Bendix

Aerospace Systems Division

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ALSEP LONG TERM OPERATIONAL PLANNING

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1.0 INTRODUCTION

This document provides engineering information relative to the long term operating characteristics of the five ALSEP systems presently active on the lunar surface. The information includes a current summary of the operational status of each of the systems and an assessment of the predicted life from both hardware reliability calculations and RTG power availability. Additionally, recommendations are given for managing each system in terms of power utilization for maximum life. Finally, some suggestions are provided for obtaining useful engineering data at the end of life of the respective systems.

The information presented in this document is intended to provide an engineering baseline which, when evaluated against an overlay of scientific achievements and expectations, will result in an overall plan for maximizing the effectiveness of the ALSEP systems. The scientific assessment, consideration of Flight Operations and requirements for data analysis and archiving will be evaluated separately by NASA and are not a part of this work.

2.0 OPERATIONAL SUMMARY

The assignments, lunar location and date of deployment of each ALSEP are summarized in Figure 1. Figure 2 presents a condensed summary of the current operational status of the ALSEP systems as of 10 January 1975.

The purpose of this report is to discuss the long term utilization of the operating systems. To this end, two ALSEP systems and one experiment, listed in Figure 1, will not be discussed further. These are the ALSEP packages flown on Apollo 11 and 13 and the laser ranging retro reflector package LRRR. The simplified Apollo 11 package, which was powered by solar cells, exceeded its fourteen day design life by fifty-seven (57) days and is now non-operational. The Apollo 13 mission was curtailed without an attempted landing. The LRRR package is a passive unit of fuzed quartz corner reflectors used as a reference point for measuring precise ranges between the array and points on earth, using the technique of short pulse laser ranging.

The following subsections amplify on the Figure 2 summary to provide the current status and note significant operational changes that have occurred during mission life of the five operating stations.

Apollo Lunar Surface Experiments Package (ALSEP) Mission Assignments

LUNAR SURFACE EXPERIMENTS / APOLLO: Date on Moon, Lunar Location - Long. - Lat.	11 July 20, 1969 Tranquillity Base 23.4°E 0.7°N	12 Nov 19, 1969 Oceanus Procellarum 23.5°W 3.0°S	13 - -	14 February 5, 1971 Fra Mauro 17.5°W 3.7°S	15 July 31, 1971 Hadley Rille 3.7°E 26.1°N	16 April 21 1972 Descartes 15.5°E 9.0°S	17 Dec. 11, 1972 Taurus Littrow 30.8°E 20.2°N
SEISMIC							
• Passive	■	■	■	■	■	■	-
• Active	-	-	-	■	-	■	-
• Seismic Profiling	-	-	-	-	-	-	■
MAGNETIC							
• 3-Axis Magnetic Field	-	■	-	-	■	■	-
PARTICLE							
• Solar Wind Spectrum	-	■	-	-	■	-	-
• Ionosphere Detection	-	■	-	■	■	-	-
• Atmosphere Detection	-	■	■	■	■	-	-
• Charged Particle Detection	-	-	■	■	-	-	-
• Mass Spectrum	-	-	-	-	-	-	■
• Ejecta and Micrometeoroids	-	-	-	-	-	-	■
SPECIAL							
• Heat Flow	-	-	■	-	■	■	■
• Laser Ranging							
- 100 Reflectors	■	-	-	■	-	-	-
- 300 Reflectors	-	-	-	-	■	-	-
• Gravity	-	-	-	-	-	-	■

Figure 1

FIGURE 2 ALSEP STATUS SUMMARY
10 January 1975

ALSEP SUBSYSTEM \ APOLLO SYSTEM	11 7/20/69	12 11/19/69	14 2/5/71	15 7/31/71	16 4/21/72	17 12/11/72
CENTRAL STATION	Mission Complete Uplink operated 1 month D'nlink operated 5 mo.	Apparent failure of Data Processor Y - Timer failed 1878 days of operation >22700 cmds.	All systems operational except timer. 1435 days of operation >15000 cmds.	All systems operational 1259 days of operation >26500 cmds.	All systems operational except xmtr. A (3/73) 994 days of operation >14550 cmds.	All systems operational except Uplink A intermittent (8/74) 759 days of operation >20000 cmds.
POWER Initial Present	Solar Cells	73.6 w 60.1w	72.5 w 63.9 w	74.7 w 66.9 w	70.9 w 67.5 w	75.4 w 73.5 w
LRRR	Operational	N/A	Operational	Operational	N/A	N/A
PSE	Mission Complete	LPX, LPY, & LPZ Sensors good. SPZ Inop. No tidal data. Apparent failure in htr. control ckt. prevents forced off mode.	LPX, LPY, SPZ sensors good. LPZ inop. (11/72) LPY intermitt. leveling No tidal data. LPY data intermittently noisy since 7/30/74	Full operation except no tidal data	LP axes intermit. level April74. normal since 28 April 74. No tidal data.	N/A
ASE	N/A	N/A	HBR operation good. Geophone #2 failed-#3 noisy. Mortars not fired.	N/A	HBR operation good. #1 Grenade not fired.	N/A
SIDE/CCGE	N/A	Hi & Lo energy detectors good at <55°C. Engr'ing data good. CCGE malfunction at start of mission.	Stby fuse open in C/S. Unable to maintain with Oper. pwr. on-Dec. '74. Apparent failure with high pwr. demand. Operation terminated Jan. '75.	Hi & Lo energy detectors good. Spurious mode changes >85°C. Engr'ing data good. CCGE science data erratic(2/73)	N/A	N/A
CPLEE	N/A	N/A	Analyzer A - partial(high voltage problem). Analyzer B failed.	N/A	N/A	N/A
SWS	N/A	Operational	N/A	Commanded OFF -6/14/74 Operated for 15 months. Op. checks unsuccessful.	N/A	N/A
LSM	N/A	Commanded OFF-6/14/74 Operated for 30 Months. Op. checks unsuccessful.	N/A	Commanded OFF-6/14/74 Operated for 28 months. Op. checks unsuccessful.	Operational - was intermittent 2/73-8/73-normal since.	N/A
HFE	N/A	N/A	N/A	Fully operational - probes not to full depth.	Cable broken during deployment - not operating	Fully operational
LEAM	N/A	N/A	N/A	N/A	N/A	Operating temp. exceeds spec. limits. Operates for~75% of each lunation
LACE	N/A	N/A	N/A	N/A	N/A	Not operating since 10/73. Apparent failure of HV power supply. Bake-out & cold-soak operations unsuccessful.
LSG	N/A	N/A	N/A	N/A	N/A	Limited oper. due to beam center prob. Lost thermal control-3/74. Normal since 4/20/74.
LSPE	N/A	N/A	N/A	N/A	N/A	Extended HBR Operation will provide a data record for one full lunation. Comp except for 331° to 024°.

2.1 Apollo 12 ALSEP

Central Station - Operational with exception of the timer and data processor Y. On 3 May 1974, there was an abrupt loss of modulation on the downlink telemetry signal. System operation was restored by ground commanded selection of data processor X. An investigation concluded that a failure may have occurred in either the clock generator/divider circuits or the modulator output gate. The Y processor may be re-selected in case of a future X processor failure or to acquire additional engineering data at "end-of-mission".

On 20 August 1974, the Apollo 12 ALSEP experienced another loss of modulation while operating with the X processor. The modulation loss was accompanied by an increase in signal level of about 6 dbm. After approximately 6 minutes, modulation and signal level returned to "normal" without any corrective action by Mission Control or the tracking station. Subsequent operation has been nominal.

On 1 January 1975, the station experienced a spurious functional command (octal 062) which selected PCU #2. Operation of this redundant power conditioner, which had not previously been used during more than 5 years on the lunar surface, was nominal. PCU #1 was reselected by command (octal 060) from MCC without incident.

Passive Seismic Experiment - Long period X and Y axis seismic operation continues satisfactory and the experiment engineering data as well as its response to commands is operational. The data from the short period vertical sensor system has not been acceptable since the beginning of the mission. On 10/16/74, the feedback loop filter was commanded in for a 30 day period (initially) at the Principal Investigators request. Operation in this configuration has continued since that time. An intermittent condition in the LPZ data was noted during January 1974 wherein the instrument failed to respond properly to calibration and the science data output went to a quiescent condition. The anomally occurred during three successive lunar night periods (28 Dec. 1973 to 2 Jan. 1974, 23 Jan. 1974 to 2 Feb. 1974 and 22 Feb. 1974 to 3 Mar. 1974). On 11 Sept. and on 9-10 Nov., the long period X and Y axes failed to calibrate on command: since that occurrance response to calibration commands has been nominal. All data have been valid since 3 Mar. 1974.

On 7, 8 & 9 Nov. '74, PSE heater checks were performed by commanding the heater to FORCED ON, FORCED OFF, AUTO ON and AUTO OFF and noting the change in system reserve power. Analysis of the data indicates that a failure has occurred in the heater relay or its control circuits which prevents operation in the FORCED OFF mode. Z motor drive power has been used for lunar night thermal control since Feb. 1970.

SIDE/CCGE - All SIDE sensors and associated circuits continue to operate; engineering data and command response is functional. A limitation in performance has been observed above temperatures of 55°C, however operational procedures limiting daytime operation have been instituted to maintain acceptable thermal conditions. Numerous mode changes have been observed when operation is attempted at temperatures above approximately 55°C.

On 3 and 4 Sept. the instrument experienced a reduction of high energy calibrations and data counts but returned to normal later during the 4 Sept. support period. During the support period on 3 Dec. (0138 G.m.t.) it was noted that the High Energy Calibrations were not functioning; however, the High Energy data counts appeared to be normal. During a check at 1740 G.m.t. on 3 Dec., normal operation was observed. The condition was observed again on 3 January 1975.

The CCGE malfunctioned at about 14 hours into the mission and has not produced acceptable data since.

Solar Wind - Continues to operate satisfactorily except for intermittent modulation loss in proton energy levels 13 and 14.

Lunar Surface Magnetometer - The experiment was commanded OFF on 14 June 1974. On 6 Sept., a spurious LSM Operate Power ON Command (octal 042) occurred. The instrument did not return any valid science or engineering data and was command OFF (octal 044) without incident: a 1 watt change in reserve power was observed.

2.2 Apollo 14 ALSEP

Central Station - Fully operational with exception of the timer and the fuze in the +29V standby power line to the SIDE experiment. This is discussed in more detail in a following paragraph.

PSE - Operational except long period vertical sensor and the feedback filter. The LPY axis is occasionally difficult to level and the "noisy data anomaly", initially observed by the Principal Investigator and during real time support on 14 April 1973, has continued, intermittently, since 30 July 1974. An analysis of the problem has been completed and will be released in January 1975.

