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TITLE- Command Problems on AS-202, AS-501 and AS-204/LM-1 Missions

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AUTHOR(S)- I. I. Rosenblum

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ABSTRACT

The Apollo program command system operations during the AS-202, AS-501 and AS-204/LM-1 missions are reviewed. A brief description of the command system configuration for each mission is given. The command system performance during flight is examined and summarized in tabular form to indicate total command words attempted from each site with both USB and UHF systems, and results. Specific command system problems arising on each mission are described, based on referenced post-flight reports. A summary of command experience provided by these missions is given.

Performance data indicate that the overall command word probability of success is approximately 99 percent. This review shows that hardware failures, operator errors and system and procedural problems were evident which can be expected to decrease with additional training and experience.

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SUBJECT: Command Problems on AS-202, AS-501 and AS-204/LM-1 Missions
Case 320

DATE: December 31, 1968

FROM: I. I. Rosenblum
TM: 68-2034-11

TECHNICAL MEMORANDUM

I. INTRODUCTION

Many command system problems arose during the Apollo missions AS-202, AS-501 and AS-204/LM-1; these problems raised issues concerning the reliability and adequacy of the command system design for future operations. As part of a general investigation by Bellcomm, the command system experience of these missions was reviewed and the performance determined with the following results.

II. AS-202 Mission

The command system experience on AS-202 was limited because:

1. the flight duration was short (ballistic shot),
2. only 2 stations were involved with actual commands, and
3. only 9 UHF real time command words were sent.

Of the command words sent, 1 was successful and 8 were unsuccessful. The major command system difficulties were:

(a) command failures at UHF which were attributed to a specific hardware problem (improper tone frequencies),

(b) hardware and procedural problems which occurred with the USB equipment even though no functional command testing was undertaken.

III. AS-501 Mission

The AS-501 mission provided extensive experience with both the UHF and USB command systems. In brief:

1. The mission covered 3 orbits.
2. 10 stations participated in exercising the command system.

3. At UHF, 99 command words were transmitted to the CSM. Six (6) were not properly received.

4. Via USB 143 command words (12, 22 and 30 bit) were transmitted to the CSM. Seven (7) were not properly received.

5. Via USB 5802 command words (35 bit flight and test words) were transmitted to the SIVB/IU. Nine (9) were not properly received.

6. Principal command system problems indicated were:

   (a) hardware failures,

   (b) operator errors,

   (c) insufficient operator training and instruction.

IV. <u>AS-204/LM-1 Mission</u>

The AS-204/LM-1 mission resulted in additional UHF command system experience and the repetition of some of the same types of problems observed previously. In summary:

1. MSFN sites were in contact with LM-1 or SIVB/IU during 5 orbital passes.

2. Seven stations participated in exercising the command system (only at UHF).

3. A total of 686 words (12 and 22 bits) were transmitted to the LM-1. Thirty-seven (37) were not verified as being received.

4. A total of 14 words (35 bits) were transmitted to the SIVB/IU. Seven (7) were not verified.

5. Principal command system problems indicated were:

   (a) Hardware failures in MSFN network equipment.

   (b) A LM spacecraft failure in the UHF RF circuitry significantly impaired command signal reception.

   (c) Operator errors.

   (d) System and procedural problems.

   (e) Station coverage limitations.

V. Results

The principal results deriving from the review of command system performance on these three missions are:

1. The overall command word "probability of success" is approximately 99%. During the three missions considered, a total of 6753 structured (12, 22, 30 or 35 bit) words were commanded and a total of 69 command words were not successful.

2. Hardware failures, primarily involving MSFN equipments, capable of adversely affecting command system operation were indicated on all three missions. Many of these problems, however, were associated with the UHF command system which is not planned to be used on future Apollo lunar missions. The USB command equipment exhibited characteristics of hardware maturity.

3. Many problems in commanding were traceable to operator errors stemming from several causes including incomplete procedures, insufficient training and unforeseen constraints in supporting mission operations. As additional mission experience is gained, as handbook procedures are updated and revised and as network personnel become more familiar with system and mission constraints it is expected that the command system performance will improve.

4. The detailed command system problems that arose on these Apollo missions, on examination, are neither surprising nor discouraging. They are typical of those to be expected when exercising new missions, new systems, new software, new personnel along with revised procedures and slightly different communications. An order of magnitude improvement in command system reliability in subsequent missions is, to the writer, a reasonable expectation, taking into account the diminishing effect with time of the factors cited above.

VI. Data

In Appendices A, B and C, respectively, each of the missions is discussed in more detail. Each of these Appendices is organized as follows: A short description of the mission is given in part 1.0, followed by an explanation of the command system configuration for the mission in part 2.0. A summary of the command system(s) performance is then presented in section 3.0 including tabulations of command word attempts and rejects. Part 4.0 enumerates the detailed problems of significance associated with the command system during the mission and part 5.0 provides a summary for that mission.

The information provided in this memorandum is garnered primarily from the review of post-mission reports as available from MSC, GSFC and MSFC. These are listed in the table of references.

Abbreviations and acronyms used in this memorandum are given in a glossary.

I. I. Rosenblum

I. I. Rosenblum

2034-IIR-$\frac{ulg}{ew}$

Attachments
Appendices A, B, & C

GLOSSARY

AGC	Automatic Gain Control
AOS	Acquisition of Signal
APS	Ascent Propulsion System
AS	Apollo - Saturn
BDA	Bermuda
BSE	Booster System Engineer
CAM	Computer Address Matrix
CCATS	Communications, Command and Telemetry System
CCS	Command and Communication System (in IU)
CIM	Computer Input Multiplexer
CLT	Communications Line Terminal
CP	Communications Processor
CM	Command Module
CRO	Carnarvon
CSQ	Coastal Sentry Quebec (Ship)
DCS	Digital Command System
DPS	Descent Propulsion System
DSC-1	Dynamic Standby Computer #1
EECOM	Electrical, Environmental Communications System Engineer (Flight Control At MCC)
EMU	Erasable Memory Unit; also External Memory Unit
ET	English Translation
FITH	Fire in the Hole

GCC	Ground Communications Coordinator
HSD	High Speed Data
I/O	Input - Output
ISA	Input System Adapter
IU	Instrument Unit
LGC	LM Guidance Computer
$K\bar{K}K$	Message Complement Check in CM
LM	Lunar Module
LMP	LM Programmer
LOS	Loss of Signal
M&O	Maintenance & Operations
MAP	Message Acceptance Pulse (Or Pattern)
MCC	Mission Control Center (Houston)
MED	Manual Entry Device
MFED	Manned Flight Engineering Div. (GSFC)
MIL	Merritt Island
MOC-1	Mission Operations Computer #1
PBT	Polynomial Buffer Terminal
PGNCS	Primary Guidance Navig. and Control System
PRA	Program Reader Assembly
PSK	Phase Shift Keying
RCS	Reaction Control System
RS	Remote Site
RT	Real Time
RTC	Real Time Command (or Controller)
RTCC	Real Time Computer Complex
S/C	Spacecraft

SCM	Station Configuration Message
SCO	Subcarrier Oscillator
SDU	Spectrum Display Unit
SPS	Service Propulsion System
SM	Service Module
T	Time
TIC	TLM & Instrumentation Console (or Controller)
TLM	Telemetry
TTS	Training & Test Satellite
VAL	Validation
VHF	Very High Frequency
UHF	Ultra High Frequency

REFERENCES

1. "Performance Evaluation of Unified S-Band Ground System for AS-202," October 14, 1966, Goddard Space Flight Center (GSFC).

2. "Supplemental Report on Communication System Performance During Mission AS-202," October 12, 1966, ISD, Manned Spacecraft Center (MSC), Houston, Texas, EB-67-3314-U.

3. "Postlaunch Report for Mission AS-202," October 12, 1966, MSC, Houston, Texas.

4. "Apollo Commanding," Memorandum For File, Robert O. Aller, NASA Headquarters/MAO, December 29, 1967.

5. "Performance Evaluation of the Unified S-Band Ground System for AS-501," X-834-68-4, GSFC, January 1968.

6. "Network Controller's Mission Report AS-501," Lawrence Lonero, MSC, November 1967.

7. "Network Operations Manager's Report for AS-501 Mission," GSFC, November 1967.

8. "CCS Command System Performance on AS-501" - Presentation at Marshall Space Flight Center (MSFC), March 7, 1968 by D. Harris.

9. "Apollo 4 Mission Report," MSC PA-R-68-1 (c), January 7, 1968.

10. "Performance Evaluation of the Unified S-Band Ground System for AS-204 LM," March 1968, GSFC, Greenbelt, Maryland.

11. "Network Controller's Mission Report Apollo 5," January 1968, MSC, Houston, Texas.

