BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: MSC Review of Requirements and Expected Performance of Communications Systems For the Apollo Spacecraft on 25 September 1967 - Case 320

DATE: November 6, 1967

FROM: J. J. Hibbert

MEMORANDUM FOR FILE

The current requirements and expected performance of the communication systems to be carried by the Apollo spacecraft during lunar missions were reviewed by representatives of MSC for the Apollo Program Director on September 25, 1967, in the Management Center at NASA Headquarters. The agenda and list of attendees are appended as Attachments (1) and (2). Copies of the slides used were distributed to attendees at the end of the presentation. However, because of the comprehensive nature of the review and its pertinence to those not able to attend the meeting, this memorandum has been prepared to record major conclusions of the review and of the discussions that followed. Copies of the presentation slides are also attached.

Mr. Howard Kyle (MSC/ISD) in his introduction, noted that the performance of the spacecraft communication systems was based mainly on specified values of the system parameters rather than measured values. However, for each mission the expected performance will be redetermined using the measured parameters for the spacecraft used in the mission. He noted that the review updates the results contained in the MSC internal note (MSC-EB-R-67-1), "A Performance Analysis of The Apollo Unified S-Band Communications System For a Typical Lunar Mission," dated May 1, 1967.

Mr. C. Beers (MSC/FCD) next discussed the operational requirements for communications between the CSM, LM, EVA, and MSFN (including ARIA and recovery aircraft) on a lunar mission. The slides used by Mr. Beers are included in Attachment 3. These show the communications requirements by mission phase for a lunar mission and represent the results of a recent reexamination of the requirements by MSC. MSC has determined that the desirable criterion for voice link performance is 90% word intelligibility and this is required for the primary modes; 70% word intelligibility is the minimum criterion and is used for backup modes. Similarly, the desirable bit error rate (BER) criterion for data transmission is one error in 10^{-6} bits which is required for primary modes and the minimum criterion is one error in 10^{-4} bit which is used for backup modes.

[redacted] (ACCESSION NUMBER) (THRU)
83 (PAGES) [redacted] (CODE)
CR#90439 (NASA CR OR TMX OR AD NUMBER) (CATEGORY)
FF No. 602(A)
AVAILABLE TO NASA OFFICES AND NASA RESEARCH CENTERS ONLY

X67-
(NASA-CR-154486) MSC REVIEW REQUIREMENTS AND EXPECTED PERFORMANCE OF COMMUNICATIONS SYSTEMS FOR THE APOLLO SPACECRAFT ON 25 SEPTEMBER 1967 (Bellcomm, Inc.) 84 p
N79-72746
Unclas
00/32 12493

Mr. Beers noted that there had been a potential performance problem during the translunar injection (TLI) phase with a requirement for a high bit rate CSM telemetry mode. This requirement is easily met when the CSM high gain antenna is deployed which will occur about sixty minutes after the end of the injection burn at a maximum slant range of about 12,000 miles. Until the high gain antenna becomes available, the CSM will use an omni-antenna element which provides acceptable high bit rate telemetry only out to a range of about 10,000 miles from an MSFN station with a 30' diameter antenna. Beyond this range, it will be necessary to use low bit rate telemetry until the high gain antenna is deployed. This latter method of operation has been accepted by MSC as satisfying their requirements.

There will be some degradation in the reception of high bit rate telemetry from the spacecraft by the Apollo Range Instrumentation aircraft (ARIA) at a slant range of 750 miles. However, the primary ARIA function is voice relay and the spacecraft ARIA voice link has adequate margin.