Active Seismic Experiment - Passive listening mode is operational but is limited in that the geophone #2 circuit is not functioning and geophone #3 data is degraded. The weekly high bit rate operation has been discontinued as a result of an assessment of the scientific usefulness. The ASE is periodically commanded to operate select, High Bit Rate ON, to ascertain operational capability. The mortar experiment has not been performed due to deployment location and questionable stability. Any further exercise of this portion of the experiment is presumed to be of engineering interest only in veiw of the current operational condition of the geophones and would only be considered as an end-of-mission experiment before final termination of the total system.

Charged Particle Experiment (CPLEE) - Limited operation on Analyzer A continues. Analyzer B failed after two months of lunar operation. The instrument continues to output engineering data and is fully responsive to commands.

SIDE - This experiment was observed to go from ON to STANDBY, by what appeared to a circuit breaker response to an over-current condition, in April of 1973. In August 1973, the instrument went from standby to off. These events are documented in SMEARS Apollo 14 ALSEP 82 and 84. Analysis concluded that the fuse supplying SIDE standby power had opened. Subsequent operational planning included a st ipulation that the experiment should always be in the power ON mode during lunar night.

In Nov. 1974 the SIDE experienced repeated functional change from ON to standby (now thought to be synonymous with OFF) and did not respond normally to power ON commands. Multiple transmissions of the ON command were required to place the experiment in the operate mode and finally it was left in a non-operate state on 14 December while in the lunar night environment. Intermittent operation was again achieved on 6-8 Jan 1975; however, when the instrument continued to return to a static condition, further attempts to command it on were abandoned.

It is now thought that further operation of the Apollo 14 SIDE is most improbable. CCGE operation is prohibited by the SIDE anomaly.

2.3 Apollo 15 ALSEP

Central Station - Fully operational on primary components.

PSE - Fully operational for all functions. Attention is required in operational profile for degraded thermal performance and routine leveling.

SIDE/CCGE - Fully operational for all functions except during high temperature condition. Standby mode is selected when the temperature approaches 85°C to preclude apparent internal high voltage arching. CCGE continues to output useful data but tends to exhibit erratic and noisy information at low temperatures.

Solar Wind - The experiment operated until June 1972 and was maintained in STANDBY with periodic switching to OPERATE to assess any change in performance from June 1972 until June 1974. The instrument was commanded OFF on 14 June 1974. On 3 Sept., a command was sent to turn the experiment on with no valid engineering or scientific data being returned in the downlink. It was noted that the electronics drew 1.5 watts and thatthe heater turned on and used 4.5 watts. The instrument was commanded off after a few minutes of power on operation.

Magnetometer - The experiment operated until December 1973 when engineering and science data went static. It was commanded OFF on 14 June 1974. On 3 September, the instrument was commanded on for an operational check. Operation was not satisfactory and the LSM was commanded off after a few minutes of power on operation. It was noted that 1.5 watts of power was consumed.

Heat Flow Experiment - Fully operational. Probes were not deployed to full depth due to problems in drilling holes in the lunar soil; however, the experiment has been fully successful.

2.4 Apollo 16 ALSEP

Central Station - All functions continue in a nominal condition with Transmitter B in use. The prime downlink transmitter exhibited anomalous performance after a year's operation. Investigation of the anomaly indicated that power output had fallen off approximately six db and resulted in intermittent ground station signal reception.

The system is operating as a consequence, with the backup transmitter. All other components are available for use should the prime fail or degrade. In the event of failure of Transmitter B, it is expected that transmitter A could still be used in a degraded mode of operation, e.g., low bit rate, to extend mission life to the maximum.

PSE - Fully operational except for tidal data operation, but with minor thermal control problem during the lunar day. Higher temperatures at lunar noon caused DL-07 to go off scale high. Additionally there are operational annoyances such as increased leveling activity. The long period y-axis has previously experienced leveling problems during lunar night operations and failed to respond to leveling commands from 22 April to 26 April 1974. On 28 April it responded correctly to leveling commands and has continued to respond since that time.

ASE - Fully operational for passive listening; however, routine scheduling of this operation has been discontinued due to an assessment of scientific usefulness. The ASE is periodically commanded to Operate Select, High Bit Rate ON, to ascertain operational capability.

Heat Flow Experiment - Non-operational due to broken cable.

Magnetometer - The instrument has been fully operational since August 1973. Prior to this time, the instrument exhibited intermittent performance in science data output and flip calibration operation.

2.5 Apollo 17 ALSEP

Central Station - All subsystems are fully operational except for response when commands are routed through "Uplink A". On 16 August 1974, immediately prior to termination of real time support, three (3) LSPE geophone calibrate commands (octal #170) were sent with no functional response or CVWs received in the downlink. Uplink A was in use at that time. On 19 August 1974, during real-time support, thirty three (33) commands were sent to the ALSEP package with only four (4) functional verifications. Uplink B was then selected by transmitting command octal #122 (switch uplink). Following the uplink switch, which occurred nominally, commands were received and processed by the central station components without indication of the anomally. Analysis indicates that the sensitivity of command receiver A has degraded by about 2 to 3 db due to a change in the AGC level. It is expected that the "A" receiver is still functional and can provide an acceptable command link under most operational conditions.

During real-time support on 14 Oct. '74, the Bermuda tracking station reported poor data quality and difficulty in maintaining decom lock with a down-link signal strength of -146 dbm. Transmitter A was commanded off and transmitter B commanded on by mission control. A 2 db increase was reported in the downlink signal level with good data and continuous decom lock. It should be noted that this was the first ALSEP support period performed at Bermuda in approximately one (1) year. Further, a review of previous operations confirmed satisfactory operation at signal levels down ot -147.5 dbm.

Operation continued with transmitter B until early December when both Canary and Ascension stations reported a signal strength of -146 to -148.5 dbm and intermittent short term data drops. On 9 December transmitter B was commanded off and transmitter A commanded on resulting in an increase in signal strength and good data. The lunar libration pattern was at or near its worst-case condition at this time. Since 9 December, satisfactory operation has continued with transmitter A.

Heat Flow Experiment - Fully operational.

Lunar Ejecta and Meteorites Experiment - Fully operational under limited temperature conditions. The instrument has continually exhibited excessive temperatures as the lunar noon condition approaches. Operations have been curtailed as temperatures approach 196°F as a conservative measure to maximize reliability and extend life relative to idealized science return during the lunar noon condition. Reassessment of the LEAM reliability in terms of stress at elevated temperatures has been performed. Results of this analysis indicate that the instrument would not be degraded at temperatures as high as 212°F. Continuous monitoring of the thermal performance indicates that the instrument temperature is affected by the slight variations of the sun during the summer/winter solstices. The temperatures recorded during any lunation are approximately 5 to 8 degrees higher than for the equivalent lunation last year. This process is not completely understood but is probably due in part to degradation of the thermal surfaces. An analysis is being conducted to compare this instrument's temperature profile with that of others on Apollo 17 ALSEP and previous systems.

Lunar Seismic Profiling Experiment (LSPE) - The LSPE remains fully operational for the passive seismic listening mode. High bit rate data is satisfactory and the instrument engineering data as well as command response continues to function properly. In order to pursue a study of meteroid impacts and moonquakes, the instrument is being operated in its passive listening mode for extended periods of about four (4) days each. Scheduling of these periods will provide a continuous LSPE data record extending over one complete lunation. To complete the record, one period remains to be accomplished.

Lunar Atmospheric Composition Experiment - The LACE operated satisfactorily for approximately 10 months. An initial failure of the number one filament was followed by an apparent high voltage power supply failure in October 1973. The instrument is configured to discriminator level, LOW; filament, OFF; high voltage power supply, OFF; the back-up heater is ON. Periodic checks have been made to ascertain if there has been any performance change and, starting on 23 September the instrument was operated in standby with the survival heater on during the lunar day. This "bake-out" operation was an attempt to correct the high voltage power supply problem; however, no improvement was noted. On 18 November the instrument was commanded OFF for 3 hours, 23 minutes during lunar night. During this "cold-soak" the electronics temperature (AM 41) decreased from $-2.3^{o}F$ to $31.3^{o}F$. Additional "cold-soak" operations were accomplished on 16 December (5^{h}, 3^{m}), 18D ecember (5^{h} 40^{m}) and on 8 January 1975 (8^{h} 23^{m}). On 8 and 9 January 1975 the LACE telemetry did not indicate any significant improvement.

Lunar Surface Gravimeter - The LSG instrument continued to perform nominally in its engineering functions until 15 March 1974 when the Heater Box heater circuit failed full on. This anomaly caused the sensor temperature to increase above a stabilized temperature of $49.2^{o}C$ and to eventually drift off-scale high. On 20 April 1974, the LSG regained thermal stability. The experiment's sensor temperature has remained stabilized at $49.2^{o}C$ since that time. Exercise of the instrument has been performed at intervals in an attempt to overcome deficiencies in the beam centering capability. The experiment is operating and configured for data collection with seismic high gain, integrator shorted node, bias out, past amplifier gain at 15, coarse and fine screws driven to the extreme lower position and the sensor beam near center.

