APOLLO 14 ALSEP UPLINK ANOMALY

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SUMMARY AND CONCLUSIONS

The Apollo 14 ALSEP system stopped downlink telemetry on March 1, 1975. Efforts to regain a signal by command switchover to an alternate transmitter or data processor failed. The downlink signal resumed 4 days later on 5 March. The only status change in the system was a switch to the redundant Power Conditioning Unit (PCU), however, command control could not be achieved. A review of telemetry data, before and after the anomaly, was made and several hypotheses developed relative to the cause of the anomaly. No single hypothesis was developed which explained the thermal transients, the lack of command receiver telemetry and the PCU switchover. The anomaly was simulated using the ALSEP test facility and the former Qual Model ALSEP central station. Several different conditions were simulated which involved severe loading of the +12 volt and +29 volt power lines, in the central station, and also a malfunction of the PCU to switch to the redundant unit.

During tests, many of the conditions noted after re-acquisition of signal (AOS) on the 5th were duplicated, but a single fault condition was not developed which duplicated all conditions.

The conclusions of the testing and investigation are:

1) The command receiver was probably the initial failure providing a severe load on the +12 volt line.

2) The circuit breaker for the command receiver either failed to operate, or delayed sufficiently to cause a PCU switchover.

3) A load, whose characteristics could not be defined during simulation testing, was large enough to absorb the reserve power available and then pull down the 12 volt line, stopping the transmitter downlink signal, before it cleared itself 4 days later; or the PCU failed to operate correctly during switchover, applying offset potentials to the central station components, which inturn stopped the transmitter, and then corrected itself 4 days later.

4) Although the anomaly could not be pinpointed, sufficient information was gained to have confidence in the conclusion that the receiver has been disabled. The command link therefore cannot be recovered.

5) There are no procedures which should be implemented to avoid this type of anomaly on other ALSEP system, however the practice of switching on experiments, which have failed and have then been subjected to lunar night conditions, should be prohibited. Such activity could result in a severe overload on the +29 volt line, and should the circuit breaker protecting this line fail, the station could receive an over load which would stop the downlink transmitter. Also, all automatic control systems, such as automatic heat control circuits, should be maintained in the operate state, otherwise, should loss of uplink occur, these functions would be lost.

6) Data from the Passive Seismic Experiment was not directly affected by the uplink anomaly. With the loss of uplink command capability, however, the PSE heater, which was in the "forced off" mode for lunar day operations prior to loss of telemetry signal, cannot be commanded on and the sensor cannot be leveled. Science data from the PSE can be used for a period of approximately 9 days per lunation when the long period Y-axis moves from offscale high to offscale low. This is sufficiently reliable to maintain the seismic network integrity and operation is satisfactory for PI needs.

INTRODUCTION

The Apollo 14 ALSEP downlink signal stopped on 1 March 1975. Efforts to regain a signal, by uplinking commands to switch to the redundant processor or transmitter, failed. On 5 March, the downlink signal resumed and telemetry indicated the only component status which had changed was a switch to the redundant power conditioning unit (PCU). Uplink command control could not be established. Telemetry indicated all command receiver parameters were off scale low implying that no power is being supplied to the receiver. The basis for this assumption is the knowledge that the receiver internal temperature monitor is among the receiver telemetry parameters and would not be expected to fail even though other receiver functions had. An analysis was made of all data just prior to loss of signal (LOS), and of the first several minutes of data subsequent to re-acquisition of signal (AOS) at 3:07 hours on 5 March. The data indicated the following:

1.. The PCU had switched to the redundant side, probably at the moment of failure because the temperature of the PCU regulator transistors indicated no transient cool down of the Side 1 regulator at AOS.

2. All receiver telemetry parameters read all zeros subsequent to AOS, indicating an open receiver circuit breaker or a no power condition exists. Data prior to the anomaly indicated no evidence of the pending anomaly relative to the receiver or relative to any other TM parameter from the central station.

3. The Power Distribution Unit (PDU) internal temperature was 15°F greater than normal and was cooling at 1°F/minute at AOS.

4. The PCU Side 2 regulator temperature was 10°F higher than stabilized conditions at AOS and was cooling at approximately 2°F/minute and the Side 1 regulator temperature was 8°F high and ooling at approximately 1°F/minute.

5. The power dump panel temperature was stable at AOS shifting from 227.3°F to 230.0°F, a one bit data change, indicating power regulation had not shifted significantly during the anomaly.

6. Transmitter temperature was warming up, associated with a corresponding thermal plate temperature rise, in the vicinity of the transmitter, indicating the transmitter had been operating in an under power condition causing the downlink signal to stop.

7. Reserve power before and after the anomaly was approximately the same at 39.3 to 40.9 watts indicating all systems were drawing normal power. The receiver load would switch to a dummy load if the receiver circuit breaker had operated and if not, the receiver load is relatively small and would not cause a significant change of this parameter.

8. The Passive Seismic Experiment had not been rippled to a standby condition to relieve load, as would be anticipated by an under power condition.

9. During the initial period subsequent to AOS, the RTG hot frame temperatures were warming up from 4° to 11°F, while sun angle was decreasing, 138.3° to 159.4° indicating an increase in PCU input current had occurred during the anomaly.

Several possible anomalies were suggested by the above information including; 1) loading of the +29V line by a malfunction of one of the experiments or an internally C/S load, 2) loading of the +12V line by the receiver, or by some other internal C/S load and 3) PCU failure to switch over properly subsequent to receiver failure.

None of the possibilities fit all the facts or appears completely reasonable.