12. "Network Operations Manager's Report for AS-204 Mission," January 1968, GSFC, Greenbelt, Maryland.

13. "Results of the Fourth IB Launch Vehicle Test Flight," MSFC, Report Number MPR-SAT-FE-68-2, April 5, 1968 (AS 204).

APPENDIX A

AS-202 COMMAND HISTORY

1.0 AS-202 Mission Description

The Apollo AS-202 mission on August 25, 1966 was a launch which was followed by a ballistic trajectory. The Coastal Sentry Quebec ship (CSQ) and three MSFN stations were involved actively in the mission. The MSFN sites were the Merritt Island Launch facility at Cape Kennedy (MIL); Bermuda tracking station (BDA); and the Carnarvon, Australia, station (CRO). MANDY and DSIF-71 at KSC, and Ascension Island (ACN) were also passively tracking the AS-202 space vehicle. Each of the stations had one view period.

The AS-202 mission provided the first opportunity for MIL, BDA, and CRO to participate in a coherent or two-way USB tracking mode, although previous missions such as Lunar Orbiter and Surveyor had provided a limited amount of one-way passive tracking experience. This was the first opportunity to evaluate the USB equipment in both the ground and spacecraft during an actual flight.

The MIL station, in addition to tracking during the launch phase, provided prelaunch and countdown checkout for the USB transponder on the pad

The launch azimuth for this mission was 105 degrees. The launch azimuth for the remainder of the Earth orbital Apollo flights is expected to be 72 degrees. The 105-degree launch azimuth provided one of the more difficult tracks for the Bermuda station, since the elevation angle never exceeded 8.6 degrees; and, consequently, the spacecraft passed through the antenna keyhole. This necessitated the performing of certain tracking operations not normally encountered during the launch and insertion phase tracking.

Certain operational aspects of the USB system were exercised during this mission. These were:

1. Two-way acquisition (up-link and down-link frequency lock)

2. One-way acquisition (down-link frequency lock)

3. Handover (transfer of active track from one station to another)

2.0 Command System Configuration

AS-202 flight tested both USB and UHF flight hardware; however, only the UHF on-board equipment was functionally utilized for command purposes, and that use was very limited. The command sites of the MSFN that were up for this mission were:

USB	UHF
	MIL
	BDA
CRO	CRO
	CSQ

USB command system exercise was confined to the transmission of the unmodulated command subcarrier (70 kHz).

3.0 AS-202 Command Summary

Command system usage on the AS-202 mission was meager, consisting of the attempted transmission at UHF of the following commands:

From MIL: - 1 RTC* (Antenna Switchover) @T+207 seconds (Successful)
From CSQ: - 4 RTC's (CM/SM Separation) @T+4302 (Unsuccessful)
From CSQ: - 4 RTC's (CM/SM Separation) @T+4316 (Unscucessful)

4.0 AS-202 Command System Problems

The noteworthy mission difficulties directly or indirectly reflecting on command system performance capability were:

4.1 UHF

a) The CSQ ship used incorrect frequencies for PSK sync and data signals resulting in rejected UHF commands for CM/SM separation. Also, the CSQ digital command system was possibly operating in the test mode.

4.2 USB

a) Inability of operator to recognize two-way lock at CRO.

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*See Glossary for Acronyms

b) Failure of AGC meter (driven by VHF telemetry) to read transponder AGC voltage contributed to inability to obtain two-way lock at CRO. Post-mission tests confirmed proper meter circuit operation. Cause is unknown.

c) Shorted cable shield in the acquisition sweep circuitry caused loss of transponder lock several times during the CRO acquisition attempts.

d) A "loss of command capability" occurred during the zero beat handover from BDA due to a combination of factors including (a) weak spacecraft signals, (b) antenna side-lobe tracking, and (c) keyhole tracking difficulties.

e) At CRO, prior to achieving up-link lock, modulation was applied to the up-link signal causing degradation on both up and down links.

f) Evidence of flame attenuation at about T+100 to T+120 seconds indicated that loss of command capability could occur on future flights (with larger boosters or less favorable antenna patterns) although such loss did not occur on AS-202.

5.0 SUMMARY

The command system difficulties appear to be distributed among operator errors, hardware problems and deficient procedures. Post-flight reporting (reference 1) indicated an awareness of these problems and recommended the institution of appropriate changes in design, operational techniques, test procedure and training.

APPENDIX B

AS-501 (Apollo 4) COMMAND HISTORY

1.0 AS-501 Mission Description

The AS-501 mission, on November 9, 1967, the first of the AS-500 series, was an unmanned mission. The vehicle for the AS-501 mission launched from complex 39 of the Eastern Test Range (ETR), Cape Kennedy, Florida, at a launch azimuth of 90 degrees from North. Main mission features are illustrated in Figure 1. After an 11-second vertical rise, the vehicle performed a roll maneuver to achieve the programmed flight azimuth of 72 degrees from True North. At an approximate altitude of 200,000 feet, the S-IC stage separated from the S-II booster following the S-II engine ignition at 2 minutes and 36 seconds after liftoff. At approximately 300,000 feet, the Launch Escape System (LES) jettisoned from the booster. The S-II stage separated after the S-IVB burn provided the thrust to place the spacecraft into a near-circular parking orbit at an approximate altitude of 100 nautical miles. After two orbits and while the vehicle was over the Eastern Test Range, a second S-IVB burn of 5-minute duration injected the spacecraft into an earth-intersecting coast ellipse with a 9767-nautical mile apogee. Approximately 10 minutes following S-IVB engine cutoff, CSM/S-IVB separation occurred, and the Service Propulsion System (SPS) engine ignited for a short-duration burn. On the earth-intersection coast return, an SPS engine burn accelerated the spacecraft to the approximate speed of a returning lunar flight. During the 4-minute coast phase between SPS engine cutoff and Command Module (CM) atmospheric reentry, the Service Module (SM) separated from the CM. Reentry of the CM began at 400,000 feet. Command Module splashdown occurred at 30:06 degrees north latitude and 172:32 degrees west longitude, at 8 hours and 37 minutes after liftoff.

MAJOR MISSION EVENTS

Event	GMT hrs	GMT min	GMT sec
Liftoff	12	00	01
S-II ignition	12	02	36
Jettison LES	12	03	11
First S-IVB ignition	12	08	46
Begin parking orbit	12	11	16
S-IVB reignition	15	12	27
Injection into translunar orbit	15	17	02
CSM/S-IVB separation	15	28	08

MAJOR MISSION EVENTS (Contd)

Event	GMT hrs	GMT min	GMT sec
First SPS ignition	15	28	06
First SPS shutdown	15	28	22
Apogee	17	46	48
Second SPS ignition	20	10	54
Second SPS shutdown	20	15	25
CM/SM separation	20	18	01
Reentry	20	19	26
CM splash	20	37	31

2.0 Command System Configuration

The AS-501 mission employed both a UHF command system and the Unified S-Band (USB) system for command functions to the CSM and a USB type system, the Communications and Command System (CCS) on the S-IVB/IU. Telemetry verification was provided by both S-Band and VHF telemetry. Figure 2 shows the command system configuration for AS-501.

3.0 AS-501 Command Summary

On AS-501 a total of 242 commands (words) were sent to the CSM and a total of 5802 commands, including test words, were sent to the S-IVB/IU. Table I summarizes the commands given at each command site of the network and provide explanation of command rejects where available.

In Table I and in Tables II and III which follow, the total structured words for all commands attempted, i.e., directed for transmission, are counted; including repeats, unsuccessfully dispatched command words, pre-amble, enter, data, computer, timing and test words, based on available information.

4.0 AS-501 Command System Problems

A number of commanding difficulties arose during the AS-501 mission. These problems included hardware, software, procedural and operator error problems and involved both the CSM and S-IVB/IU (CCS) command systems.

The detail problems of the mission, as reported in reference reports, are summarized below:

4.1 BDA - Prelaunch - Program Loading Improper - At T-2 minutes the program came to a "seven" stop. This was an operator error by the computer technician. Stop key seven is set during the bootstrap loading and should be reset during program loading. Resetting of the key and restarting the program cleared the problem in a few seconds. (Ref. 6, page 53).

4.2 MIL - REV. 3 - Uplink Commands Attempted In 1-A Mode - Before Revolution 3, MIL placed the IU/CCS subcarrier oscillator (SCO) in the 1-A (carrier and PRN ranging only) per the SCM. After two-way lock was achieved, uplink of S-IVB "SS command 1" was attempted while still in the 1-A mode. Apparently on the third attempt, the command was processed by the 70-kHz subcarrier oscillator and subsequently validly received by the S-IVB. However, the accompanying data words were not so processed and uplink was reinitialized after completion of the three retransmission attempts. About this time, the MIL M&O switched the SCO to mode 1-E and uplink was again reinitialized. However, since the mode word had been accepted by the spacecraft computer and it was looking for data words, the subsequent transmissions of the original mode word were rejected. During this period, one ground reject was observed, but appears to be associated with a program problem. The problem of the command processed while the SCO was in the 1-A mode appears to be an anomaly in the hardware. The MFED is investigating this area, and appropriate modifications will be made. (Ref. 5, page 7-15).