3.0 OPERATING LIFE

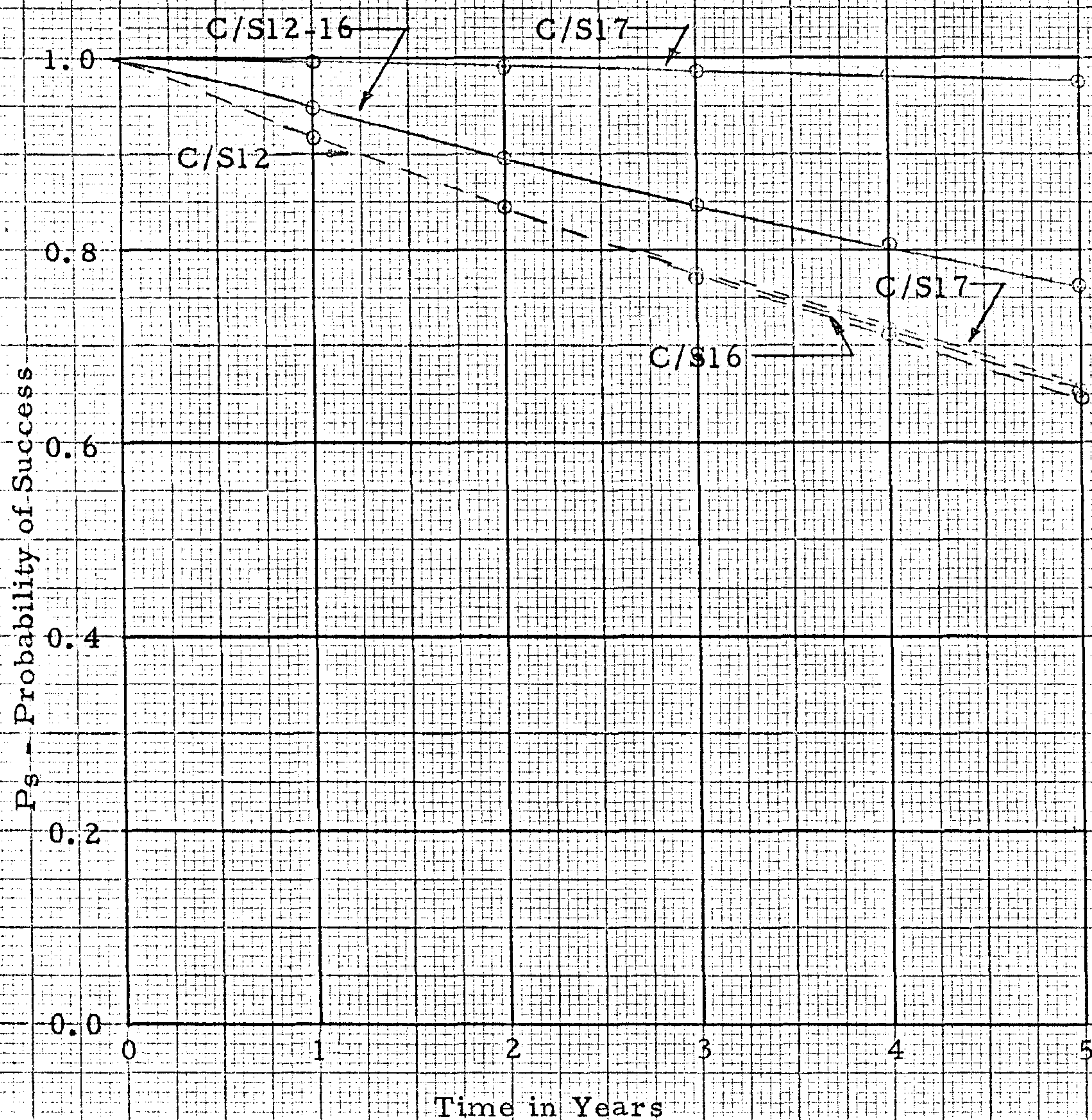
The prediction of the operating life of the ALSEP systems is a function of a reliability assessment of the individual subsystems and the availability of RTG power to maintain thermal control as well as functional requirements. The reliability assessment results in a probability of success relative to life time, and is based on cumulative failure rate calculations of the parts and materials used in each subsystem or component. This probability calculation is relatively fixed and is dependent primarily on maintenance of the operating thermal environment within pre-established limits. Initial selection, screening and burn-in of parts and materials precludes consideration of wear-out in this assessment since typical life characteristics of individual parts are in the order of 20-30 years minimum.

Availability of RTG power is, on the other hand, a real limitation on the life of the ALSEP systems. Judicious management of system power is required to maximize the total operating life of the ALSEP systems. This management is dependent on continued real time assessment of each system and is based on science priorities as well as engineering performance of each experiment and the central stations.

3.1 Reliability Predictions

The probability of success for each deployed ALSEP central station and experiment is graphically shown in Figures 3 through 5. Although each of the subsystems was theoretically designed to meet 1 or 2 year life requirements, there are significant probabilities that individually and collectively, the systems will continue to provide useful science data for the next several years. Given that an individual subsystem is operating today, the prediction may be taken at 0 time, and viewed over the next several years.

Figure 3 - ALSEP Central Station Reliability



Time Years	P_s^1 12-16	P_s^1 17	P_s^2 12	P_s^3 16	P_s^4 17
1	.9468	.9951	.9185	.9173	.9199
2	.8964	.9902	.8436	.8414	.8463
3	.8487	.9854	.7748	.7719	.7786
4	.8035	.9805	.7117	.7080	.7163
5	.7608	.9757	.6537	.6495	.6590

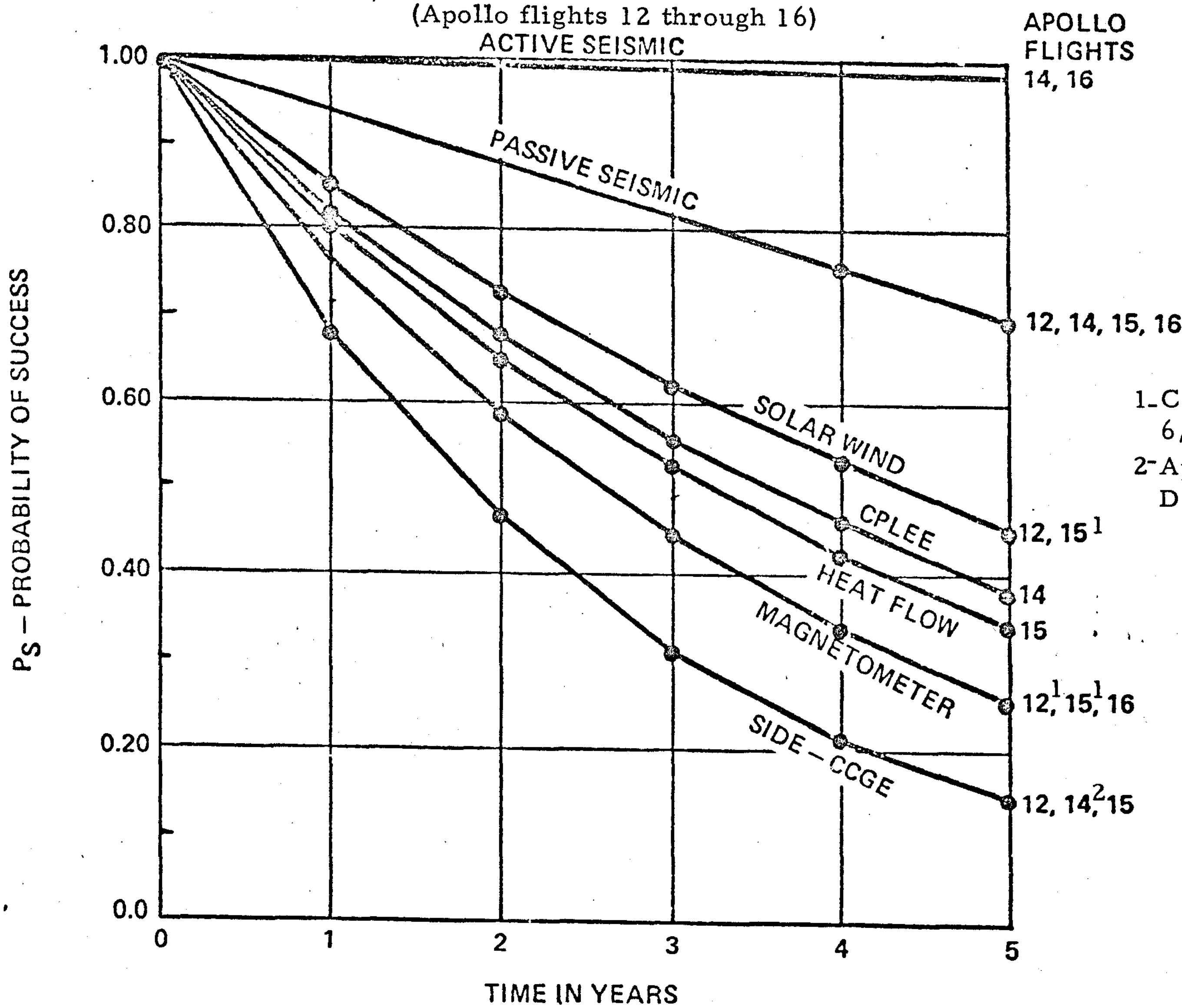
1 - Original
2 - Revised--due to suspected failure of redundant data processor.
3 - Revised--due to possible failure of one transmitter.
4 - Revised--assumes failure of Uplink A.

wt ~~9x74~~ 1/75

Figure 4

ALSEP EXPERIMENT RELIABILITY

(Apollo flights 12 through 16)