In the first case, a failure on the +29V line does not explain the loss of receiver telemetry unless, it is hypotesized that a multiple failure occurred, and this is unlikely. In the second case, the +12V line, which powers the receiver, is protected by a circuit breaker and this device would have to fail if the receiver were the souce of loading. The third case involves a failure of the PCU switch over relay circuit where, one contact of the double pole relay makes but the other does not, causing the RTG input power ground return to be open. This possible condition, noted during early design tests in 1967, was corrected by a circuit design change and has not occurred in hundred of hours of testing since that time. The failure results in abnormal output voltages from the PCU such as a 3 volt offset of all voltages about ground. The anomaly is sometimes self clearing but sometimes requires disassembly of the PCU to clear manually.

TELEMETRY ANALYSIS

A review of the D log, a digital data dump of all telemetry data from ALSEP 14 prior to computer processing, was made of the first several minutes prior and subsequent to LOS and AOS. The data prior to LOS was stable, showed no evidence of the pending anomaly and, gave no indication of an instable condition in the command receiver. Subsequent to AOS, a review was made to determine if additional transient data existed. Of particular interest were the PCU temperature monitors which have a time constant on the regulator transistors of just a few minutes.

A summary of internal temperature conditions are given in Table 1 and the location of the central station thermistors is shown in Figure 1. For comparison purposes corresponding temperatures, at approximately the same sun angle (SA) for the previous year, are given. Data shown in parentheses are for the date, sun angle, and time noted below each data set, in parentheses. Of particular interest are various temperature differences as shown in Table 2. The thermal plate temperature differences show, for instance, that the difference between AT03 and AT04 is 1.4°F higher on 3/5/75 where as one would expect a lower difference as seen on 3/1/75 and 3/14/75.

This 1.4°F difference is real and is caused by the transmitter running cooler, having been under powered; it can be verified by noting the decrease in the AT03-4 difference on 3/6/75 to 11.3°F, when the transmitter had operated for over 24 hours at full power and AT04 had increased 1.7°F. The AT03-6 difference is also caused by the transmitter operating under power where as the AT03-7 difference is 10.5° higher than will be anticipated. This large difference is caused by AT07, located next the command receiver, operating cool and implying the receiver is switched off, or is not dissipating much power.

XMTR UNDER
RCVR OFF

The other transient temperatures of interest are:

a) The internal PDU temperature which was 15° higher than normal and cooled 15° within 26 hours.

PDU HIGH & DECREASING

TABLE 1

ALSEP 14 TEMPERATURE °F

Thermal Plate Temp. (LOW AND INCREASING)

	3/1/75 SA=109.4° LOS	3/10/74 SA=107.7	3/5/75 SA=158.3 AOS	3/14/74 SA=156.1	Location
AT 03	121.7	119.0	70.0 (70.0)	77.5	PCU-PDU
AT 04	110.1	108.0	57.0 (58.7)	68.3	ADC-DP-PSE
AT 05	114.2	112.1	59.6 (62.2)	72.0	ADC-PSE
AT 06	109.4	107.3	53.5 (57.9)	68.3	ASE-TX
AT 07	116.2	113.5	64.0 (65.7)	73.4	REC-DiPx

(3/6/75, SA=159.4; 26 Hr. Later)

Res. Pwr	39.1	42.6	39.3 3 AMPS	43.7 3.4 AMPS

PDU Temp.

(LOW & INCREASING)

AT34 Base	120.4	117.6	69.1 (69.1)	76.8	PC BD #2
AT35 Int.	145.8	142.9	110.1 (94.7)	102.5	(HIGH & DECREASING) THEN FOLLOWING TREND

(3/6/75, SA 159.4; 26 Hr. Later)

Receiver

See AT 07 Above

Command Decoder (LOW & INCREASING)

AT31 Base	109.4	107.3	56.1 (58.7)	68.3
AT32 Int.	111.4	109.4	57.0 (59.6)	70.7
AT33 Vco	126.0	123.8	72.0 (73.4)	82.9

(3/6/75, SA 159.4; 26 Hr. Later)

Analog Multiplexer (LOW & INCREASING)

AT27 Base	112.8	110.7	59.6	70.7
AT28 Int.	128.2	125.2	74.1	85.0

TABLE 1 (continued)

Digital Processor

AT29 Base	110.1	108.8	57.0	69.1
AT30 Int.	119.7	117.6	64.0	76.1

Transmitter A

AT25 Xtal	117.9	115.5	61.9	76.2
AT24 HT/S	117.3	114.8	63.2	76.8

PCU (AT 39 & 38 HIGH & DECREASING / 36 & 37 LOW & INCREASING)

AT36 Osc.	136.2	133.3	76.8 (76.8)	90.2	
AT38 Reg.	170.7	160.8	86.3 (82.9)	117.6	PCU #1
AT37 Osc.	127.4	124.5	79.5 (80.2)	82.2	
AT39 Reg.	130.4	126.0	140.7 (137.0)	84.3	

(3/5/75, SA 158.3°; 3 min. Later)

RTG (HOT FRAMES LOW & INCREASING)

AR04 CF#1	497	497	494 (493)	497
AR05 CF#2	464	466	448 (448)	451
AR02 HF#2	1138	1147	1125 (1127)	1142
AR03 HF#3	1121	1131	1106 (1114)	1121
AR06 CF#3	459	461	440 (439)	443

(3/5/75; SA 158.3; 3 Min. Later)