During the lunar phase, the primary phase modulated (PM) communication modes have the desired performance, but the backup PM modes for both the LM and CSM (using the omni-antennas) are marginal if both voice and low bit rate telemetry are required simultaneously. Either voice or telemetry can be received separately with acceptable margins. The frequency modulation (FM) data and voice dump modes from the CSM are the only primary USB communication modes that have a performance deficit for worst case values of the specified parameters. The calculated deficit is 1.4 db as is shown in the slides used by Mr. R. W. Moorehead (MSC/ISD) which are contained in Attachment 4. Mr. Moorehead noted that the performance margin could be improved by (1) increased power from the CSM power amplifiers (2) reduced CSM cable losses and (3) an increased MSFN 85-foot antenna gain. In particular, the CSM power amplifiers have been exceeding their specified power output by about 0.5 db and recent measurements of the gain of one MSFN 85-foot antenna using a Lunar Orbiter at the moon as a source indicate that the minimum gain is about 1 db greater than the presently specified minimum value.

Mr. Moorehead stated that the theoretical performance figures presented do not include degradation caused by (1) incidental phase modulation (IPM), (2) finite transmitted signal-to-noise ratios or (3) tolerances in modulation indices. The amelioration of the effects of these sources of degradation is under continued investigation.

Mr. Moorehead also noted that the FM demodulators in the MSFN ground receivers at the Electronic Test Facility (MSC) required from 0.5 db to 2.5 db more input signal than the specified

input signal of 8.0 db to obtain a voice intelligibility of 70% or a bit error rate of 10^{-4} in the output signal. Mr. P. Varson (GSFC) confirmed this observation, stating that some FM demodulation in their USB training station at GSFC had been found to be out of alignment. GSFC will check the alignment of all the FM demodulators at the MSFN stations, in order to insure that the FM demodulators meet their specified performance.

Mr. Moorehead pointed out that additional measured performance data on the MSFN station parameters were needed to predict USB system performance more accurately. Moreover, certain parameters (see Attachment 4) are not yet included in the Performance and Interface Specifications. There was a general discussion of the desirability of a Performance and Interface Specification for the MSFN which would state a minimum performance for each station. Mr. C. Beers (MSC/FCD) noted that this would remove a current constraint on mission planning which makes it necessary to assume only the minimum performance for all MSFN sites. GSFC observed that generating a P&I specification for each MSFN station would be a lot of work and would be time variable. After the discussion, it was the consensus that GSFC should obtain performance data for each MSFN station and transmit it to MSC. Mr. G. Truzynski (OTDA) suggested that after the MSFN station data becomes available, changes in the specification values for the MSFN stations be considered. This will be more appropriate after flight data on some of the early test missions is obtained.

Mr. D. Eggers (MSC/IESD) reviewed the current plans for modifying the LM steerable antenna to permit continuous communications with the Earth during the lunar descent phase. He also described the additional qualification testing planned for the CSM high gain antenna to eliminate failures that had occurred in the earlier qualification tests (see Attachment 5). MSC is also investigating methods of reducing the jitter of the LM and CSM steerable antennas when they are automatically tracking a modulated up-link. The probable solution is the use of reduced up-link modulation indices.

Mr. R. Dietz (MSC/IESD) discussed current problem areas and changes in the LM and CSM communication systems (see Attachment 6). These problems are receiving intensive attention and their prognosis is favorable.

Mr. Howard Kyle (MSC/ISD) then reviewed the performance of the VHF links used by the LM, CSM and EVA. He commented that the computed performance (see Attachment 7) revealed no major problems. The VHF performance is not adequate at maximum

range between the CM beacons and the recovery aircraft using its secondary receiver (which has no preamplifiers), but this was expected.

Mr. Kyle summarized the MSC presentation as follows:

a. Based on the operational requirements as presented, all primary real-time modes are predicted to be satisfactory.

b. The contingency modes, to be used in event of loss of the CSM or LM high gain antennas, will not provide simultaneous voice and telemetry.

c. The CSM FM modes, with playback voice and telemetry, are predicted to be negative.

d. Other problems, including spacecraft antenna tracking errors, degradation due to incidental phase modulation, interference of backup voice to PCM, LM PCM bit transition density, are recognized and solutions are available or are being actively pursued.

Conclusions

Although no detailed action items were assigned at this review, several general actions were requested by the Apollo Program Director, namely:

(1) MSC and GSFC should keep each other informed in real time of the status of the spacecraft and MSFN station performance parameters.