1. Commanded OFF 6/14/74
2. Apparent failure Dec. 1974.

Figure 5 - ARRAY E EXPERIMENT RELIABILITY

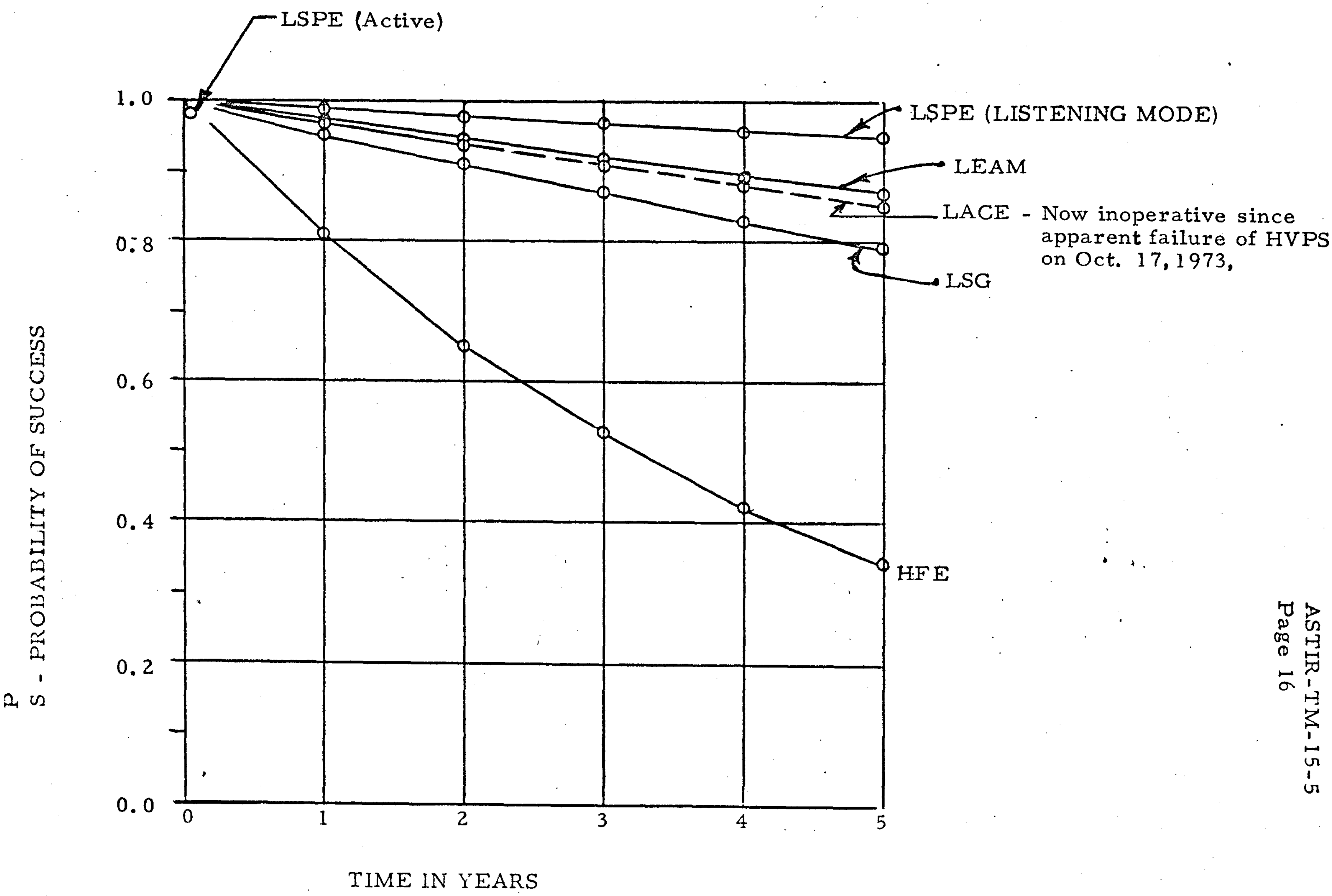


Figure 3, Central Station Reliability, shows a separate dotted curve for C/S 12, C/S 16 and C/S 17. These curves should be used as the current prediction of probability of success. They are lower than original predictions due to the suspected failures. For C/S 16 it is believed that one transmitter has degraded or failed: for C/S 12 analysis indicates failure of one data processor and for C/S 17 there was an indication (in August 1974) of degradation or failure in one of the redundant command signal processing components (uplink A).

3.2 RTG Power Availability

The RTG power output decreases with time as the fuel element is depleted, the thermal coatings degrade, the inert gas pressure decreases and the thermopile efficiency degrades. The degradation that has occurred to date is shown in Figures 6 through 10 for ALSEPs 12, 14, 15, 16 and 17 respectively. These graphs were produced from data accumulated from each ALSEP and represent the regression curves for the power values in each lunation. The actual power values shown are within about one (1) watt off the predicted curves. In each system, as the RTG power decays, load adjustements will be required to maintain Central Station thermal plate temperatures above $-10^{\circ}F$ during lunar night operation and to avoid activation of the ripple off circuits. A tradeoff analysis was performed and documented in ASTIR-TM-44-2 to determine the operating configuration of the experiments and Central Station heaters that results in optimum usage of the remaining power. The recommendations for power management as the available power decays are given in the following section.

4.0 RECOMMENDATIONS

4.1 Power Management

The optimum long term profiles which give the maximum scientific return from each array can be obtained through the selection of one of several operating load configurations.

The recommended turn-off sequences are based on maintaining the minimum temperature of the Central Station thermal plate above $-10^{\circ}F$, considering the Passive Siesmic Experiment (PSE) as the highest priority experiment. This means that PSE will normally be the last experiment to be turned off, unless it experiences a failure. Where possible experiments are initially set to standby ON, for survival during lunar night, so that operation may be commanded during lunar day. The A12 LSM and the A15 LSM and SWS have apparently not survived the lunar night, after having been commanded off in June 1974, since operational checks were unsuccessful. Other experiments are not expected to survive if left off for any extended time for exposure to the (approximate) -300°F lunar night temperatures.

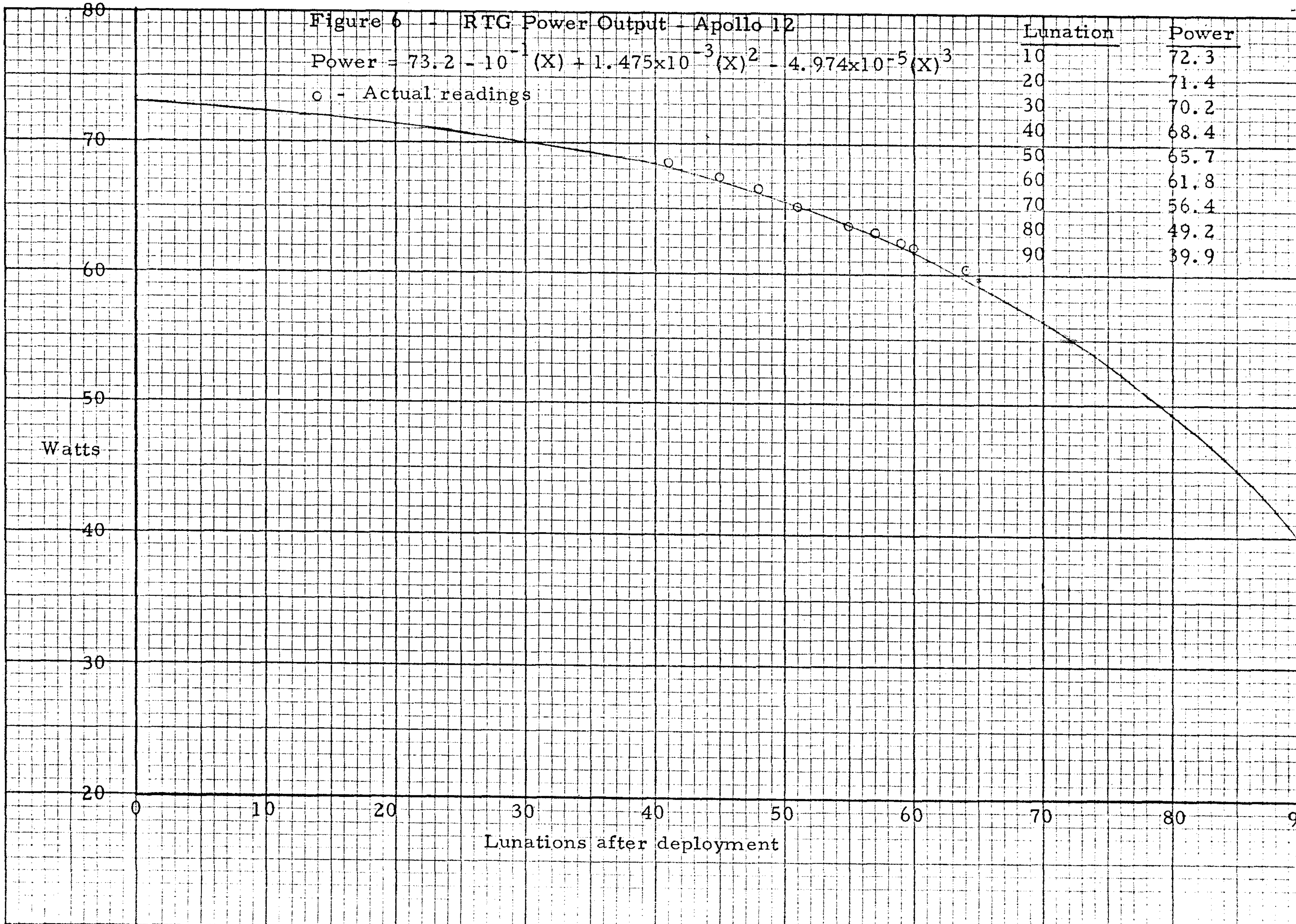


Figure 6 - RTG Power Output - Apollo 12

$$Power = 73.2 - 10^{-1}(X) + 1.475\times10^{-3}(X)^2 - 4.974\times10^{-5}(X)^3$$

Lunation	Power
10	72.3
20	71.4
30	70.2
40	68.4
50	65.7
60	61.8
70	56.4
80	49.2
90	39.9

Figure 7 Apollo 14 RTG Output

$$Power = 71.985 - 5.41 \times 10^{-2}(X) - 1.727 \times 10^{-3}(X)^3$$

o - Actual power readings

Lunation	Power
10	71.27
20	70.21
30	68.81
40	67.06
50	64.96
60	62.53
70	59.74
80	56.60
90	53.13
100	49.31