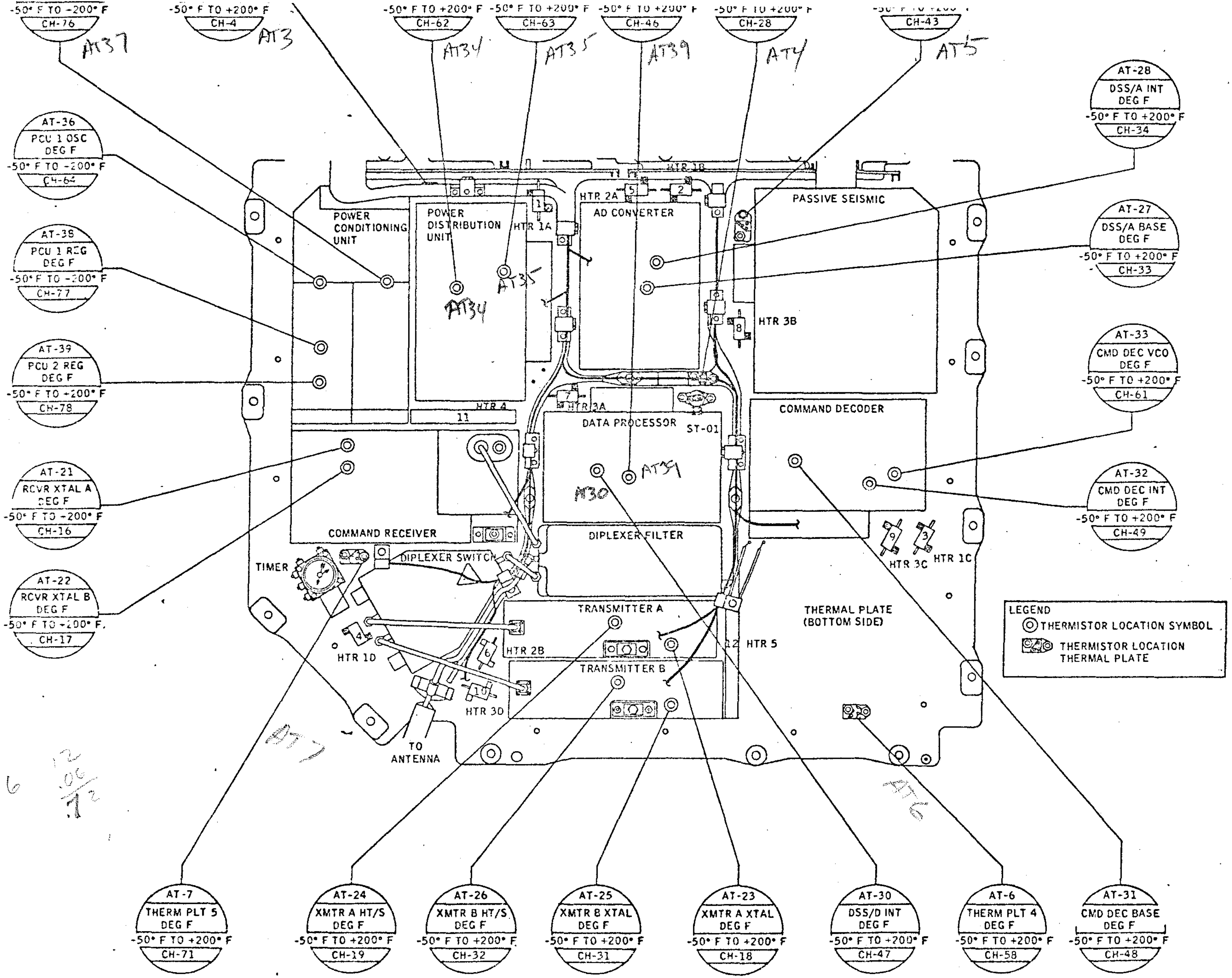


Figure 1 - ALSEP Central Station Thermal Plate Thermistor Locations

TABLE 2

ALSEP 14 Temperature Deltas on 3/5/75

Thermal Plate Temp.

	3/1/75	3/10/74	3/5/75	3/14/74
AT03-4	11.6	11.0	13.0	9.2
AT03-5	7.5	6.9	10.4	5.5
AT03-6	12.3	12.3	16.5	9.2
AT03-7	5.5	5.5	~~16.0~~ 6.0	4.1

1) On 3/5/75 AT03-4 $\simeq$ + 1.4°F

2) AT03-6 $\simeq$ 4.2°F higher; i.e. Transmitter Cooler

3) AT03-7 $\simeq$ 10.5° higher; i.e., Receiver Cooler

PDU Temp.

AT34-35	25.4	25.3	41.0	25.7

1) On 3/5/75 PDU Int. Temp. $\simeq$ 15° Higher
On 3/6/75 Delta = 25.6°

Command Decoder

AT31-32	2.0	2.1	.9	2.4
AT31-33	16.6	16.5	15.9	14.6

Analog Multiplexer

AT27.28	15.9	14.5	14.5	14.3

Digital Processor

AT29-30	9.6	9.6	7.0	7.0

Transmitter A

AT25-24	0.6	0.7	1.3	.6

1) XTAL $\simeq$ 1.3° cooler than HT/S, normally .6° hotter
Delta = 2.0°

b) The PCU regulator temperatures which cooled down several degrees at AOS.

c) The RTG hot frame temperature which warmed up slightly.