4.3 BDA - REV.3 - Uplink Commands Attempted While Locked On Spur (Component of Range Code) - On Rev. #3 at BDA, EECOM attempted to uplink RTC 70 three times, but received S/C rejects. The S/C Telemetry indicated insufficient signal strength (BDA had lost two-way lock). BDA requested permission to sweep the exciter with the command subcarrier off but permission was denied and additional command was attempted even though BDA did not have valid lock. After the third reject, handover to VAN was initiated. BDA apparently had established 2-way lock on a component of the range code. (Ref. 7, page 30).

4.4 GDS - REV. 1 - Failed to Assume 2-Way Lock On IU/CCS - During the Rev. 1 pass GYM was tracking IU and the command program had faulted. The Controller (RTC) advised GDS in real-time to take two-way lock, however, the vehicle was not identified. GDS reported two-way lock on CSM. At 20 seconds before LOS, RTC advised GDS to take two-way lock on IU. By the time GDS reacted, LOS had occurred. (Ref. 6, page 54).

4.5 GYM - REV. 1 - Command Program Faulted - 642B Computer Failure - The command program faulted on the first pass. Postpass checkout was successfully completed but chassis A-12 and A-13 of the command computer were replaced. Postmission checkout revealed a sense amplifier bias varying. Regulator A1A1303 of chassis A-13 (command 642B) was replaced. This appeared to clear up the intermittent memory problem. (Ref. 5, page 7-5).

4.6 TEX - REV. 1 - Continuous Uplink of Priority Command Because of Failure of MCC-H To Clear - On Rev. #1 the Booster System Engineer at MCC-H had executed Special #1 command and did not execute the priority clear before handover to MIL from TEX. The M&O at TEX could not obtain priority clear and finally cleared the system by setting skip switch #3, which simulated a spacecraft MAP. Continuous uplinking of Special #1 occurred until clearance was accomplished. (Ref. 6, page 5).

4.7 TEX -REV. 2 - Failure to Transmit Valid Command Analysis Patterns (CAP's) from TEX To MCC-H - During Rev. 2, TEX uplinked thirty-six 35-bit words to the S-IVB with valid ground and space vehicle verification at TEX but lack of spacecraft verification to MSC. This appears to be a software problem between TEX and MSC/RTCC and will be pursued further. (Ref. 5, page 7-16).

4.8 BDA - Launch Through REV. 2 - H. S. Printer Buffer Inoperative - From launch through Rev. 2, the 1222 high-speed printer buffer at BDA was RED- "Cannot Support". This resulted in the M&O being unable to verify a high-speed data format change or command functions when requested by MCC-H. The format change could be verified by the computer technician at the 1232 I/O console and all MCC-H Commanding was verified by the 2.4 kbps high-speed telemetry. The problem was connected by a card change, prior to Rev. 3. (Ref. 7, page 55).

4.9 CRO - REV. 2 - Failure of UHF Transmitter #1 - On Rev. 2 CRO had problems uplinking on UHF to the CSM. This appears to have been the result of a misaligned UHF transmitter caused by a faulty piece of test equipment. A switchover to the standby transmitter resulted in the valid uplink of commands. Post mission evaluation indicated an improper level in the signal from the updata buffer. (Ref. 6, page 31).

4.10 MIL - Launch Phase - Signal Dropouts Due to Flame Attention, etc. - Some loss in command capability of the CCS system occurred during launch due to flame effects at separation, etc., on the uplink data or downlink TM (verification) signals. Uplink dropouts of the 70 kc subcarrier included:

(a)	S-IC/S-II Separation	1.0 seconds
(b)	Interstage Jettison	.6 seconds
(c)	Unexplained Dropout At 189.3 seconds	.5 seconds

Downlink dropouts were:

(a)	S-IC/S-II Separation	13 seconds
(b)	Interstage Jettison	8 seconds
(c)	Unexplained Dropout At 189.3 seconds	13.5 seconds
(d)	Handover to MILA	3.5 seconds

(Ref. 8)

4.11 TEX - All Mission - Lack of Part For UHF Transmitter - TEX was RED for an RF rotary switch (S-II) for the FRW-2, No. 2 backup transmitter. The part was received on station 10 Nov., one day too late. (Ref. 7, page 51).

4.12 GYM - REV. 2 - Faulty Circuit Cards Inhibited Command History - After LOS Rev. 2, a command history was requested using CAM 044. The computer interpreted as an 844. Replacing circuit cards in the input system adapter (ISA) cleared the problem. No data was lost. (Ref. 7, page 56).

4.13 Several Sites - All REV's - Excessive Phase Shift Between 2 kHz and 1 kHz tones - Phase shift of the 2 kHz oscillator frequency with respect to the 1 kHz signal was excessive at several stations. For comparison with a nominal 45° phase shift limit for successful commanding, the values found from postflight evaluation of verification receiver No. 1 command waveforms as recorded on tape were: MIL 34°, CRO 41°, ACN 34°. (Ref. 8).

4.14 HAW - REV. 2, CRO REV. 1, 3 - Modulation Discrepancies - A total of 8 commands generated at HAW and CRO were rejected by the S-IVB/IU vehicle decoder because of modulation discrepancies such as:

Subcarrier Interrupted

No Subcarrier Modulation

Transmission Shortened

No Vehicle Address

Incorrect Sub-Bit Pattern

Large Amplitude Fluctuations (Ref. 8).

4.15 ACN - REV. 3 - Command K$\bar{K}$K Failure In CSM - On Rev. 3 at 05:24:17, ACN attempted a navigation update with the S/C near apogee. The first transmitted sequence, the word VERB was accepted by the updata receiver/decoder and transferred to the computer. The following word SEVEN was transmitted and accepted by the updata receiver/decoder; however, the K$\bar{K}$K check, a redundancy check of the transmitted keycode characters by the computer failed and the data was rejected by the computer, resulting in an uplink block condition. This was cleared by the transmission of a clearing sequence after which the navigation update was transmitted. All computer update words were accepted by the computer without reoccurrence of the K$\bar{K}$K check failure. Because the S/C was at maximum slant range with the highest probability of errors, this load was transmitted with AGC OVERRIDE OFF. Evaluation after the mission showed that the SEVEN word had been transmitted with the correct bit structure, and was accepted by the updata receiver/decoder. The K$\bar{K}$K failure apparently occurred at the interface between the receiver/decoder and the guidance computer 15 bit register. (Ref. 9).

4.16 GWM - REV. 3 - Time Delay Problem - An apparent problem developed in transmitting an SPS engine shutdown command from GUAM on REV. 3. Since a message acceptance signal was not immediately received at MCC-H, three automatic retransmissions of the message took place. However, the time delays in the command validation loop (about 1 second) are enough to account for the three automatic retransmissions, and telemetry data confirmed updata receiver/decoder acceptance of all four commands.

A similar problem was experienced at GUAM on the same pass with the SPS ON/OFF reset command. In this case a second command was sent about 8 seconds after the initial command because of a delay at MCC-H in receiving message acceptance. Telemetry confirmed receiver/decoder acceptance of both signals. (Ref. 9).

4.17 TEX, MIL, BDA, VAN - REV. 2 - Extended Interruption In Command Coverage - A question as to the adequacy of the USB command system arose as a consequence of a series of difficulties that occurred after GDS handover to TEX on REV. 2 at T + 3:06:31. Four stations in a row experienced difficulty of one kind or another. TEX was sidelobe tracking from acquisition to handover to MIL at 3:09:01 and rejects were noted on commands sent to CCS.

Before the vehicle pass, MIL placed the IU/CCS subcarrier oscillator (SCO) in the 1-A mode (carrier and PRN ranging only) per the teletyped station configuration message (SCM). In the middle of the pass, the MIL M&O switched the SCO to mode 1-E (carrier, PRN and command).

MIL attempted command operations to CCS while still in the 1-A mode, with rejects, and after mode switch apparently experienced ground rejects associated with a program problem prior to handover to BDA at 3:14:01. BDA had lock-on and tracking difficulties and eventually locked onto a sideband (range code component) signal at 3:21:01 giving rise to S/C rejects on 3 commands to the CSM. VAN, in contingency command status, also experienced 3 command rejects of commands to the CSM as a result of failure to turn uplink modulation on prior to 3:23:27 after handover initiation from BDA at 3:22:55 and completion at 3:23:11. (Ref. 5 and 9).