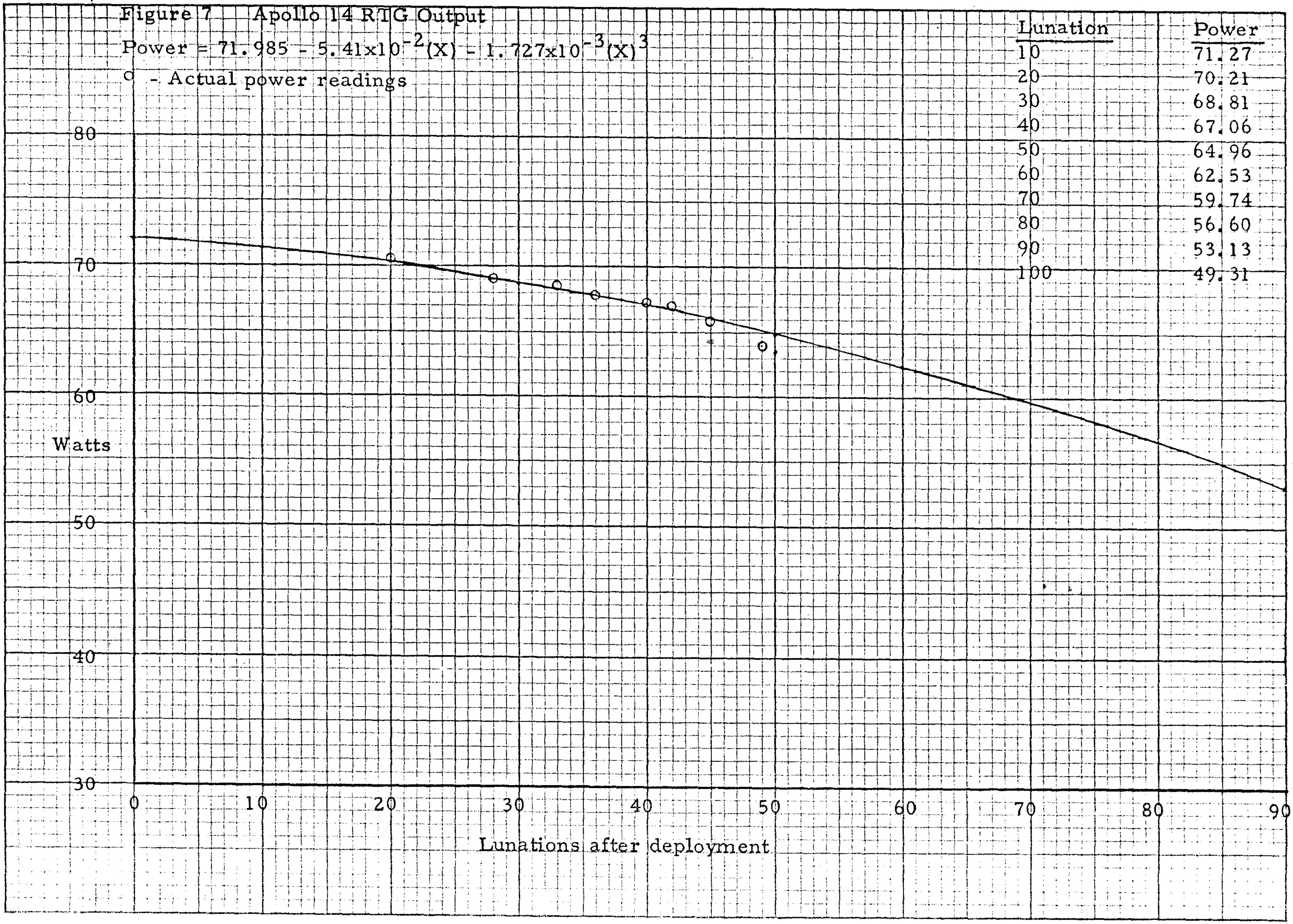
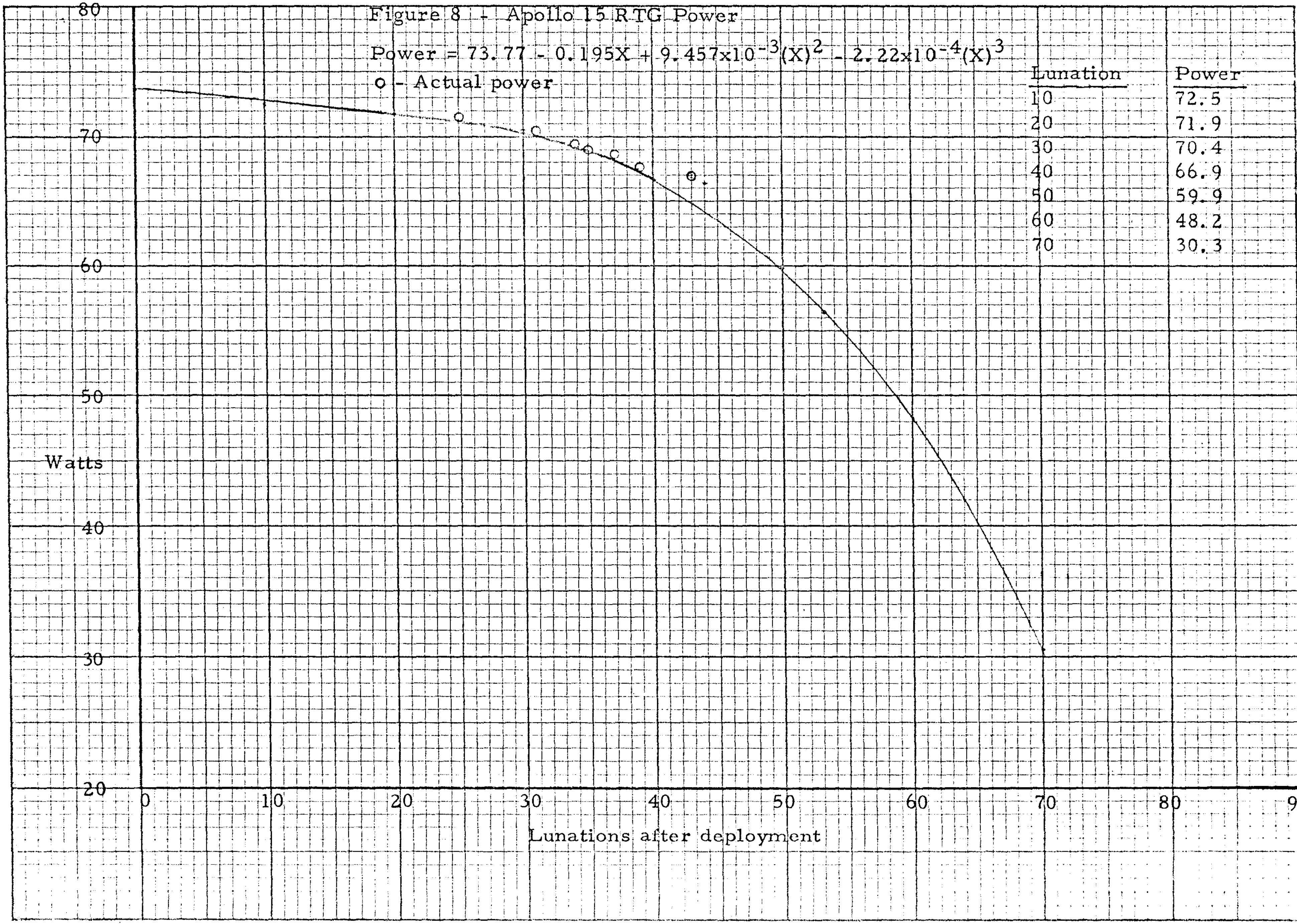


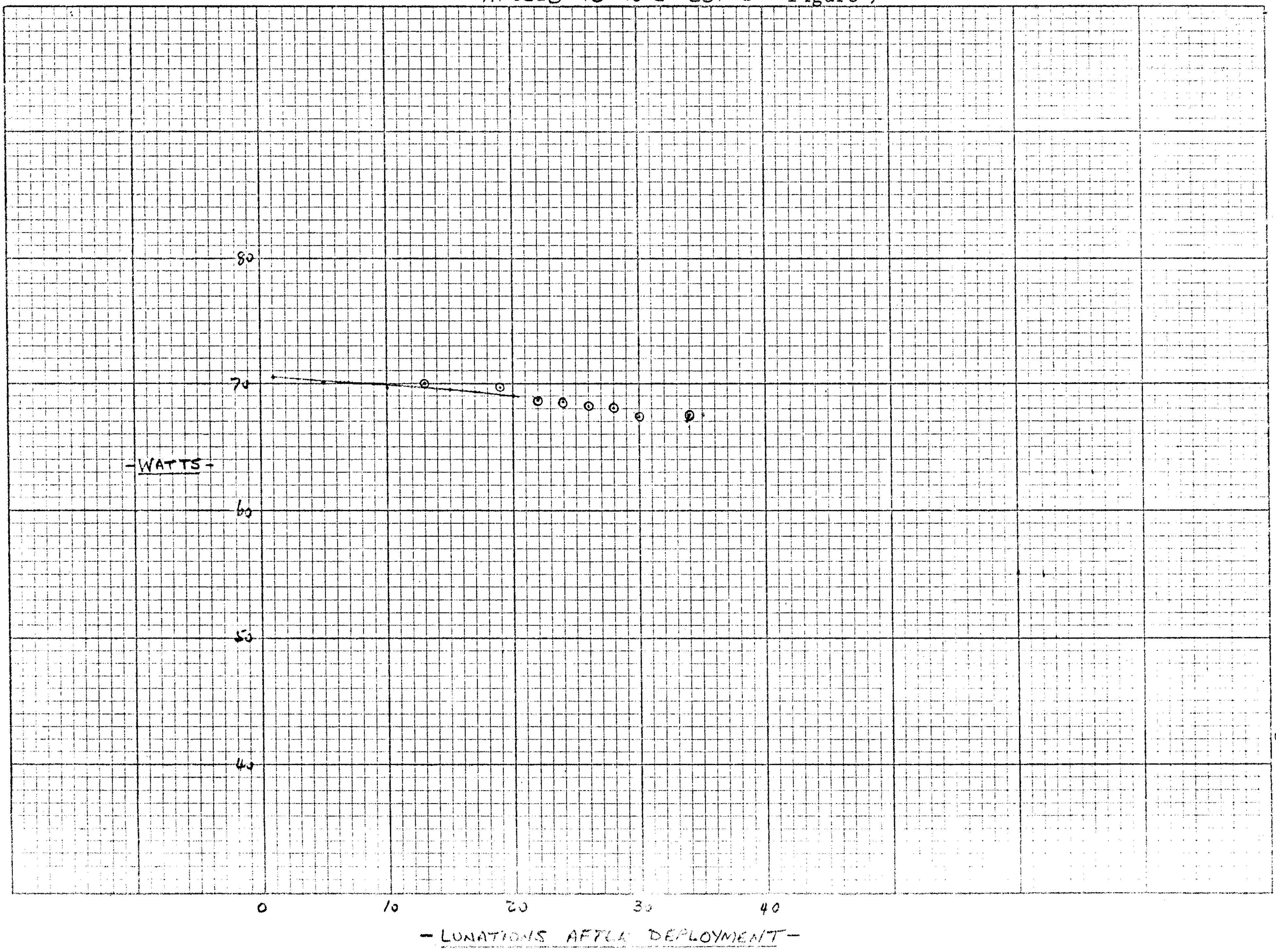
Figure 8 - Apollo 15 RTG Power

$$\text{Power} = 73.77 - 0.195X + 9.457\times10^{-3}(X)^2 - 2.22\times10^{-4}(X)^3$$