The internal PDU temperature rise was investigated to determine what conditions could cause the rise. The temperature sensor is located on Board 2 of the PDU. A simplified thermal analysis was made to determine what level heat souce would be required to cause a 15° rise; a 300 millivolt load on Board 2 could cause this rise otherwise a load of several watts would be required if located elsewhere. A review of circuitry by board was made to determine potential cause or failure. Most possibilities are eliminated since a majority of the circuitry is known to be operating correctly from downlink telemetry. The more likely causes are given in Table 3. Board 2 electronics include the experiment 2 power control circuitry and the RTG operational amplifier circuits. Operational amplifier #8 is located next to the temperature sensor and could have caused the heat rise. This amplifier is associated with the RTG hot frame #1 temperature and telemetry has read off scale low for this parameter for months previous to the LOS. A failure of this circuit would only require a 300 milliwatt dissipation to raise the temperature sensor 15° but this loss of power is insignificant compared to the 40 watt central stations reserve which would have to be dissipated before the transmitter would become underpowered. Also the RTG amplifier circuits are power limited and could not draw this type of load or effect the operation of the command receiver.

Other possibilities on Boards 1 and 4 involve maximum loads in the order of 9.3 watts. The SIDE power control circuit is on Board 3 and is a possible heat source, however, a spurious command would have been required to turn this experiment on, the circuit breaker would have had to fail and some mechanism would be required to effect the receiver status. These factors make this possibility unlikely, but tests were run on the +29V line and also on the experiment circuit breaker to provide additional data to eliminate this possibility.

The receiver circuit breaker is located on Board 5, furthest from the temperature sensor, and is a possible heat source. The heat would be dissipated in the breaker if it failed to operate, or if a mechanical short developed between the circuit breaker sense coil and the switched receiver input power connection, pin 1 on circuit breaker CB6. The mechanical short would not require a dual failure of both the receiver and circuit breaker to occur and the load would not be relieved by operation of the circuit breakers CB1 and 6 as shown in Figure 2.

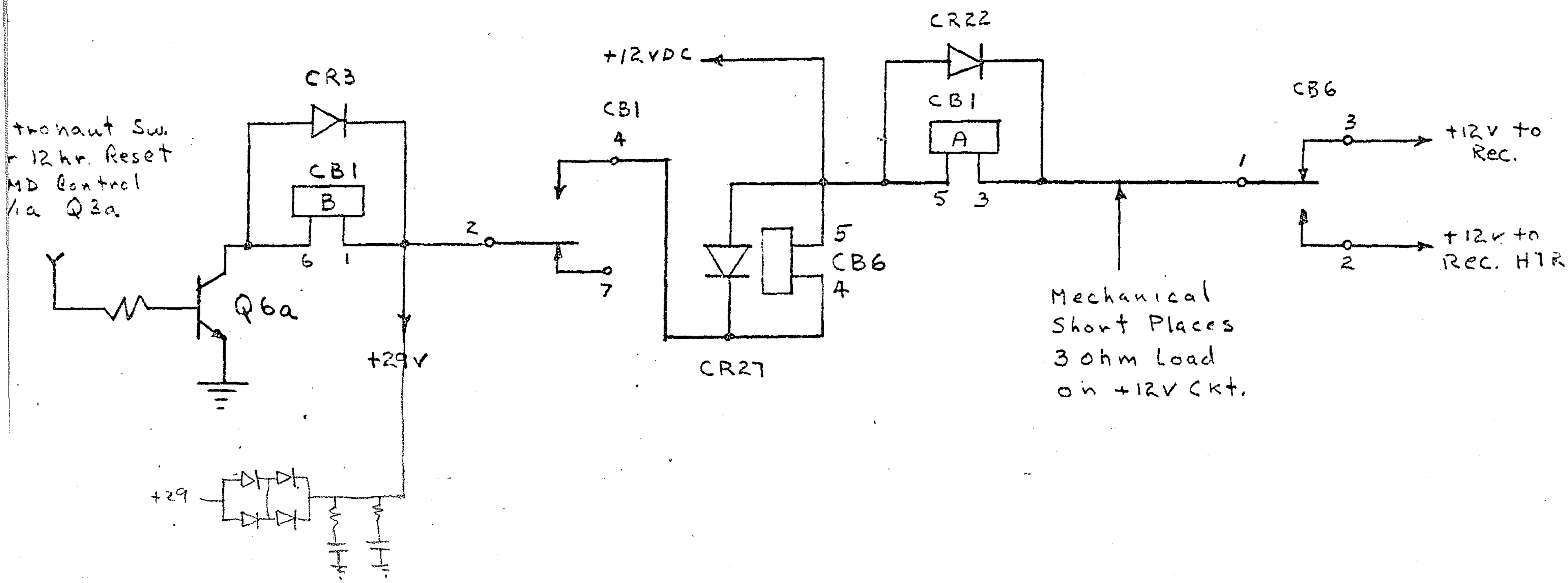
TABLE 3

POTENTIAL PDU HEAT SOURCES

1)	Board #2	-	RTG HF #1 OP. AMP #8, Possible; Only 300 m Watt Load However
2)	Board #1	-	29V Hold Off CKT C10 or C11, 100 uf and 70 uf Capacitor Possible; Possible 9.3 Watt Load to Resistor on BD #4.
3)	Board #3	-	Exp. #3 Pwr Control CKT (Side with STBY Fuse Blown) Possible; Would Require Spurious CMD and Failure of Breaker.
4)	Board #4	-	Resistors R27 or R29 Possible 9.3 Watt Load if C10 or C11 Fail on BD. #1.
5)	Board #5	-	Receiver CB Location; Greater than 25 Watt Load Possible if Mechanical Failure (Short to GND) Occurred.
6)	NA	-	Improper Voltages to PDU Circuits.