4.18 CCATS CP-All REVS - Various Data Communication Problems - During the course of the AS-501 mission, the following difficulties were experienced at CCATS/CP:

a) The Polynomial Buffer Terminal (PBT) output hung up on the standby Communications Processor (CP).

b) The PBT input hung up on the standby CP.

c) The on-line CP timed out to the Mission Operations Computer #1 (MOC-1) and the Dynamic Standby Computer #1 (DSC-1) many times.

d) RTC and GCC did not receive low speed ET's on loads 4713, 4901 and 4902 to ACN and CYI.

e) TIC reported CSM data dropouts to RTCC.

f) CP to DSC 1 channel timed out 3 times.

g) CP to MOC 1 channel timed out 3 times.

h) Standby CP had to be recycled because the CP input PBT buffer count was at a dangerously low level. (Ref. 6, page 20).

4.19 All Stations - Difficulties With Signal Acquisition Throughout the mission station operators were plagued with handover errors, false locks and delayed acquisitions. Improved procedures and additional operator training, including acquisition practice with the Training and Test Satellite (TTS) and fuller use of the Spectrum Display Unit (SDU), as now planned, should improve performance on future missions.

5.0 AS-501 Summary

The AS-501 command system experience may be summarized in terms of which problem areas require further investigation and effort and which are substantially resolved as follows:

5.1 Closed Areas

a) Flame Effects During Launch

b) Hardware Failure - Computer 642B Regulator

c) Hardware Failure - H. S. Printer

d) Operator Training - Key Setting For Program Loading

e) Operator Training - Failure to Turn Modulation On.

5.2 <u>Open Areas</u>

a) Operator Training: Improper USB Lock-Up

b) Improper Station Instructions:

Which Vehicle to Track
Failure to Issue Priority Clear
Which Mode to Configure For Next Pass

c) Software:

Lack of S/C Command Verification To MCC-H (TEX)
Eight Instances of Modulation Discrepancy

d) Hardware Problems:

UHF Transmitter #1/Up-Data Buffer
Phase Shift 1 kHz + 2 kHz Tones
Faulty Circuit Cards in Input System Adapter (ISA)

e) Spacecraft/LV Equipment:

K$\bar{K}$K Failure in CSM (ACN)
Missed SIV-B Command (SEN)

f) Time Delay:

Time Delays in Command Validation Loop Cause Unnecessary Repeats

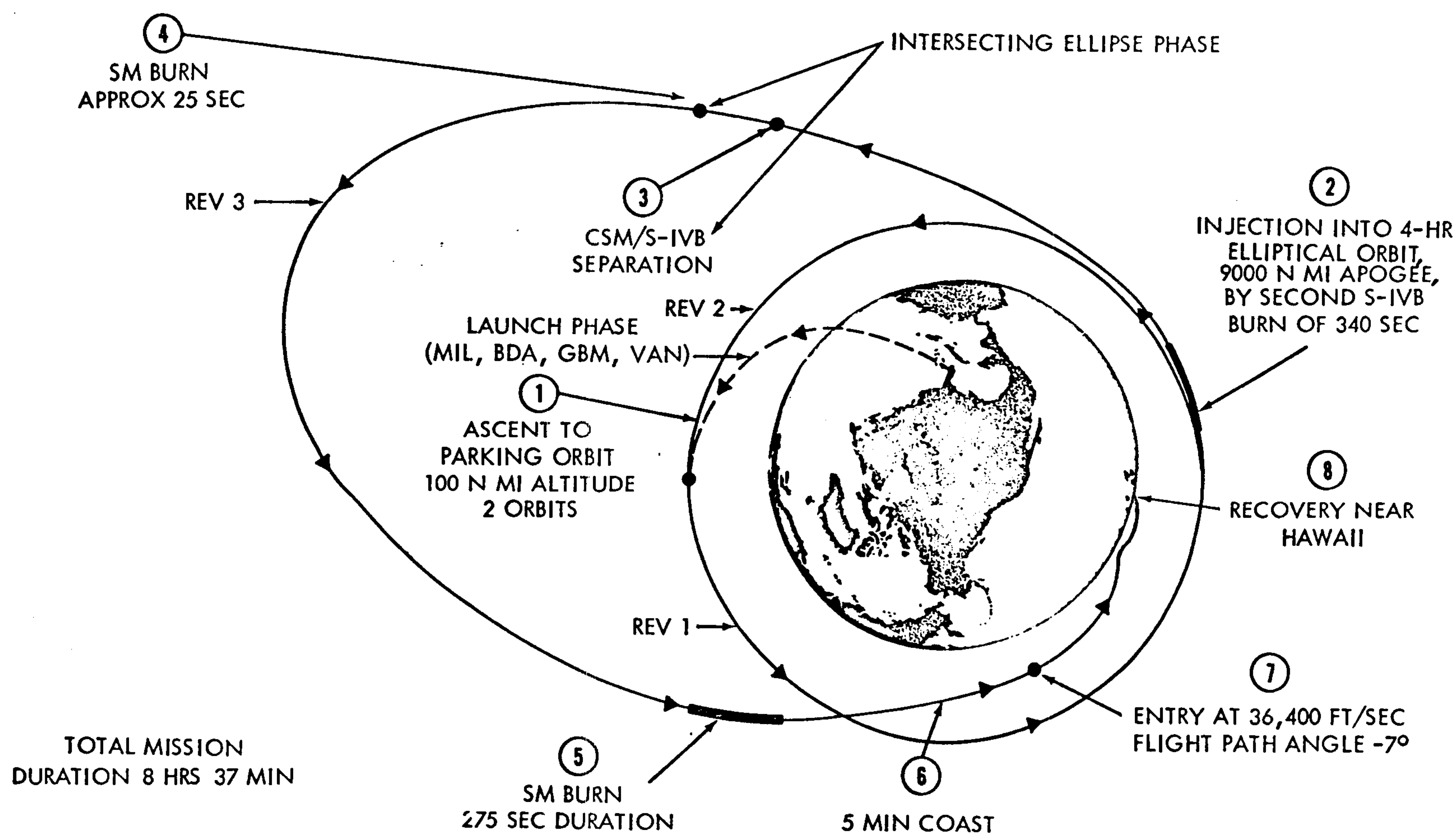


Figure 1. AS-501 Mission Description

(APPENDIX B)

