fastener counterbores within the new framework will serve the same purpose.

The recommendation with regard to fasteners is to continue the use of Boydbolts. With the experience gained in the course of the ALSEP program deployment failures have been virtually eliminated. Minor modifications to the installation technique, and a new installation tool, should make the Boydbolt very close to the ideal fastener mechanically. However, there is still the disadvantage of the astronaut workload in releasing each fastener individually. The use of automatic, gas-released fasteners for the experiment subpallets on Subpackage 1 has been considered as an alternative. The automatic system is promising but requires detailed engineering improvements. It is recommended that a parallel, engineering level study be made, with a view to the possible introduction of the automatic system at a later date in the program. The basic Array E, F, G design would allow the change to be made with no significant problems.

An automatic gas-release system would not be recommended for two sunshield-to-primary structure fasteners, nor for Subpackage 2.

The mountings of the Central Station experiment connectors and the Power Dump Module (PDM) upon the primary structure of Subpackage 1 will be modified to allow easier disassembly, without wiring disconnections. A protective case for the PDM will be added.

3.7.3 Weight and Volumes of Candidate Experiment Arrays

All candidate arrays of known experiments can be mounted within the specified weight and volume limitations. Four experiments will be mounted upon the Subpackage 1 sunshield and one upon Subpackage 2. HFE, if carried, will always be upon SP-2 as it cannot fit on SP-1 complete with ALSD. The PSE, and if carried the LSM, will always be on SP-1. If HFE is not carried in a five experiment array then the LMS will be carried on SP-2. New experiments may be substituted without constraint if their size and weight are no greater than those of the smallest experiment. Larger experiments are limited to the size of the HFE or LSM, and could only be carried if either HFE or LSM was not carried.

3.7.4 Astronaut Traverse Carry Method

The traverse carry system has been considerably modified, with the following advantages:

a. Antenna mast no longer has dual use as carry bar.

b. Greater reliability of carry system from simplified design.

c. Less complex and fewer astronaut tasks in setting up carry system.

d. Less fatiguing hand grip design.

3.8 Thermal Design of Central Station

3.8.1 The passive thermal control system will broadly follow previous ALSEP design, but with modifications necessitated by the five experiment flexibility, wider day-night power variations and the 3.5 inch sunshield extension. Even though Automatic Power Management is proposed, the passive thermal control design must keep internal temperatures within acceptable wide limits in the event of APM failure.

For deployment at sites within lunar latitude limits of $\pm 5^{o}$ the passive configuration will be an 'open' design, similar to that of the mainstream ALSEPs, with sunshield, specular reflector, two side curtains and two open sides facing North and South. The insulation masks on the thermal radiator will be set to optimize the day-night temperature swing. The average thermal plate temperature of this open design will increase with an increase of latitude.

For deployment between 5^{o} and 25^{o} latitude the passive configuration will be similar to the 'closed' ALSEP Flight 4 design, with sunshield, specular reflector, three side curtains and one open side facing away from the lunar equator, towards the nearest pole. The 3.5 inch sunshield extension will be towards the equator for best thermal performance, which necessitates a 180^{o} rotation of the Central Station from the current ALSEP deployment position. This means that the third side curtain is in fact on the front, opposite to its position on the Flight 4 ALSEP. The temperature swing of the closed design decreases markedly with increase of latitude.

3.8.2 Predicted Central Station Day-Night Temperature Swing

Unlike Array D, in which an almost constant dissipation of 40 watts applies, the Array E, F, G Central Station will have to cope with power dissipations from 32 watts minimum (night, no APM) to 47 watts maximum (noon, no APM). The worst-case Central Station noon mean temperature is 141°F (proposed Array F, Apollo 18, BOM) and the worst-case night mean temperature is -11°F (Apollo 18, EOM), both temperature extremes being outside the target limits of 0° to 135°F. In this particular case APM cannot affect the lower limit by more than 1°F because at night, with SNAP 27, reserve power will be available, but at the upper end it can reduce the temperature to 127°F. In the cases of Arrays E and G the use of APM can make a really significant difference and can maintain mean C/S temperatures inside the desired limits at all times (Array E extremes 26°F-112°F, Array G extremes 1°F-113°F).

3.8.3 Predicted Power Dump Module (PDM) Temperatures

The wider system power variations and the use of APM are reflected in the predicted wider temperature swing of the PDM, from -225°F at night to +325°F at lunar noon. This will necessitate a re-examination of the PDM design from the reliability standpoint.

4.0 RELIABILITY DEMONSTRATION

It is not possible, on both schedule and cost grounds, to provide a statistically satisfactory practical demonstration of the predicted two-year reliability of the new design. A test program with complete 1-to-1 similarity would require 68 two-year tests, under simulated lunar conditions, to provide the required level of confidence. Even using one system under accelerated test conditions (equivalent to one 136-year test) would require more than one year of real-time continuous operation, and the validity of the results might be questionable. The best that can be done for Apollo 17, Array E, is a thorough reliability analysis based upon the best available data.

5.0 GROUND SUPPORT EQUIPMENT

5.1 System Test Set (STS) Modification

5.1.1 The DPS 2000 programmer-processor will be retained in the STS but approximately 48 man-months worth of software changes will be necessary.

5.1.2 Uplink Modifications

The complement of commands and addresses for Arrays E, F and G will be the same as for ALSEP, but the command codes must be capable of being reassigned to functions which differ from those in ALSEP and which may also differ between the new arrays. The proposal is to remove the one-button-per-function arrangement of the existing STS and instead to provide a three column (0-7, 0-7, and 0-1) keyboard, for command selection by command octal code number. This is compatible with all old and new systems and is in fact considerably simpler in terms of circuitry than the existing STS system.

The introduction of the 70 kHz subcarrier requires that the corresponding modulator and demodulator are available in the STS.

The STS command bit streams must reflect the proposed one second lock-on period of the new Demodulator Phase Lock Loop.

5.1.3 Downlink Modifications

The main carrier frequency must be changed, but this is a standard modification.

The high data rate for the active LSP experiment will be 3,533 bps, intermediate between the normal data rate of 1060 bps and the 10,600 bps data rate for ASE and the passive LSP. The slow 530 bps rate is retained. The STS will be able to work at any of the four rates as required.

5.1.4 Experiment Interface Test and Simulation

The new experiments impose new requirements on the STS.

5.1.5 Test Connector Interface

The permanent test connections outlined in Paragraph 3.6 require a suitable interface with the STS.

5.1.6 Replacement of Worn-Out STS Components

Some deteriorated items in the existing STS which will still be required in the modified system are capable of being, or have been, refurbished back to an acceptable standard. Others must be replaced - in particular, all items in the recorder unit, i.e., High Speed Printer, Magnetic Tape Recorder and Time Code Generator/Auto Search Unit.