FIGURE 2

ALSEP 14 Receiver Power Control Circuit



Such an event would switch off the receiver and power dissipation in the breaker itself would not be relieved until the short was eliminated, perhaps by the circuit breaker coil itself burning out. It is assumed diode CR22 would burn out and the circuit breaker is small (TO5 transistor case) and would dissipate approximately 25 watts with the 12V line pulled down to approximately 8.5 volts. The relay would therefore become extremely hot.

The remaining possibility in the PDU, is the application of improper voltages to the PDU circuits. This event could occur if the PCU relay failed to switch correctly opening the ground return. Engineering tests in 1967 indicated all potentials shifts negative approximately 3 volts when this anomaly occurs i.e. the ± 12 volt line would shift to +9 volts and -15 volts. Increased dissipation of 300 milliwatts could easily be developed, in the RTG operatinnal amplifier circuits, if such potentials were applied to Board #2, the thermistor circuit board.

To summarize, there are three potential heat sources in the PDU which could be associated with the anomaly, a) the receiver circuit breaker itself being operated continuously, b) the SIDE circuit breaker operated continuously and c) the RTG operational amplifiers dissipating an additional 300 milliwatts of power due to improper supply voltages.

The last two transient conditions noted in the telemetry data, which have not been discussed, involve the PCU and the RTG. The PCU regulator transistor temperatures did not appear to shift significantly due to changing load. The external dump panel temperature AT11, on which the PCU regulator load is mounted, was also stable at 237.3°F indicating no significant shift in load occurred at AOS. This data is surprising since a significant load, the transmitter, was known to be under powered during LOS and thermal data, indicating transmitter warm up, supports this assumption. A careful review of the D log was made to see if early data at AOS were available because both the PCU regulator and dump panel temperatures have response times in the order of several minutes. The D long indicated main frame lock up occurred about one half of the housekeeping telemetry cycle prior to the playback data available, at Gmt 03/08/27, at Houston. During this period AT11 shifted one bit and the PCU regulator temperature was 140.7°F, as read out at Houston.

The regulator transistors for both PCUs were operating hotter during LOS and were 78.8°F for side one and 131.1°F for side two 24 hours after AOS. This indicates more power was being dissipated in the PCU during LOS with the operating regulator transistor operating approximately 10° above normal temperature. Of this 10°, approximately 7° was due to a general rise with only a 3° to 4° transient occurring immediately after AOS. This type of shift can be expected since the transmitter was under powered, however a corresponding shift in dump panel temperature would also be expected.

The slight transient noted on the RTG hot frame temperature may not be significant relative to its operating temperature of 1100°F, however, the telemetry resolution is sufficient to resolve 1°F for this parameter and therefore the transient must be considered since sun angle was decreasing at AOS. This transient implies that the RTG was operating cooler during the period between LOS and AOS which means that the central station drew slightly more current than normal during this period.

SIMULATION TESTS

Since none of the anomalies hypothesized fit all circumstances, lab tests were conducted employing the Qual A central station. The tests were performed on the Qual model central station (C/S) which had been used last as the MSFN test model. All tests were performed with the central station initialized to the Apollo 14 ALSEP condition prior to LOS with the exception of simulating the +29V experiment loads. These were not simulated because test cables were not readily available and the more likely fault possibilities involved the +12 volt line which powers the receiver. Initialization conditions were:

a) Transmitter A select

b) PCU #1 select

c) Experiments 1 thru 4 power on

d) Data subsystem heater 2 off

e) Reserve power of 39-40 watts

The experiment power status was left on to provide an indication of partial ripple off, but no power was drawn from the experiment interfaces.

Two initial sets of tests were conducted to characterize heavy loading on the +12 and +29 volt lines. An additional set of tests were performed to attempt to eliminate the PCU switch-over fault and to obtain better thermal response data for heavy +12V line loads. The initial tests included:

A. Characterization of +12V circuit under load

a) Simulate the receiver circuit breaker and hold off relay and determine trip limits.

b) Load receiver circuit breaker to the trip point in the C/S.

c) Load the +12V line until transmitter oscillator drops out.

d) Short out +12V line thru a simulated receiver circuit breaker circuit (see Figure 2).

e) If necessary short out 12V line to ground.

B. Characterization of +29V circuit under load.

a) Simulate the SIDE interface and load down +29V thru interface.

b) Simulate +29V loads internal to the C/S.

C. Simulate SIDE circuit breaker operation under heavy load for 2500 Operations.

The second series of tests involved applying transient loads to the C/S to duplicate the condition in which the PSE would not be rippled to standby power on. Other tests were performed to simulate the hypothesized PCU fault and included applying +9 and -15 volts to the PDU, to determine power differences from the $\pm$12 volt condition, and also the operation of the PCU without the input power ground return connected at the switchover relay.

The tests conducted were time limited since dismantling of the lab prior to moving to the new facility was previously scheduled.