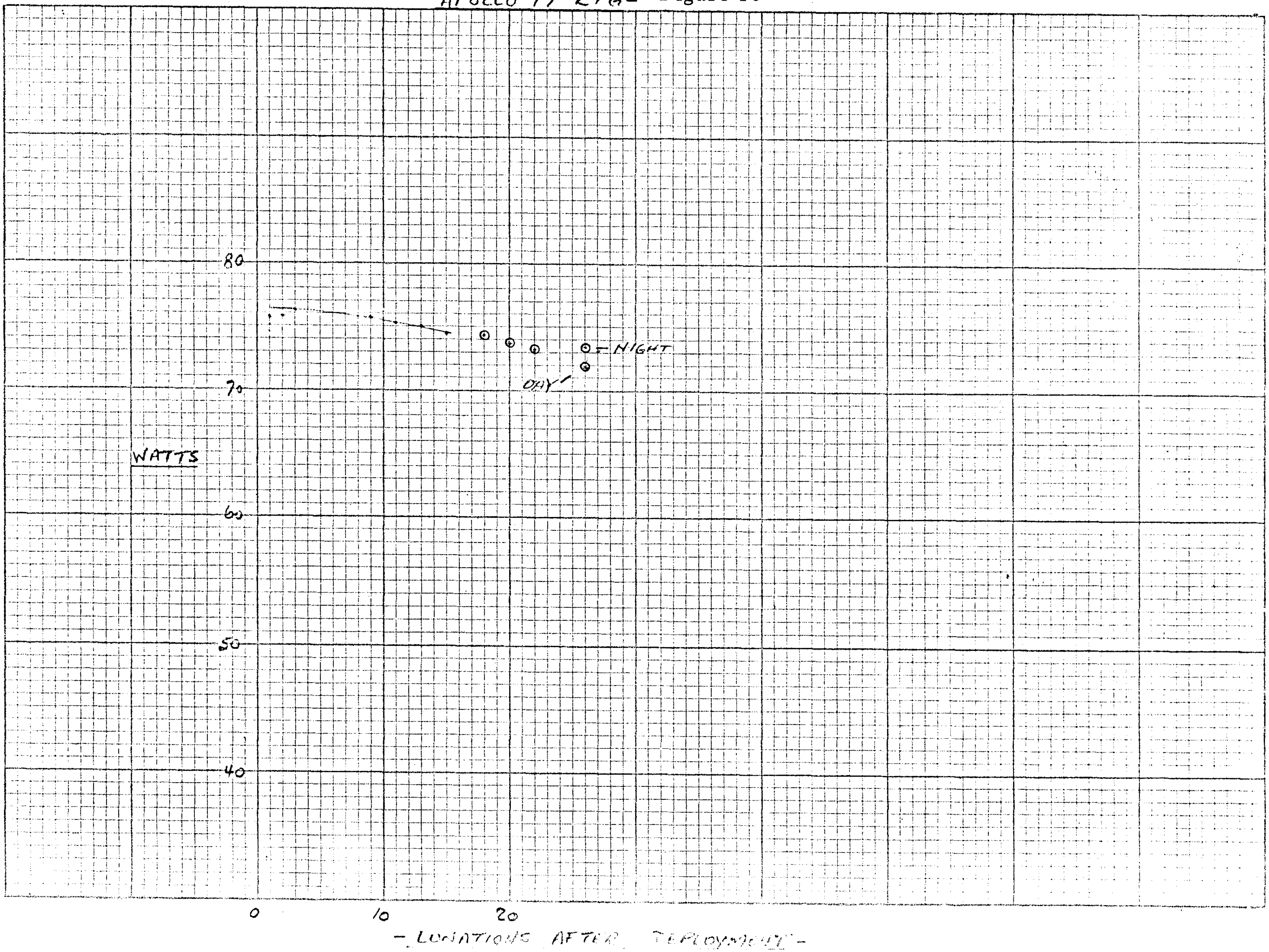


Lunation	Power
10	72.5
20	71.9
30	70.4
40	66.9
50	59.9
60	48.2
70	30.3

APOLLO 16 RTG OUTPUT Figure 9



- APOLLO 17 RTG - **Figure 10**



4.1.1 Apollo 12, ALSEP Turn Off Sequence

Figure 11 indicates the prime options available for turning off experiments and the power levels at which decisions must be made. The option which is selected will depend upon operational status when the decision is made and the relative merits of the scientific data being received.

The LSM on Apollo 12 ALSEP was commanded OFF on 14 June 1974 when the RTG power had reached a level of 63.4 watts (on day 164). This is shown as the cross-hatched block of Figure 11. A further experiment load adjustment is required when the RTG power level reaches approximately 55 watts. From Figure 6 it is anticipated this will occur near the 72nd lunation or about August of 1975. Three (3) options are shown in Figure 6: selection will be based on an evaluation of the performance and mission objectives which are current at the time.

4.1.2 Apollo 14, ALSEP Turn Off Sequence

The functional options available when this report was last revised are shown in Figure 12 together with the power levels at which decisions should be made. The SIDE, which had been operating without its standbymode since August of 1973, has now apparently experienced an additional failure (Dec. 1974) and is thought to be non-operational. With SIDE off, Figure 12 can be revised to reflect the current conditions; the new options and decision points are shown in Figure 12A. The computer program used with ASTIR-TM-44-2 to determine the power levels shown in Table 6 (page 18 of ASTIR-TM-44-2), was used to obtain the new decision points (power levels). This summarized as follows:

Condition		PCU #1 RTG	PCU #1 Reserve	PCU #2 RTG	PCU #2 Reserve
SIDE OFF, ASE STBY, PSE ON, CPLEE ON	0 Htr Pwr.	52.34	15.49	52.61	15.98
	5 W. Htr ON	48.87	6.58	48.97	6.98
	10 W. Htr ON	48.13	1.02	48.14	1.40

These values assume a minimum average thermal plate temperature of -10^{o}F. The conditions with 10 W Heater on are invalid since this would most likely result in