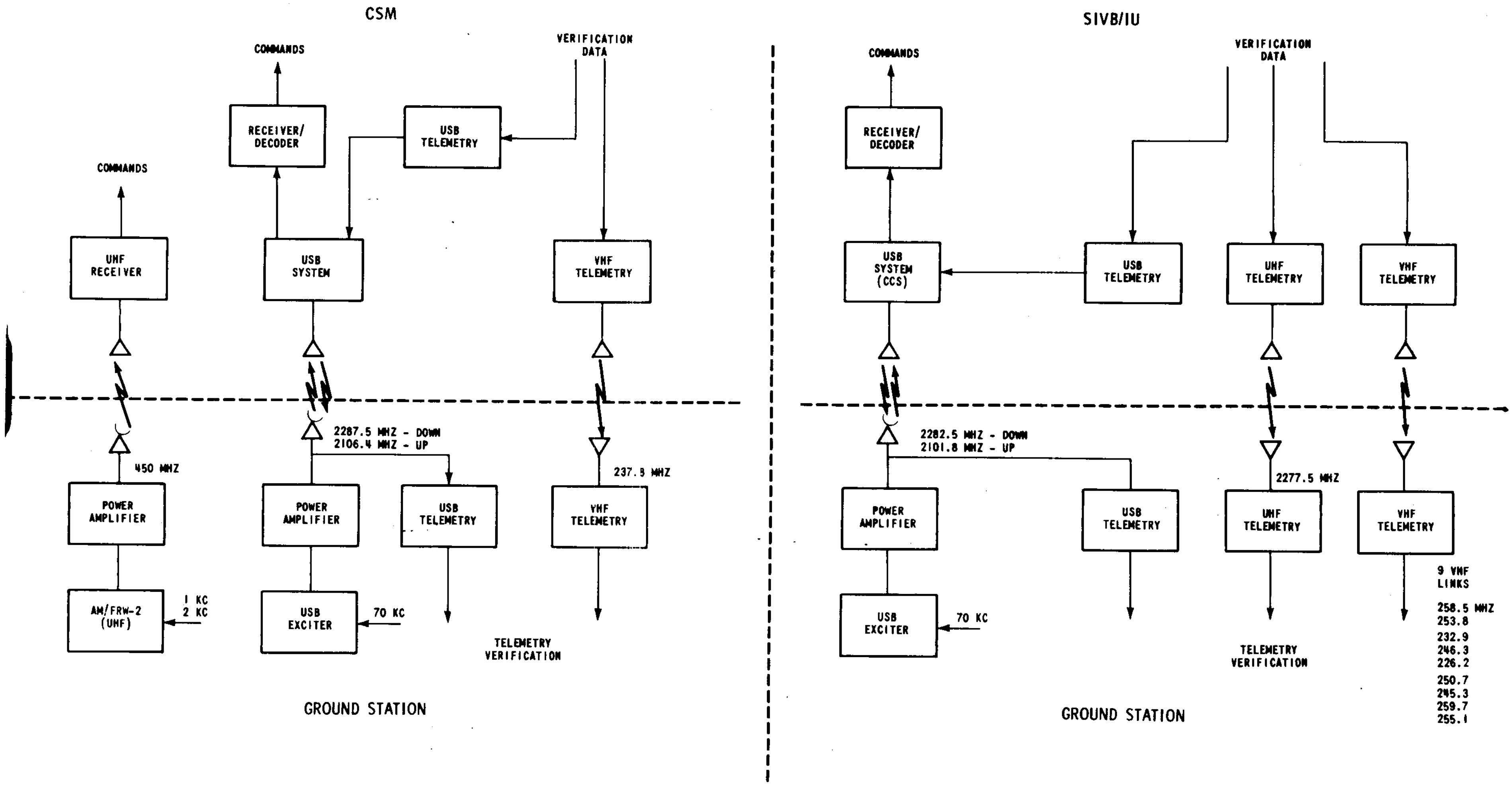


FIGURE 2 AS-501 COMMAND SYSTEM CONFIGURATION

(APPENDIX B)

TABLE 1

AS-501 COMMANDS TO CSM

SYSTEM	SITE	REV	UPLINK ATTEMPTS			S/C REJECTS	GROUND REJECTS	REASON FOR NON-VALID UP LINK AND COMMENTS
			12	22	30 BITS			
A. UHF COMMANDS TO CSM	CRO	2	1	98	0	0	6	UHF TRANSMITTER #1 FAILURE SUSPECTED OVERDEVIATION DUE TO IMPROPER LEVEL FROM THE UPDATA BUFFER
B. USB COMMANDS TO CSM	MIL	1 (PRE.L)	5	4	1	0	0	
	HAW	2	1	0	0	0	0	
	CRO	3	8	4	0	0	0	
	GWM	3	6	0	0	0	0	
	BDA	3	3	0	0	0	3	LOCK ON USB SPUR
	VAN	3	1	7	0	0	3	UPLINK MODULATION NOT ENABLED
	ACN	3	0	103	0	1	0	$K\bar{K}K$ FAILURE - 1 WORD OF NAV UPDATE
	TOTALS		25	216	1	1	12	

(APPENDIX B)

TABLE II

AS 501 COMMANDS TO SIVB

	SITE	REV	UPLINK ATTEMPTS		S/C REJECTS	GROUND REJECTS	REASON AND NON-VALID UPLINK AND COMMENTS
			35 BITS				
			TEST	FLIGHT			
USB COMMAND TO SIVB/IU	TEX	1	172		0	0	
	CRO	1	616		0	2	MODULATION DISCREPANCIES
	GYM	1	0	0	0	0	COMMAND PROGRAM FAULTED
	MIL	1/2	177		0	0	
	HAW	2	137		0	2	MODULATION DISCREPANCIES
	TEX	2		36	0	0	VALID GROUND VERIFICATION BUT LACK OF S/C VERIFICATION TO MCC-H
	MIL	2/3		5	0	0	INDICATION OF GROUND REJECTS AT MIL - WRONG MODE AND PROGRAM PROBLEM
	SEN	3	2352	119	1	0	REASON FOR MISS IS NOT KNOWN
	CRO	3	1975	213	0	4	MODULATION DISCREPANCY - INVESTIGATED FOR PROGRAM ANOMALIES
			5429	373	1	8	

(APPENDIX B)

APPENDIX C

AS-204/LM-1 (Apollo 5) Command History

1.0 AS-204/LM-1 Mission Description

The AS-204/LM-1 mission was conducted on January 22, 1968. Lift-off was at 22/2248:09Z. This mission was the first flight test of a fully configured Lunar Module (LM). The main mission features are shown in Figure 3. This mission provided the first opportunity to evaluate the LM performance in a space environment under operational conditions.

The vehicle was launched from ETR launch complex 37B at a launch azimuth of 90 degrees from true north. After a 10-second vertical rise, the vehicle rolled to a gravity-turn trajectory with a 72-degree azimuth heading. Following a coast phase after cutoff, the spent S-IB was jettisoned and the S-IVB ignited and burned until orbital insertion was achieved. During orbital coast, the S-IVB/SLA/LM was maneuvered to enhance LM/MSFN communications. Spacecraft LM Adapter (SLA) panel deployment occurred during the first revolution. After Reaction Control System (RCS) ignition, the SLA/LM restraining straps were severed and the LM withdrawn from the SLA. At the beginning of the orbital coast, the LM was maneuvered to a specified inertial attitude for the first Descent Propulsion System (DPS) burn. After this burn sequence, the LM was inserted in an orbit defined by an apogee of approximately 180 n.m. and a perigee of approximately 119 n.m., with an orbital period of approximately 90 minutes. Up to this point the mission went according to plan. However, when the first DPS burn was initiated, chamber pressure data showed that thrust built up to 9.5 per cent in about 4 seconds. An engine-off signal was received from the LM guidance system because velocity did not build up as predicted. The resulting apogee and perigee altitudes were 119.1 n.m. and 91.6 n.m., respectively. This early cutoff caused the flight plan to be shifted to alternate mission C which was the minimum requirements sequence with no schedule for a long DPS burn.

Second DPS burn was initiated at 06:10:00 (GET) and lasted 33 seconds, followed by a 32-second coast and another burn period of 28 seconds. Immediately thereafter, the first APS ignition was initiated (06:11:33), and the FITH abort staging was accomplished. The first APS burn duration was 60 seconds as planned in alternate mission C, and the resulting apogee and perigee were 520 n.m. and 94 n.m., respectively. The new trajectory resulting from the alternate plan firings considerably reduced the MSFN coverage. The resulting reduction in available ground command time led to the decision to command the second APS firing as soon as practical.

Near the end of rev. 5, the second APS burn (long duration) was initiated (07:44:19) and continued to propellant depletion at 07:50:30 under PRA control. This burn included an APS/RCS propellant interconnect test. RCS propellants were depleted during this burn, completing the primary mission.

The last contact with the LM was at GYM during rev. 5. MSFN tracked the LM until it reentered the atmosphere on February 12, at approximately 17:35 GMT.

2.0 Command System Configuration

Both the launch vehicle and the payload Lunar Module were configured on this mission to receive commands via only the UHF command system.

Figure 4 shows the LM telecommunications configuration. As shown, command capability was provided only through UHF. Telemetry command verification, however, was provided by both USB and VHF.

3.0 AS-204/LM-1 Command Summary

Table III tabulates LM and S-IVB commands attempted from each command site during the AS-204 LM-1 mission. Rejects and explanations are given where available.

Table IV details the UHF signal strength and other link conditions at the time 20 of the command rejects were noted at the MILA, HAWAII and CARNARVON sites.

4.0 AS -204 LM--1 Command Problems

Various difficulties arose with the command system in the course of the AS-204 LM-1 mission. At times the seemingly unreliable or inadequate command system performance impacted adversely on real time mission operations. Below are described the specific command problems reported during the mission.

4.1 TEX - All Revs. - Defective FRW-2 Modulator

During all passes, TEX No. 2 transmitter was "Red" for a defective modulator, apparently caused by overheating. The site configuration was such that 10 KW operation was continued since either FRW-2 transmitter could feed either 240 D power amplifier. (Reference 10, Page 6-5)

4.2 CNV - All Revs. - Backup 240 D Power Amplifier "Red"

The command destruct building at CNV (Cape Kennedy) reported backup 240 D power amplifier"Red"from 22/19:07 until mission termination. Site configuration is such that any of four FRW-2 transmitters can feed either 240 D and maintain high power uplink. (Reference 10, page 5-6)

4.3 HAW - Rev. 2 - Prime 240 Power Amplifier Failed

At HAW, just prior to revolution 2, the prime 240 D No. 2 came up on the line automatically. The No. 1 unit was brought up and stayed up as standby without failure. No apparent reason is known for the failure, but no data were lost, and operation continued normally through mission termination. (Reference 10, page 6-5)

4.4 ANT/MIL - Rev. 3 - Commands Attempted With Carrier Down

During Rev. 3, MIL uplinked two S-IVB words about 5 and 15 seconds after the UHF carriers at MIL were brought down. These two commands were uplinked through the transmitter at AMT, which was up. However, the telemetry verification loop through MIL was inoperative because of TLM LOS. Consequently, there was no valid ground loop or booster vehicle acceptance, and rejects were recorded. This is considered a procedural error and should be overcome as mission experience is gained.