TEST RESULTS

A. 12V and 29V load characterization

Tables 4 and 5 provide the result of loading the 12 and 29 volt lines. As the 12 volt line is loaded the voltage on the 29 volt line increases while input current to the PCU decreases. This condition is caused by the central station voltages, other than the 29 V line, decreasing and thereby

Table 4

+ 12 V Line vs. Load

12 v	12 v Current (Amps)	29 v	PCU Input Current (Amps)	Remarks
11.96	.225	29.37	3.7	No load
11.94	.300	29.48	3.7	
11.90	.400	29.71	3.7	
11.86	.510	29.95	3.6	
11.83	.600	30.14	3.6	
11.80	.700	30.35	3.58	
11.73	.900	30.75	3.51	
11.56	1.36	31.68	3.38	
11.51	1.45	31.87	3.25	
11.00	2.15	32.63	3.12	
10.53	2.34	32.34	3.20	Lost MF Lock Tx Partially on
10.02	2.51	31.69	3.28	Tx Off
9.74	3.00	32.48	3.18 } IF RCVR +12V INPUT SHORTED	3.52 ohm load
8.80	3.20	31.15	3.32 }	3.0 ohm load
7.71	3.58	36.37	3.52	2.47 ohm load
6.10	4.00	36.6	3.84 16	1.49 ohm load

24.4w

requiring less power. The lower power requirement raised RTG input voltage which, in turn, increases the 29 volt line.

The input current, which is the current drawn from the RTG, is seen to fall off as load increases until very severe loading of about 3.0 ohms. The 3.0 ohm figure is the type of load which would be applied if the receiver circuit breaker coil, without diode, were applied across the 12V line. If the RTG did operate cooler as indicated by telemetry then loads in the order of 2.5 to 1.5 ohm would need to be applied to obtain an RTG current of greater than 3.7 amps, the normal operating current. The RTG operates cooler as loading is increased to the short condition.

Loading the 29V line is different than the 12 volts in that the PCU current increases with load. This occurs because the 29 volt power dissipation increases faster than the central station component load decreases. The 5.36 ohm load represents the maximum load which would be applied if the SIDE experiment load were to become shorted at the experiment. This type load would explain the cooler operating RTG but would not explain how the receiver was switched off.

Continuous loading is depicted by the data in Tables 4 and 5 will cause the PSE to ripple to standby if applied slowly. If the loads are applied instantaneously, as was simulated in the lab employing a switch to apply the load, then there is a point where the 12V circuit is pulled down stopping the ripple off clock and disabling this circuit. This condition can be made to occur by either 12V or 29 volt loading. Tables 6 and 7 provide the status changes noted caused by transient loading when the load is applied thru a switch. The 12 volt line must be drawn below 8.8 volts to not ripple off the PSE as is the case in the Apollo 14 anomaly. This implies the load must be greater than 3 ohms on the 12 volt line or greater than 7 ohms on the 29 volt line. This is a load which will stop the transmitter and also cause PCU switch-over; it would also cause the RTG to operate cooler if the anomaly were the 29V line, but would probably have to be less than 3 ohms on the 12 volt line to cause a cooler RTG.

B. Receiver Circuit Breaker Tests

If the receiver circuit breaker were to fail many of the symptioms noted could be explained. The circuit was bread-boarded, using flight quality parts from inventory, as shown in Figure 2. The diode, CR22, - a IN645, as well as other diodes across the other coils shown, was included in the design

Table 5

+ 29 v Line vs. Load

12 v	29 v	29 v Current (Amps)	PCU Input Current (Amps)	Remarks
11.97	29.22	.248	3.58	No Load
11.97	29.17	.480	3.58	
11.97	29.13	.680	3.58	
11.97	29.13	.780	3.55	
11.97	29.12	.880	3.55	
11.96	29.09	.940	3.52	
11.96	29.08	1.13	3.51	
11.23	27.40	1.36	3.7	Lost MF Lock Tx Partially On
11.03	26.85	1.43	3.82	
10.43	25.42	1.53	4.05	
9.83	24.12	1.72	4.20	Tx OFF
8.55	18.00	2.16	4.10	7 ohm load
7.72	15.83	2.48	4.25	5.36 ohm load

Table 6

Status Changes vs. + 12 Volt Load

+ 12 v	+ 12 v Current (Amps)	+ 29 v	PCU Input (Amps)	Status Changes
11.50	1.50	32.00	3.22	None
11.01	2.15	32.63	3.12	PSE STBY
10.53	2.34	32.34	3.20	PSE STBY, PCU SW
10.02	2.51	31.69	3.28	PSE STBY, PCU SW; Load - 4.40 ohm
8.80	3.20	31.15	3.32	PSE STBY, PCU SW; Load - 3.0 ohm
7.71	3.58	36.37	3.52	PSE ON, PCU SW; Load - 2.5 ohm
6.10	4.00	36.6	3.84	PSE ON, PCU SW; Load = 1.5 ohm

Table 7

Status Changes vs. + 29 Volt Load

+ 12 v	+29 v	29 v Current (Amps)	PCU Input Current (Amps)	Status Changes
11.96	29.13	1.13	3.53	None
11.34	27.61	1.38	3.72	PCU SW, PSE STBY
11.03	26.85	1.43	3.82	NO PCU SW, PSE STBY LOST MF LOCK, Tx partially ON
10.43	25.42	1.53	4.05	PCU SW, PSE STBY
9.83	24.12	1.72	4.20	PCU SW, PSE STBY, Tx OFF
8.55	18.00	2.16	4.10	PCU SW, PSE ON, Tx OFF

to overcome a design deficiency. This deficiency caused the circuit breaker to hang up and not trip when subjected to large current overload. The trip point of the circuit breaker is approximately 450 millivolts, 150 milliamp and 2.9 ohms, which is near the forward voltage drop of the diode; excess current is therefore shunted by the diode.

Tests were performed to determine the trip point of the circuit since there was some question as to how much current would be shunted by the diode. The trip point was consistent and between 140 - 148 milliamps. The drop out point of the holding coil CB6 was also measured at 14.7 volts by reducing the +29V. This indicates this relay would remain latched with as little as 2.7 volts across the coil. The pull in point was 23V.