Figure 11 Apollo 12 Turn-Off Sequences

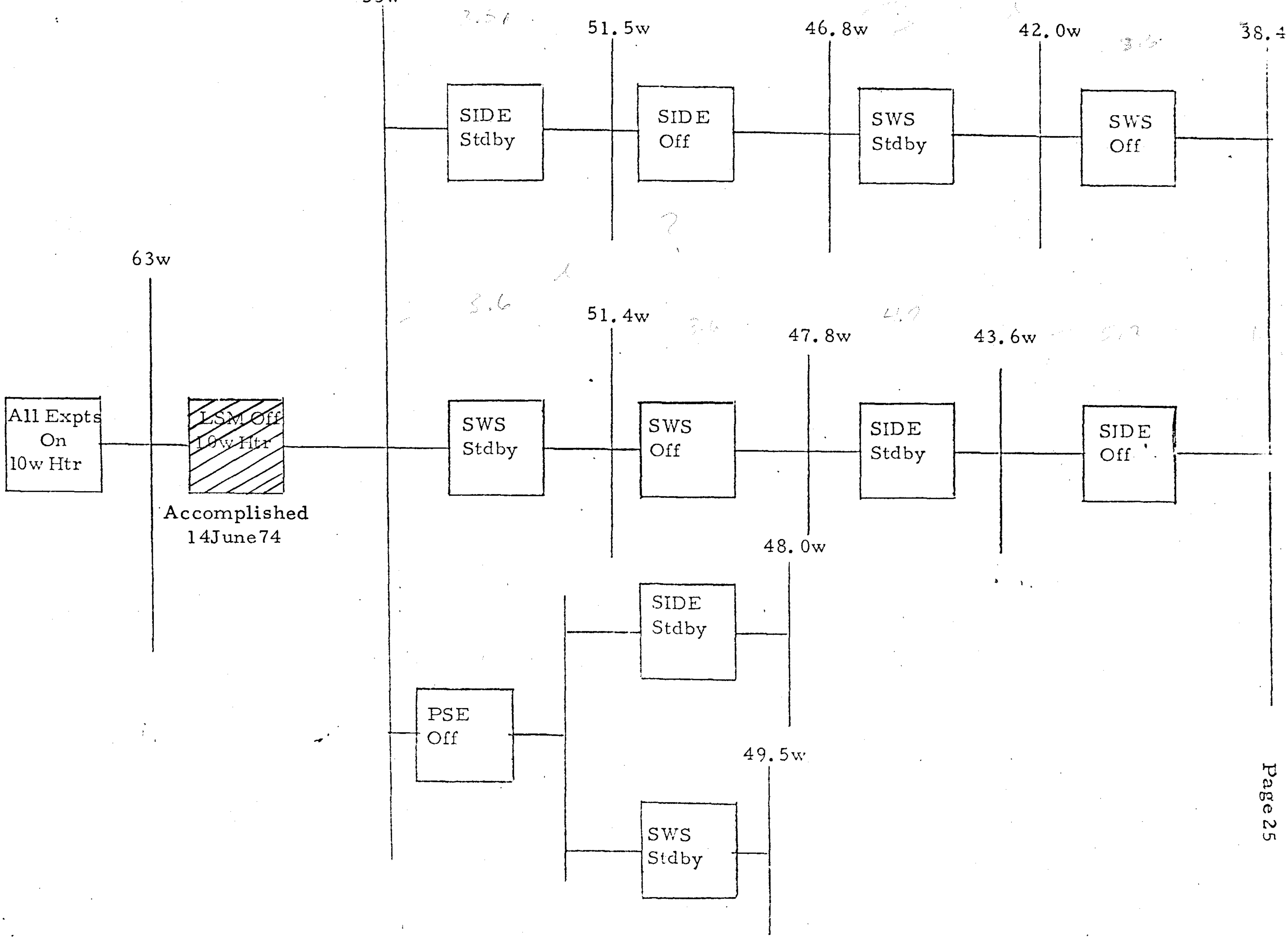


Figure 12

Apollo 14 ALSEP Turn-Off Sequence

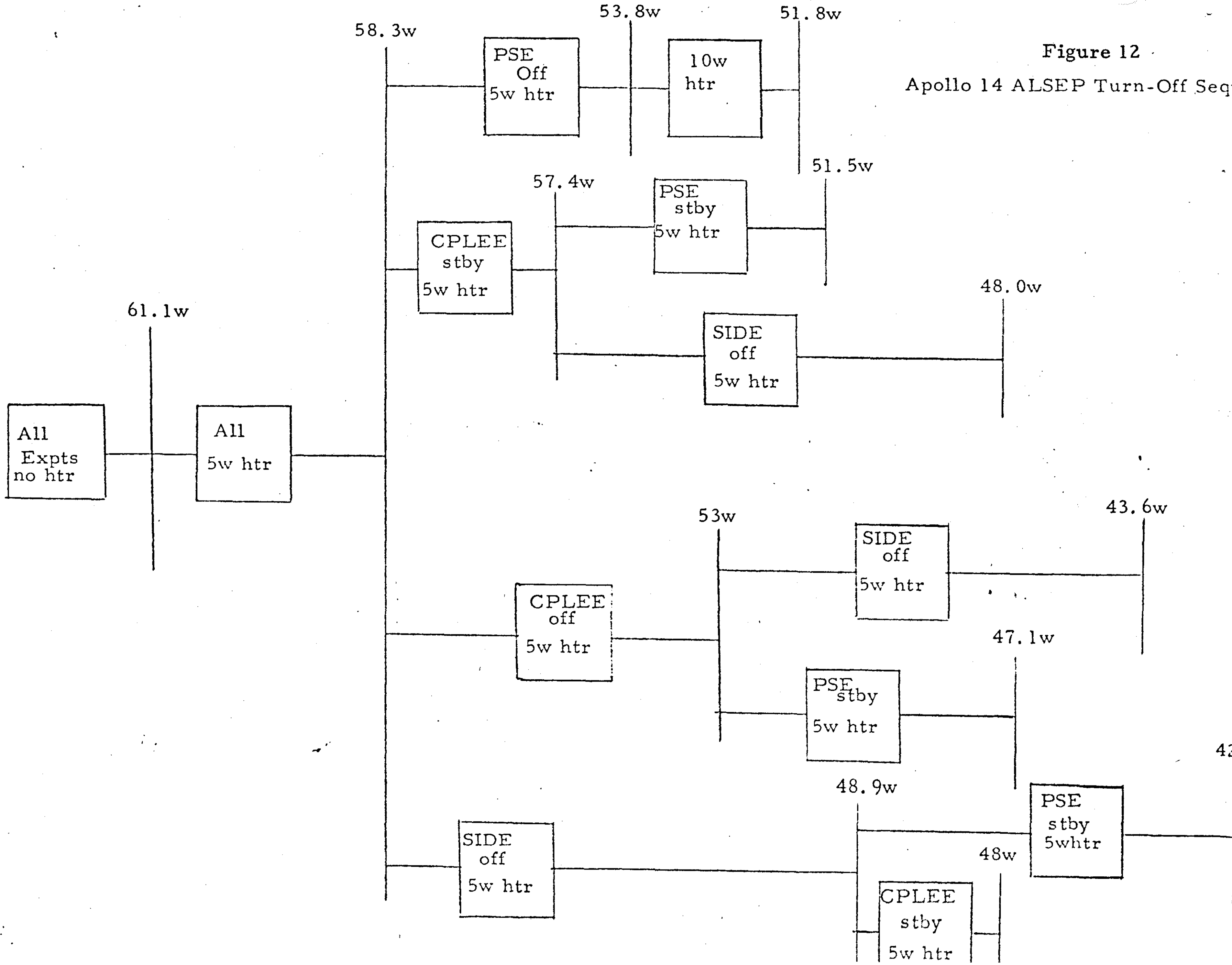
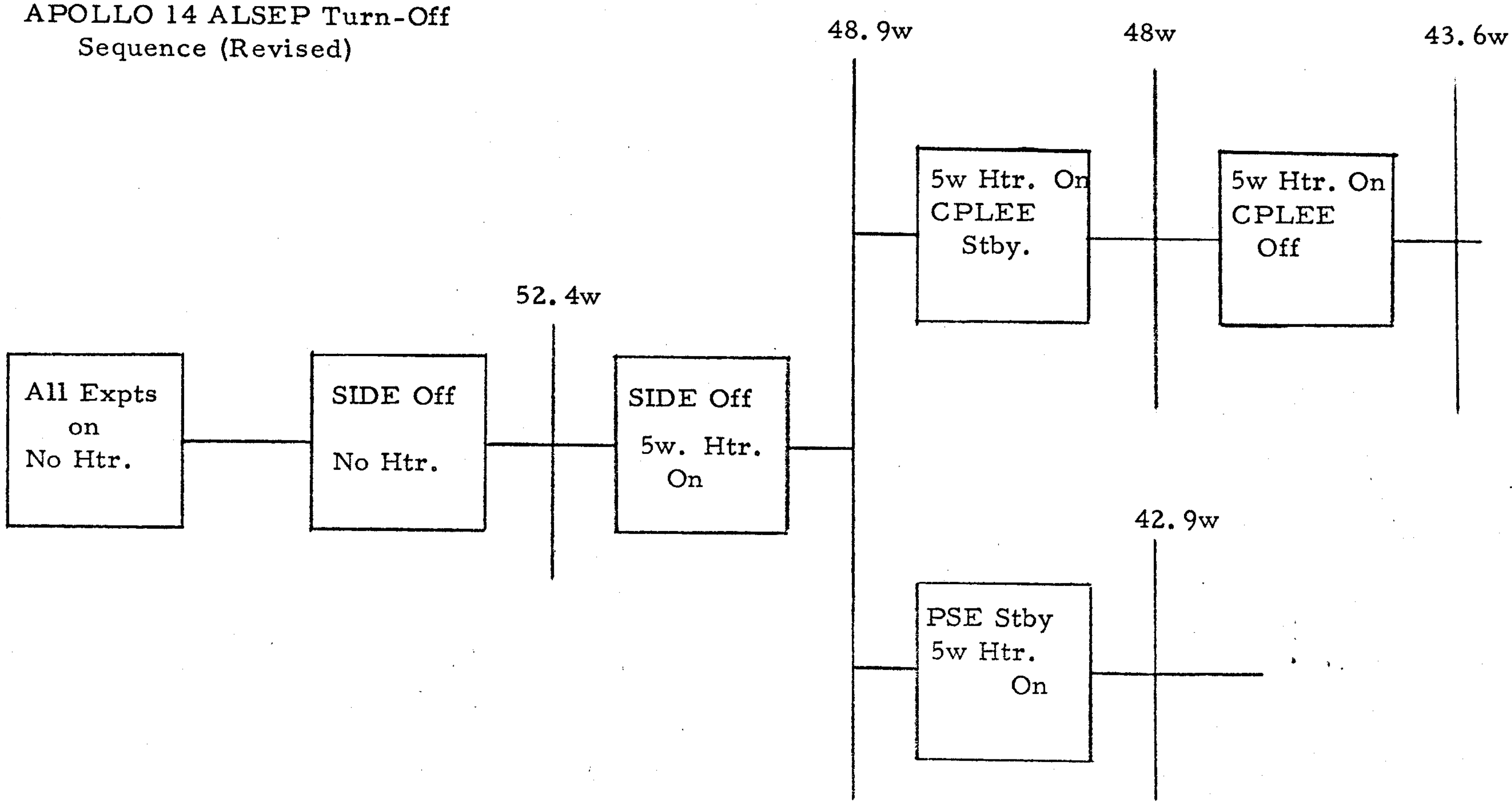


Figure 12 A

APOLLO 14 ALSEP Turn-Off
Sequence (Revised)



activation of the ripple off circuits. From the curve of Figure 7, it is seen that RTG power will not drop to 48.9 watts until after the 100th lunation or almost four (4) years from January 1975. Actual readings are quite close to the curve; however, more recent readings are about 1 watt below the curve. This may require adjustment of the equation as more operational data are obtained and will be checked on the next revision of this TM.

4.1.3 Apollo 15, ALSEP Turn Off Sequence

The available options and recommended power level decision points including three (3) optional experiment termination sequences are shown in Figure 13. On 14 June 1974, both the SWS and LSM experiments were commanded to OFF when the RTG power reached a level of 68.79 watts (on day 153). The next decision point will be reached when RTG power drops to about 56.4 watts: from Figure 8 this should not occur near the 53rd lunation near the end of 1975. RTG power will be monitored and this prediction re-examined for the next revision of this TM.

4.1.4 Apollo 16, ALSEP Turn Off Sequence

The two options and power level decision points are shown in Figure 14. The Heat Flow experiment is inoperative and Active Seismic experiment is normally OFF except for infrequent listening periods, leaving only two possible options, which include turning PSE to standby. No decisions are likely to be required for approximately 2-1/2 years-near July of 1977.

4.1.5 Apollo 17, ALSEP Turn Off Sequence

The power subsystem design provides for automatic management of available reserve power; therefore the Apollo 17 experiments may be turned off in any preferred sequence which may be dictated by scientific requirements or functional status. The excess power is automatically controlled by dissipating it either into the heaters on the thermal plate or into the external load resistor as required by the thermostat which senses thermal plate temperatures.

The power at which action must be taken to turn an experiment to standby or off is 64 watts for a fully operating system, operating down to -10^{o}F, or 60.5 watts for a fully operating system, operating to -22^{o}F. The temperatures are average thermal plate temperatures.