Reference 13 data indicates that on this pass the ground command equipment inproperly dispatched seven (7) mode words to the SIVB/IV instead of data words. This would imply a defect in the hardware or software area rather than a procedure/experience problem. (Ref. 10, page 6-7) (Ref. 13, Table 15-1)

4.5 MIL-Rev. 3 - Rejects Because of Low Signal Strength

During Rev. 3, MIL uplinked 5 LM 22-bit words. The five LM attempts resulted in two spacecraft rejects. The command history indicates a valid ground loop; it appears the spacecraft rejects are attributable to a decrease in the spacecraft UHF receiver signal strength. An analysis of the signal levels shows the following:

Time-GMT	COMMAND	Signal Strength	MAP
01:58:21	DCA Test-35140000	-109 dbm	No
01:58:35	DCA Test-35140000	-106 dbm	No
02:01:07	DCA Test-35140000	-92 dbm	Yes

The nominal receiver sensitivity is -93 dbm, and threshold is -99 dbm. The tabulation above supports the assumption that the signal strength was below threshold and rejects may be expected. (Reference 10, page 6-7)

4.6 MCC-H - Rev. 1 - Computer Input Multiplexer (CIM)

RTC reported two computer input multiplexer (CIM) failures at 2246 Z. They did not harm the system or cause erroneous outputs of executes. The CIM inputs were confirmed erroneous by CCATS CMD high speed printer, light logic, Franklin printers, 1218 history and CP delog. (Reference 12, page 15)

4.7 CRO-Rev. 3,4 - Rejects occasioned by Poor Signal Strength

During rev. 3, six rejects occurred while the spacecraft UHF receiver signal strength was varying between -101 dbm and -105 dbm. Rejects are attributed to marginal signal strength. During a command sequence on rev. 4, one spacecraft reject appeared. The signal strength during a good command was - 70 dbm; 10 seconds later, the level was -103 dbm, and a spacecraft reject was recorded.

These abrupt changes of about 30 - 40 db in spacecraft received UHF signal strength were detected throughout the mission. Corresponding changes did not occur in the ground received signal strength from the VHF data transmitters which shared the same two antennas through a diplexer. These abrupt changes in received power frequently caused the received command signal power to be below the message acceptable threshold. Consequently, command transmission had to be delayed or repeated. Figure 5 shows typical signals.

The received signal power variations are consistent with an intermittent condition in either the digital command assembly RF stage, the coaxial cable assembly connecting the diplexer and digital command assembly, or in the internal diplexer connections. (Reference 10, page 6-8)

4.8 CRO-Rev. 5 - Rejects Caused by PCM TLM Droputs or Multipath

Nine spacecraft rejects occurred on rev. 5. Five (5) of these may have been due to telemetry since strip chart records show dropouts during these time periods. The other 4 command rejects occurred during periods of good signal strength; however, the maximum elevation angle was about 3.6° and slant range was about 1700 n. miles. Thus rejects may have been caused by multipath effects. (Reference 10, page 6-8)

4.9 HAW-Rev. 4, 5 - Command Rejects Caused by Low Signal Strength and/or Multipath

At the beginning of rev. 4, a 12-bit RTC was uplinked nine times before spacecraft acceptance. A subsequent RTC was also uplinked three times before acceptance. Throughout this period, the spacecraft signal strength was varying rapidly from -104 dbm to -94 dbm. The elevation of the spacecraft rose from 4.0° at first uplink to 6.14° during the latter attempts, and multipath may have affected the uplink commands.

At the beginning of rev. 5, commands were attempted, and one spacecraft reject occurred. The receiver signal strength was approximately -89 dbm, and the spacecraft elevation was approximately 4.6°. It is possible that here, too, the rejects were the result of multipath effect. Later, during the same pass, four spacecraft rejects were noted, while valid ground loops were registered. (Reference 10, page 6-8)

4.10 TEX - Rev. 5 - Command Attempts With Carrier Off

MSC tried two uplinks during Rev. 5 even though no "GO for Command" was given. At this time there was no command carrier up and no solid TM. This procedure did not cause any anomalies in the mission plan, however. (Reference 10, page 6-9)

4.11 RED-Rev. 1, 2, 3 - TM Computer Faulting Indirectly Affected RED Command Capability

There was prolonged faulting of the telemetry computer on the Redstone (six failures). Because of this, RED supported the first pass with the CMD 642 B computer only. For the second pass, RED was advised to load the telemetry program in the command computer and vice versa. Since the TLM computer still faulted with the command program, RED supported passes 2 and 3 with telemetry only, and pass 4 in a command configuration, and did not support pass 5 and subsequent. The fault was traced to an error made in the telemetry computer during the installation of EI 2396. The EI concerns the Erasable Memory Unit (EMU). The clock phase timing was wired incorrectly in chassis A7. A wiring connection was made to a terminal with plus 15 volts instead of the minus 4.5 volts required. (Ref. 10, page 6-3) (and Ref. 11, page 1)

4.12 CYI-Rev. 1 - Command History Lost Because of Command Computer Lockout From Multiple Input/Output Requests

CYI suffered a command computer lockout just after REV 1 LOS, apparently from multiple input/output requests. The site reports a sequence of events at LOS as follows:

23:12:02	CYI TLM DECOM LOS
23:13:06	MSC requested CMD history
23:13:06+	6001 load (liftoff time update) received from MSC
	(6 VAL's transmitted)
23:13:06+	Command computer went into loop

During this time, MSC queried the site if they had received a Type II S-IVB command history request. The M&O reported negatively and attempted CAM 215 (S-IVB Cmd. Hist.) but the computer was still in a loop with all interrrupts locked out. A similar fault occurred in the TLM computer. The CMD computer was subsequently reloaded, but the S-IVB command history could not be recovered. Normal operation was resumed. This sequence is being investigated by Network Computing Branch, Manned Flight Engineering Division, for possible network effect. (Reference 10, page 6-4) (Reference 11, page 29)

4.13 MCC-H-All Revs - Polynomial Buffer Terminal (PBT) Hang-ups

PBT output hang-ups occurred 14 times on the standby system and 11 times on the online system. The PBT's were manually cleared and were reinitialized within ten seconds of each occurrence. It is believed that the problem was hardware rather than software. Work is now in progress to modify the PBT's by February 10, 1969. The modification will give each PBT an individual I/O channel to interface with the CP's, thus eliminating the scanner selector on the PBT to CP interface. (Reference 11, page 2)

4.14 CSQ-REV 3,5 - 1218 Computer Faulting Due to Wiring Short

During rev. 3 and possibly rev. 5 at AOS, the CSQ 1218 program faulted. The CSQ recycled it but again it faulted. The CSQ reloaded and was operating again at Rev. 3 LOS. The problem was attributed to test point wiring shorting to an input indicator register caused by the ship's vibration. (Reference 12, page 55)

4.15 GSFC-All REVS - Station Communication Line Terminals (CLT's) Not Properly Patched - Loss of Loads

Several stations reported receipt of low-speed load NBR 60XX, liftoff time, but no high speed load. This was probably due to the station communications line terminals (CLT's) not being patched at GSFC. Other stations received high speed load 60XX without low-speed English Translation (ET). (Reference 12, page 56 and Reference 11, page 28

416. MCC-H/RS's-All REVS- Problem in Transmitting Command Loads between MCC-H and Remote Sites

There were 378 uplink requests executed for the Spacecraft or Launch Vehicle during prelaunch and mission. Eighty-eight of these were issued before lift-off and 290 post launch. Only five of these failed to get to the remoted site. One was executed during a PBT hang up, three are suspected to have occurred when the Wide Band data line was attempting to fail over to the alternative line, and one loss of an execute request is unexplained.

During prelaunch and mission, there were 36 loads transferred. The RTCC generated 32 loads, 9 for prime site only, 22 for prime and backup sites and 1 (GMTLO) for all sites. CCATS Manual Entry Device (MED) was used to generate four loads, two for prime site only, and two for prime and backup sites. On 11 occasions, a site did not receive, or reject, the HSD load. For five of these, the load was retransmitted, once by RTCC and four times from CCATS. Eight low speed ET's were not output from MCC (six GMTLO and two 3801). One ET was not received at the site, as TTY line checks were in progress at the time the load was transferred. (Reference 12, page 28)

4.17 CRO-REV 5 - Wide Band Data Line Dropouts

Three and possibly four uplink requests from MCC-H to CRO failed to reach the site. These included the commands V, 6, 7, and 5. The suspected cause is wide band data dropout. (Reference 11, page 78)

4.18. <u>Several Sites+ Revs. - Command Uplink Operational Problems</u>

The following is a synopsis of the operational problems experienced in commanding the lunar module on the AS 204 - LM mission. These problems in toto gave rise to questions as to the traffic handling capabilities of the command system.