Tests were performed by directly shorting the 12V relay circuit to ground. Initial tests were current limited to 250 or 500 milliamp, however later tests were conducted with 10 amp potential to determine if such loads could cause diode C22 to fail. For all tests, the circuit operated correctly relieving the 12 volt overload and there were no diode failures.

Tests were also conducted without the diode to gather data relative to the hypothesis that perhaps the diode failed before the circuit breaker could trip. These tests confirmed that the circuit breaker will hang up if large overloads without the diode occur. At 250 milliamp current limit, the breaker hung up on the 5th attempt; at 500 milliamp current limit the breaker hung up 5 of 6 attempts. This type of test was also performed using the central station. In these later tests, the bread-boarded circuit, without diode, was connected to the central station 12V and 29V lines and various loads were employed. The objective was to determine that if the circuit breaker hung up, would it remain hung up, as the PCU switched and lower potentials were incountered during switch-over. A 3 ohm load was applied initially, as a receiver load, and the results were that the relay hung up for approximately 10 seconds after applying load, but the load was finally relieved by the breaker operating. Additional tests resulted in hang up times in the order of 1 - 3 seconds or no hang up at all. The PCU switched in all cases. The load was reduced to directly shorting the circuit breaker to ground. This is a 2.9 ohm load on the 12V line and results were not significantly different from those using a 3 ohm load, or a total of 6 ohms in the circuit. A second CB1 circuit breaker was employed with approximately the same results but no hang up of durations greater than 2-3 seconds occurred although the initial attempt may have been in the 3-4 second range.

Finally, tests were conducted using the PDU receiver circuit breaker itself. The trip point measured at 155 milliamp. The circuit operated correctly without hang up with a 3 ohms load at the receiver terminals. Initially, applying a direct short at the receiver terminal caused the PCU to switch however the PSE did not ripple to standby.

The test was repeated several times, however, the circuit operated correctly and no PCU switch-over occurred.

The conclusions of this set of tests are:

a) The receiver circuit breaker nominally trips at 150 milliamps.

b) The breaker will hang up with large overloads if the diode is not present.

c) The breaker will hang up without the diode, thru PCU switch-over for periods in the order of seconds.

d) With the diode, the circuit operates as designed but PCU switch-over can occur before operating.

e) The operation of the relay appeared sluggish for initial overloads with hang up times longer than subsequent repeated tests.

C. 29V Experiment Overload Tests

Resistance measurements were made on the PDU to determine internal resistance in series with the experiment interface connector. Also, the resistance of the SIDE flat cable, at 60 feet, was calculated to determine worst case loading which could occur on this circuit. The minimum resistance at lunar noon for the entire circuit, assuming a short at the experiment end of the cable, is 5.7 ohm. A simulated load of 5.36 ohms was used to characterize the 29 volt load. The load was also used to test the experiment circuit breaker switching capacity under severe loading. The circuit breaker was operated 2500 times with the 5.36 ohm load to simulated actual operations on the Apollo 14 central station. There was no evidence of degradation to this circuit subsequent to testing.

D. PDU Power Dissipation at +9 and -15 Volts

This test was performed on the PDU to determine if a faulty PCU switchover could explain the rise in PDU temperature. The power dissipation of the ± 12 volt lines were measured with the power buses at nominal potential. The voltages were then offset to +9V and -15V, to simulate the faulty PCU switch-over in which the ground on the switch over relay does not make contact, and the power dissipation remeasured. The results noted below were a decrease rather than an increase in power dissipation as would be required to increase the PDU temperature. These results tend to dispute the faulty PCU switch-over hypothesis, however, the exact offset potentials are not known since engineering records for the original anomaly in 1967 are not available.

TABLE 8

± 12V PDU Power Dissipation

	± 12V	+9V, -15V
+12V current (milliamp)	78	58
-12V current (milliamp)	20	18.5

E. PCU Regulator Transistor Temperature Test

When the 12 and 29 volt lines were being characterized, the loads were applied only long enough to obtain data. This series of tests were run subsequently to determine the PCU regulator transistor temperature response time, and to characterize the temperature response of this power transistor for various 12V loads. The loads were applied to the second side of the PCU to simulate the condition believed to exist during LOS. They were gradually applied for longer periods and higher loads, the worst being a 1.5 ohm load which was applied to the 12V line for 5 minutes. Data was then taken after removal of the load to obtain the temperature response of the PCU regulators which is in the order of several minutes. The test is believed to be representative of lunar conditions because these transistors are thermally coupled, conductively, to the thermal plate.

The loads were applied for the duration noted in Table 9 and subsequent to removal temperature data was taken for the two regulator transistors each housekeeping pass to compare with the transient data noted at AOS. Loads in the order of 3 ohms or less were employed to simulate the conditions which would cool the RTG i.e. more input current than the normally required.

TABLE 9

PCU REGULATOR TEMPERATURE VS TIME

SUBSEQUENT TO 12V LOADING

A. 3.0 Ohm Load Applied for 30 Sec.

HK Cycle (54 Sec/Cycle)	HK 78; AT-39 PCU Reg #2	HK 77; AT-38 PCU Reg #1
1	265	202
2	272	200
3	275	200
4	277	200
5	300	200
6	301	200
7	301	200
8	301	200
9	302	200

B. 3.0 Ohm Load Applied for 1 Min.

HK Cycle (54 Sec/Cycle)	HK 78; AT-39 PCU Reg. #2	HK 77; AT-38 PCU Reg. #1
1	274	203
2	277	203
3	300	203
4	302	203
5	303	203
6	304	203

C 3.0 Ohm Load Applied for 3 Min.