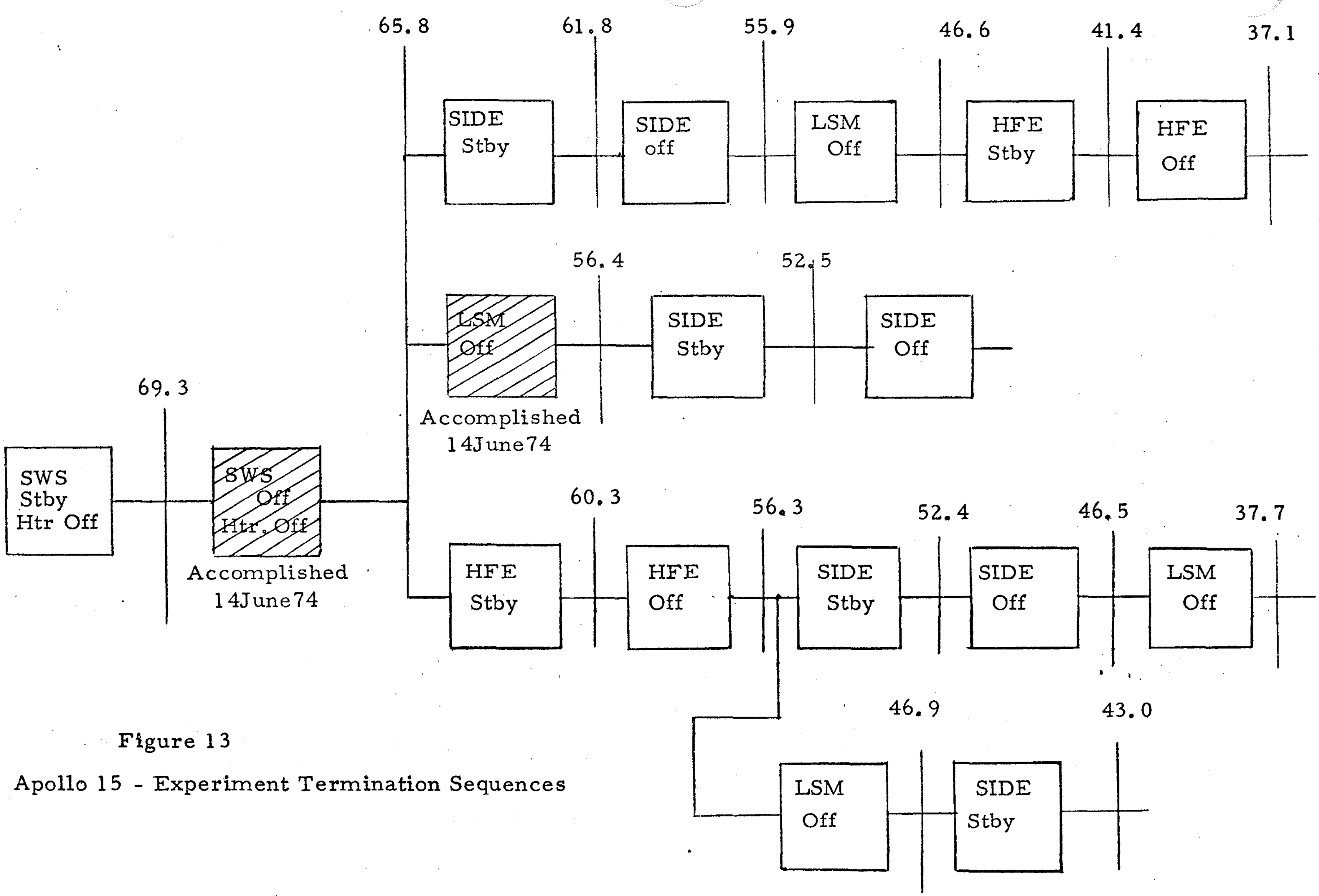
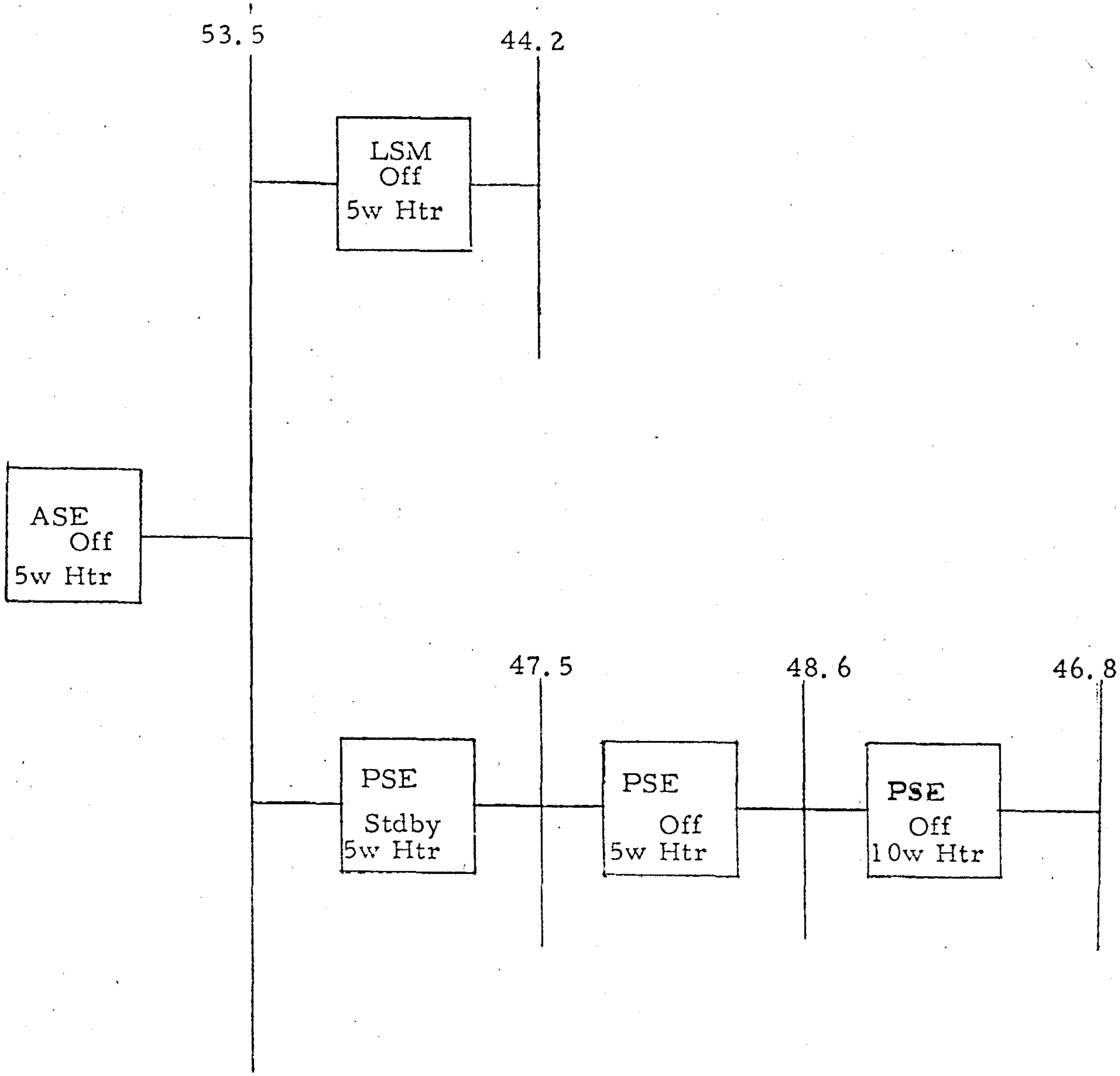


Figure 13

Apollo 15 - Experiment Termination Sequences

Figure 14

Apollo 16 - Experiment Termination Sequences



The minimum RTG power required to maintain -10°F as the average thermal plate temperature is given by,

RTG power = 33.5 + sum of all experiment powers

or

RTG power = 30 + sum of all experiment power, for -22°F.

Thus the required power levels can be determined for any combination of experiments. The experiment load should be calculated from the telemetered values of RTG power, reserve power, etc. No actions are likely to be required for about 2 more years of operation. Additionally, since the LACE operation is questionable, it may be the prime candidate for termination thus extending other A17 experiments for an even longer period.

4.1.6 Summary

The RTG power degradation curves shown in Figures 6 through 10 for the Apollo 12 through 17 ALSEPs respectively, have been updated by adding actual operating power level data obtained from central station printouts. Day/night power on Apollo 17 ALSEP shows a delta of about 1.5 watts as shown on Figure 10. All power values are in close agreement with the basic curves published with the September 1974 issue of this TM. Thus the estimates given for required actions to adjust loads appear to be valid using the presently available data. These will be re-evaluated as further operational history is obtained.

4.2 Engineering Test Recommendations

The primary objective of each ALSEP mission is to obtain the maximum amount of scientific data possible from the operational instruments. While it is recognized that this objective must not be compromised, it is also important to note that data of significant engineering value are continuously available from these operating systems. When a final decision is made (expected to be several years hence) that the scientific usefulness of the ALSEP systems is at an end, a plan should be available for conduct of engineering test prior to final station shutdown.

Each of the central stations contains component redundancy which may not have been exercised during the course of the mission. It is important that these components be tested - valuable "shelf life" data may result. Although a redundant component or section may have been inoperative due to a suspected failure, it should still be subjected to "end-of-mission" operational tests unless such tests are considered hazardous in terms of affecting future system operation such as response to a transmitter off command. Additionally, it is recommended that all systems be operated as long as power is available from the RTG. Continued carefully planned tests with monitoring on an intermittent (rather than full time) basis would result in a cost effective but valuable engineering test program for the ALSEP hardware. Operations of the hardware between test periods would be in an unattended, transmitter off mode.

4.2.1 Recommended Test Plan

Objective - Obtain status information on redundant subsystems and/or circuits which have, for the most part, been unused during the lunar mission. An extensive series of tests does not appear necessary; hence recommendations are limited to obtaining go-no/go indications at maximum and minimum temperature extremes. The PCU test should be performed last, otherwise the sequence is not critical unless some previous anomaly indicates a potential hazardous condition.

Each test is a three step sequence:

1. Transmit command to exercise redundant element.

2. Observe and evaluate response.

3. Transmit command for return to prime subsystem.

The following specific tests are recommended for Apollo 12-16 ALSEPs.

Test #1 — Transmit selected command using alternate command decoder address. The command selected should produce an abservable system response which can be seen in the downlink telemetry: experiment power control OFF-STANDBY-OFF is suggested.

This test should be performed at or near minimum ($\pm$ 5°F) average thermal plate temperature.

Observation - verify CVW in downlink and status change for AB-4 or AB-5.

Test #2 — At or near minimum ($\pm$ 5°F) average thermal plate temperature, transmit command to select alternate data processor. Note that Apollo 12 ALSEP data processor may have failed.

Observation - verify sync loss, lock-up and telemetry data processing from alternate data processor. For Apollo 16 ALSEP, verify change in AB-6 (Data Processor X ON/OFF).

Transmit command to select original processor.

Test #3 — Photograph (for reference) the downlink PCM waveform. At or near minimum ($\pm$ 5°F) thermal plate temperature, transmit command to select redundant transmitter.

Observation - verify loss of sync and re-sync. Measure signal strength, downlink frequency and photograph PCM waveform.

Transmit command to select original transmitter. Verify transmitter switch.

Test #4 — Repeat tests #1, 2 & 3 at or near maximum ($\pm$ 5°F) average thermal plate temperature.

Test #5 — At or near maximum (± 5°F) average thermal plate temperature, transmit command to select redundant PCU.

Observation - verify PCU switch via telemetry. Check values of all PCU output voltages, RTG voltage and current.

Transmit command to select original PCU.

Test #6 — Repeat test #5 at or near minimum (± 5°F) average thermal plate temperature.

The following tests are recommended for Apollo 17 ALSEP (Array E).

Test #1 — At or near minimum (± 5°F) average thermal plate temperature, transmit command to select alternate analog data processor (command octal 024 or 025).

Observation - verify processing of engineering status data.

Test #2 — At or near minimum (± 5°F) average thermal plate temperature, transmit command to select alternate Digital Data Processor (command octal 034 or 035).

Observation - verify change in AB-10 and correct processing of telemetry data.

Test #3 — At or near minimum (± 5°F) average thermal plate temperature, transmit command to select alternate analog data processor (command octal 025 or 024).

Observation - verify processing of engineering status data.

Transmit command to select alternate Digital Data Processor (command octal 035 or 034).

Test #4

Photograph (for reference) the downlink PCM waveform. At or near minimum (± 5°F) average thermal plate temperature, transmit command to select redundant transmitter.

Observation - verify loss of sync and re-sync. Measure signal strength, downlink frequency and photograph PC waveform.

Transmit command to select original transmitter. Verify transmitter switch.

Test #5

Repeat tests #1, #2, #3 and #4 ar or near maximum (± 5°F) average thermal plate temperature.

Test #6

This test will consist of steps to verify redundant uplink components and alternate power routing circuits. It should be noted that the redundant command link is suspect since the anomaly of August 1974.

Discontinue the operational procedure which requires periodic transmission of command octal 105 - "Periodic Commands Inhibit".

Observation - allow the on-board timer controled functions to select redundant components and circuits. Verify that automatic selection occurs and performance of redundant elements by telemetry and command processing. Allow the periodic switching to occur for one complete lunation.

Test #7

At or near maximum (± 5°F) temperature of the thermal plate, transmit command to select redundant PCU.

Observation - verify PCU switch via telemetry; check valves of PCU and put voltages, RTG voltage and current and reserve power.

Transmit command to select original PCU. Repeat Test #7 sequence at minimum temperatures.