CRO-REV 3	There was insufficient station pass time to complete DPS-1 burn phase (If this had been decided on following premature DPS-1 shutdown).
POST CRO LOS-REV 3	MCC priorities of mission alternatives were strongly based on predicted low elevation passes which could cause commanding problems.
CONUS-REV 3/4	Alternative mission plan L was abandoned in part because of the danger at predicted low elevation angles of failure to get in command to terminate DPS-2 burn.
CSQ-REV 5	Site configuration prevented sending mass update command to LM (LGC - LMF command)
CRO-REV 5	In part because of rejects in mass update commands, necessitating commands manually one at a time, there was insufficient time to transmit the following commands (Required for desired PRA Sequence): . Increase deadbands . APS-2 target update . Timer update
HAW-REV 5	During APS-2 burn it was desired to inhibit the closure of an interconnect valve, in order to maintain attitude control. However, the time slot for this command occurred 12 seconds after HAW LOS and it was not received.

HAW-REV 6	There was insufficient site coverage predicted for updating the LM and performing the APS depletion burn phase (Execution under PGNCS control) on REV 6 over HAW.

5.0 AS-204 LM-1 Summary

The command system experience on AS 204/LM-1 can be summarized as follows:

5.1 AS-204/LM-1 Performance Summary

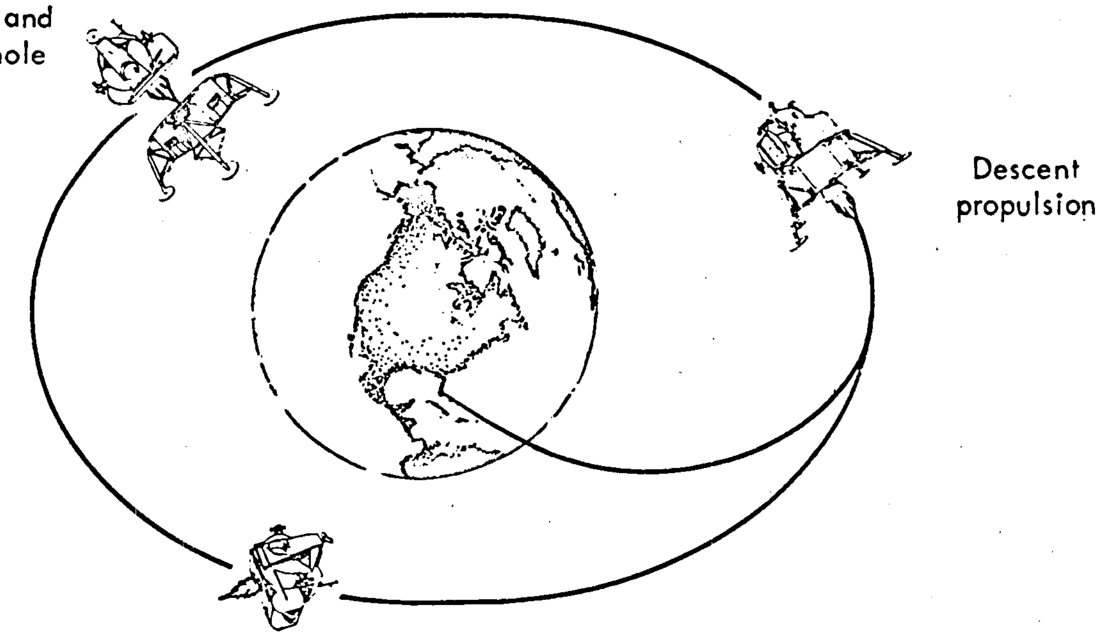
. Command loads generated @ MCC-H (Prelaunch and Mission)	36
. Command loads not received or rejected	11
. Command loads retransmitted	5
. Uplink requests generated @ MCC-H (Prelaunch and Mission)	378
. Uplink requests not reaching remote site	5
. Command words uplinked - LM	686
. Command words rejected - LM	32
. Command words uplinked - SIVB	14
. Command words rejected - SIVB	7

5.2 AS-204/LM-1 Hardware Failures

. Wide band data circuit (dropouts)	-CRO
. FRW - 2 modulator	-TEX
. 240D power amplifier	-CNV
. 240D power amplifier	-HAW
. 642B computer (wiring error)	-RED
. Poly buffer terminal (hang-ups)	-MCC-H
. 1218 computer (wiring short)	-CSQ
. Computer input multiplexer (CIM)	-MCC-H
. UHF RF connection to digital command assembly (probable)	-LM SPACECRAFT

5.3 AS-204/LM-1 Command System and Procedural **Problems**

. Rejects because of low and varying UHF signal strength	-NUMEROUS STATIONS
. Rejects because of TLM dropouts or multipath	CRO HAW
. Command attempted at low elevation angle	CRO, HAW
. Commands attempted with carrier down	ANT/MIL
. Commands attempted with carrier down	-TEX
. Command computer lockout from multiple 1/0 requests - CMD history lost	-CYI
. Communication line terminals (CLT's) improperly patched	-GSFC
. Transmission path interruptions on loads and uplink requests to remote sites	-MCC-H/RS
. Station coverage limitations (insufficient time for desired vehicle commands) constrained mission operations	CONUS, CRO, HAW



Total mission duration (planned activities) approximately 9.5 hr

FIGURE 3

AS-204/LM-1 MISSION

(APPENDIX C)

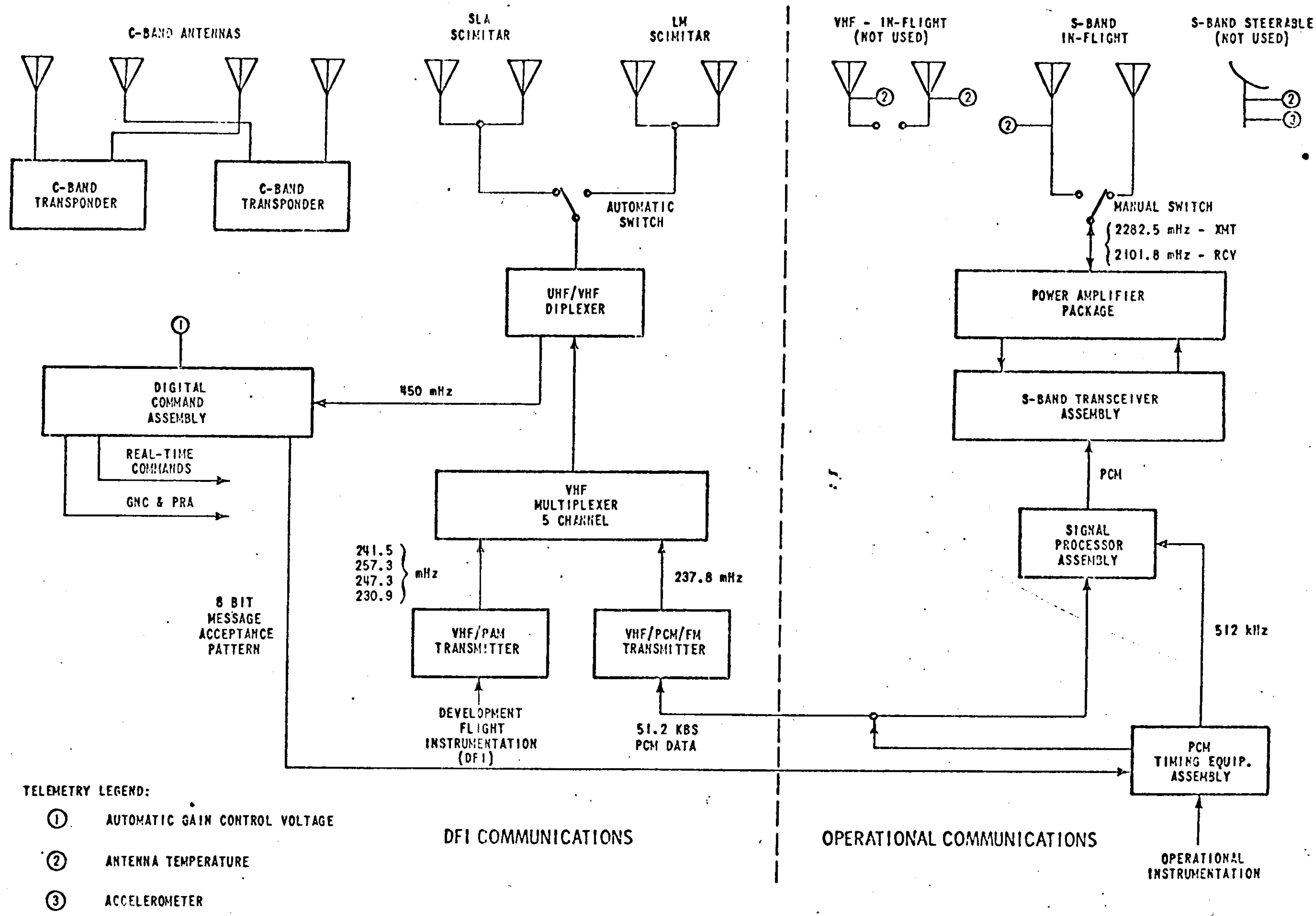


FIGURE 4

LM-1 COMMUNICATION FUNCTIONAL DIAGRAM

MAS/BELLCOMM

(APPENDIX C)