HK Cycle (54 Sec/Cycle)	HK 78; AT-39 PCU Reg #2	HK 77; AT-38 PCU Reg. #1
1	271	200
2	275	202
3	301	203
4	303	204
5	305	205
6	305	205

TABLE 9 (continued)

D. 2.0 Ohm Load Applied for 1 Minute

HK Cycle (54 Sec/Cycle)	HK 78; AT-39 PCU Reg #2	HK 77; AT-38 PCU Reg #1
1	300	210
2	303	210
3	305	210
4	Missed Data	Missed Data
5	310	210
6	310	210

E. 2.0 Ohm Load Applied for 3 Minutes

HK Cycle (54 Sec/Cycle)	HK 78; AT-39 PCU Reg #2	HK 77; AT-38 PCU Reg #1
1	275	205
2	302	205
3	305	207
4	307	210
5	310	211
6	310	211

F. 1.5 Ohm Load Applied for 1 Minute

HK Cycle (54 Sec/Cycle	HK 78; AT-39 PCU Reg #2	HK 77; AT-38 PCU Reg #1
1	303	213
2	306	213
3	310	213
4	311	213
5	312	213
6	313	213

TABLE 9 (continued)

G. 1.5 OHM Load Applied for 5 Minutes

HK Cycle (54 Sec/Cycle)	KH 78; AT-39 PCU Reg #2	HK 77; AT-38 PCU Reg #1
	A4	
1	273 144.5°	205
2	303	210
3	305	212
4	310	213
5	Lost Lock	Lost Lock
6	313	214
7	314	215
8	314	215
9	315	215
10	315	215
11	315	215
12	315	215
13	315	215
14	315	215
15	315 158.4°	215

As noted in Table 1, the operating PCU regulator was at 140.0°F at AOS and dropped to 137.0°, a decrease of approximately 5 PCM counts, within 3 minutes. The test data, on the other hand, shows that for all cases, the operating PCU regulator, AT-39, increased its PCM counts rather than decreased.

This thermal response data tends to dispute the hypothesis that during LOS, the Apollo 14 ALSEP had a severe load on the 12 volt line or other power lines. The temperature response of this circuit is dependent on the amount of system reserve power and not on the loading of indepent power lines.

F. Simulation of Faulty PCU Switch-Over

The simulation of the faulty PCU switch-over was the last test conducted prior to dismantling of the test facility. This test was conducted because of the disagreement noted between the thermal response of the PCU regulator, with power loading, versus the actual data noted from Apollo 14 ALSEP. The fault was simulated by removal of the ground return connection at the PCU relay internal to the PCU. The ground return to the second side of the PCU was opened and a switch inserted. With the ground connection removed from this relay, the central station seeks its own ground potential, which is a function of loading, via the remaining ground connections in the PCU regulator. Table 10 provides information relative to the changes in central station potentials noted. During the tests, the central station, with the ground open, actually operated and provided a downlink signal which the telemetry receiver locked up on. The test therefore did not duplicate the conditions previously noted for this anomaly during engineering model testing, i.e., during previous tests voltage offsets were symmetrical about the normal ground and there was no downlink TM.

SUMMARY OF TEST RESULTS

OR 29 VOLT

The test results indicated that severe loading on the 12 volt line would be required to simulate most of the symptoms noted on the Apollo 14 ALSEP. These include, the PSE not being switched to standby; the transmitter being off, a mechanism to heat the PDU, the PCU switchover and a cooler operating RTG. X

The thermal response of the PCU regulator transistor disputes the hypothesis that after the command receiver failure, the remaining problem was 12V loading. X

TABLE 10

CENTRAL STATION POWER

WITH PCU SWITCH OVER RELAY

GROUND REMOVED

Central Station Power	With Relay Ground (Volts/Amps)	Without Relay Ground (Volts/Amps)
12V	12.03	11.21
12V Current	.20	.173
29V	29.43	24.5
29V Current	.255	.217
15V	15.35	13.86
15V Current	.008	.001
-12V	-11.90	-6.53
-12V Current	NA	.034
-6V	-6.08	-2.25
-6V Current	.04	.023
5V	5.20	6.05
5V Current	.480	.56
RTG Input Current	3.5	4.0

The 29 volt loading will duplicate the same symptoms as the 12 volt loading with the exception of providing a mechanism to turn-off the command receiver. The hypothesis that some 29 volt load caused the anomaly is rejected for this reason.

The hypothesis that the receiver failed and the transmitter subsequently shut down due to a faulty PCU switch over was neither proved nor disproved by the simulated tests. The PDU offset voltage test tends to dispute this hypothesis and the actual fault simulation was not conclusive since the test failed to duplicate the results previously known to happen i. e. loss of downlink did not occur.

The results therefore indicate that

a) The command receiver was probably the initial fault since none of the loading tests switched the receiver off, and a review of circuitry indicate there is no known method of switching the receiver off other than a power overload.

b) The loading of the 12 and 29 volt lines duplicated many of the symptoms but not the transient thermal response of the PCU regulator transistor. The loading was therefore more complex than simple 12 or 29V loads, or some other phenomenon caused the transmitter to stop for 4 days. X

c) The faulty PCU switchover was not successfully demonstrated in the simulation tests and therefore was not eliminated as a possible explantion for the failure of downlink telemetry. The PDU power tests tends to dispute this hypothesis, but sufficient engineering records are not available to completely rely on the result of this single test.