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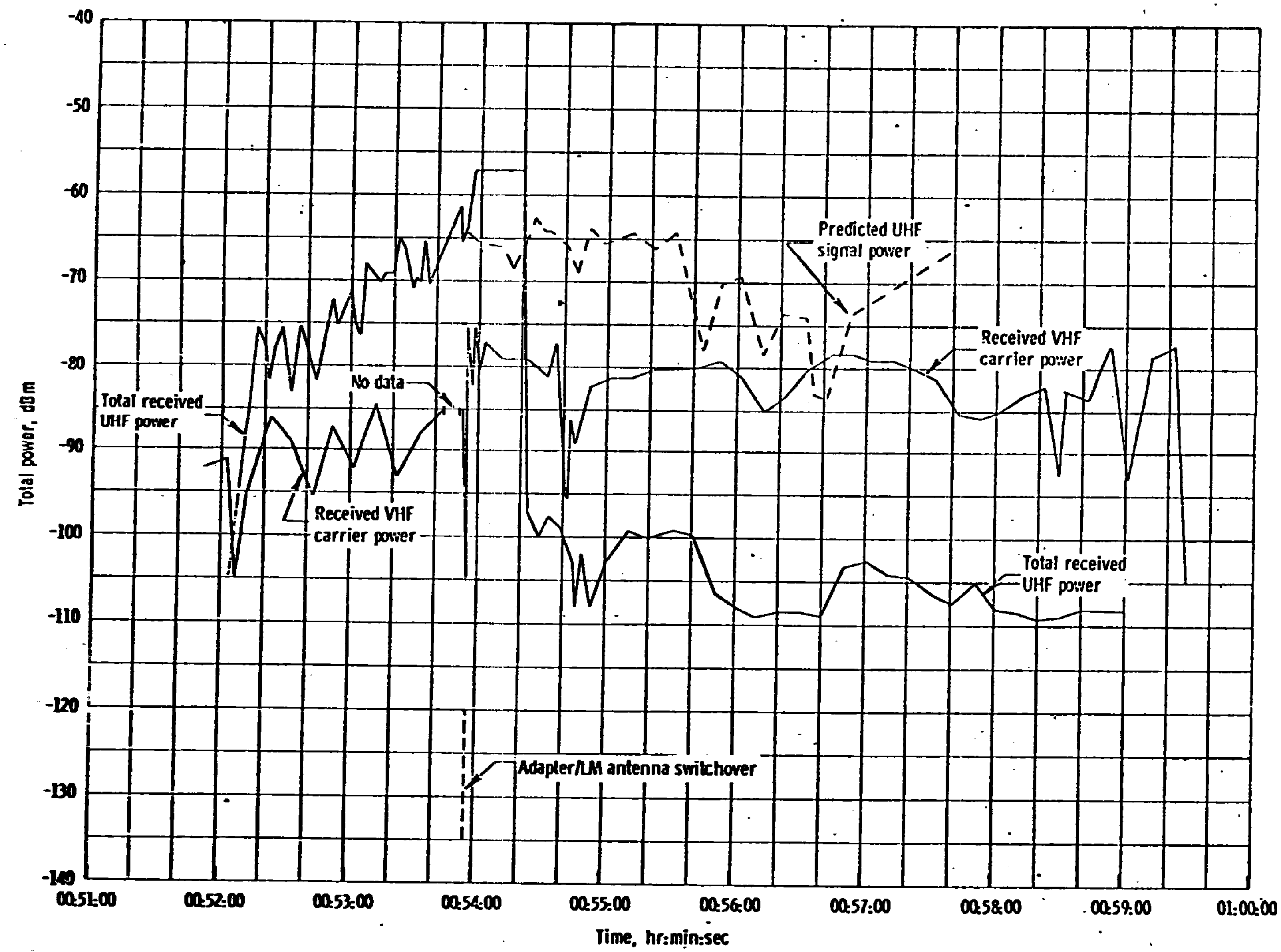

FIGURE 5 - Total received UHF and VHF power, Carnarvon, revolution 1.

(APPENDIX C)

TABLE III UHF COMMANDS - AS-204/LM-1 MISSION

	SITE	REV	MCC REQUESTS	UPLINKED COMMAND WORDS		S/C REJECTS		GROUND REJECTS		COMMENTS
				12 BIT	22 BIT	12 BIT	22 BIT	12 BIT	22 BIT	
a) TO LM	MIL	1	2		2		0		0	
	TEX	1	14	2	30	0	0	0	0	
	MIL	2	6		18		0		0	
	MIL	3	5		5		0		0	LOW UHF SIGNAL STRENGTH
	CRO	3	9	3	6	2	0	0	0	UHF SIGNAL STRENGTH FLUCTUATING
	HAW	3	7		7		0		0	
	TEX	3	23		23		0		0	
	MIL	4	64		64		0		0	
	CRO	4	12		91		1		0	LOW UHF SIGNAL STRENGTH
	HAW	4	5	5		2		0		VARYING UHF SIGNAL
	RKV	4	2	1	1	0	0	0	0	
	TEX	4	19	5	13	0	0	0	0	PBT HANGUP ON 1 REQUEST
	MIL	5	9		92		0		0	
	CRO	5	62	10	243	0	9	0	0	LOW UHF SIGNAL STRENGTH TLM DROPOUTS
										WBD DROPOUT SUSPECTED ON 4 REQUESTS
	HAW	5	44	5	42	0	5	0	0	POSSIBLY MULTIPATH
	TEX	5	2	2		0		2		COMMAND CARRIER NOT UP
	HAW	7	4	16		16		0		TRANSMIT IN BLIND - NO CONTACT
	TOTALS			49	637	20	15	2	0	

				35 BITS	35 BITS	35 BITS	
b) TO SIVB/IU	CYI	1	1	3	0	0	
	ANT	3	2	12	C	12	MIL HAD TLM LOS
	TOTALS			15	0	12	

(APPENDIX C)

TABLE IV - UHF COMMANDS

SITE	REVOLUTION	COMMAND	TIME	VALIDATED REAL TIME	VALIDATED PLAYBACK	Received UHF Signal Power, dBm	Elevation deg	Slant Range n. mi.
MILA	2/3	DCA Self Test	03:10:12	No		-108.9	6.4	493
MILA	2/3	DCA Self Test	03:10:26	No		-106.2	8.3	439
Carnarvon	3	Prime Relay Reset	04:01:18	No		-101.8	21.2	289
Carnarvon	3	Prime Relay Reset	04:01:39	No		-103.9	28.9	226
Carnarvon	4	LGC "enter"	05:33:49	No	No	-99.6	<5	722
Hawaii	4	Prime Relay Off	05:59:22	No		-97.0	3.8	604
	4	Prime Relay Off	05:59:31	No		-97.5	4.2	591
Carnarvon	5	LGC "three"	07:12:02	No	Yes	-82		
	5	LGC "enter"	07:13:42	No	Yes	-66.2		
	5	LGC "one"	07:15:43	No	No	-68.6	3.2	1639
	5	LGC "three"	07:15:44	No	No	-69.7	3.2	1639
Carnarvon	5	LGC "three"	07:15:45	No	No	-70.7	3.2	1639
	5	LGC "three"	07:17:32	No	Yes	-96		
	5	LGC "seven"	07:17:34	No	Yes	-90		

(APPENDIX C)

TABLE IV - UHF COMMANDS (Continued)

SITE	REVOLUTION	COMMAND	TIME	VALIDATED REAL TIME	VALIDATED PLAYBACK	Received UHF Signal Power, dBm	Elevation deg	Slant Range n. mi.
	5	LGC "clear"	07:18:20	No	No	LOS	<3	1640
Hawaii	5	LGC "enter"	07:38:49	No	No	-93	<3	900
	5	PRA start	07:43:19	No	No	-65.4	6.6	602
	5	PRA start	07:43:19.6	No	No	-65.4	6.6	602
	5	PRA start	07:43:20	No	No	-65.4	6.6	603
	5	PRA start	07:43:21	No	No	-65.4	6.6	603

(APPENDIX C)