(2) GSFC should continue their collection of performance data for each MSFN station for early transmission to MSC.

(3) The performance of all communication elements should at least be brought up to their specified values.

(4) If experience indicated that measured performance values were consistently different from the specification values, changes in the specification should be made.

(5) If adequate performance to satisfy an operational requirement for communications is difficult to attain, the basis for the requirement and alternate methods of operation should be evaluated before an expensive and lengthy modification of equipment is undertaken. The requirement for simultaneous

voice and telemetry at lunar distance using the omni antennas is an example of such a requirement.

(6) MSC and GSFC's planned attack on the LM PCM bit transition problem should be expedited to obtain a solution. The rationale for the solution should be fully documented (MSC/ISD).

(7) Any changes that affected the equipment for the LM or CSM should be made known to the Apollo Program Director as soon as possible. Such changes should be kept tc a minimum.

(8) The requirement for television for the lunar missions will be reviewed by OMSF.

(9) A sufficiently large number of problems still exist in the communications area that continued pressure must be maintained to find acceptable solutions.

In concluding the review, Maj. Gen. S. C. Phillips complimented the speakers on their presentations which he described as "a very useful set of briefings."

2034-JJH-ew

J. J. Hibbert

Attachments 1-7

ATTACHMENT I

MSC APOLLO COMMUNICATIONS REVIEW

25 September 1967

List of Attendees

OMSF

NAME	CODE
W. B. Allen	MOR
B. Porter Brown	MOR
G. P. Chandler	MAOP
C. W. Childs	MOR
T. G. Elwell	MOR
S. W. Fordyce	MLA
J. K. Holcomb	MAO
W. J. Hymes	MOR
L. B. James	MA
A. W. Kinny	MOA
C. M. Lee	MA
D. G. Luke	MOR
J. T. McClanahan	MOR
W. E. Miller	MOG
J. P. Nolan, Jr.	MOA
Maj. Gen. S. C. Phillips	MA
L. M. Robinson	OTDA/TS
J. D. Stevenson	MO
G. M. Truszynski	OTDA/TD
I. Mason	MOG

Goddard Space Flight Center

NAME	CODE
D. A. Dalton	MFED
W. A. Dentel	MFED
J. J. Donegan	MFPAD
R. H. Newman	MFPAD
R. L. Owen	MFOD
B. W. Reich	523
J. P. Shaughnessy	MFPAD

GSFC (Cont'd)

NAME	CODE
R. C. Taylor	MFED
P. Varson	MFSO
C. Roberts	

Marshall Space Flight Center

NAME	CODE
T. A. Barr	R-ASTR-IR
Ann R. McNair	I-MO-R

Manned Spacecraft Center

NAME	CODE
K. J. Allen	FOD-FSD
C. A. Beers	FCD
R. H. Dietz	IESD
D. S. Eggers	IESD
E. L. Keith	OSRO
M. G. Kingsley	IESD
M. B. Luse	IESD
R. W. Moorehead	ISD
P. H. Vavra	ISD
M. McKenzie	ASPO
L. Packham	IESD

Bellcomm, Inc.

NAME
A. P. Boysen, Jr.
J. J. Hibbert
J. Z. Menard
J. T. Raleigh
R. D. Raymond
R. L. Selden
P. F. Sennewald
R. L. Wagner
A. G. Weygand

Attachment 2

APOLLO COMMUNICATIONS REVIEW BY MSC

1:00 PM, September 25, 1967

Management Center, FOB 10B

I.	Introduction	H. C. Kyle - ISD
II.	Operational Requirements	C. A. Beers - FCD
III.	USB System Performance	R. W. Moorehead - ISD
IV.	USB System Problems (and efforts to solve)	R. W. Moorehead - ISD
V.	Spacecraft Equipment Status and Problems	D. Eggers - IESD R. H. Dietz - IESD
VI.	VHF System Performance and Problems	H. C. Kyle - ISD
VII.	Summary	H. C. Kyle - ISD

MODE DESIGNATION

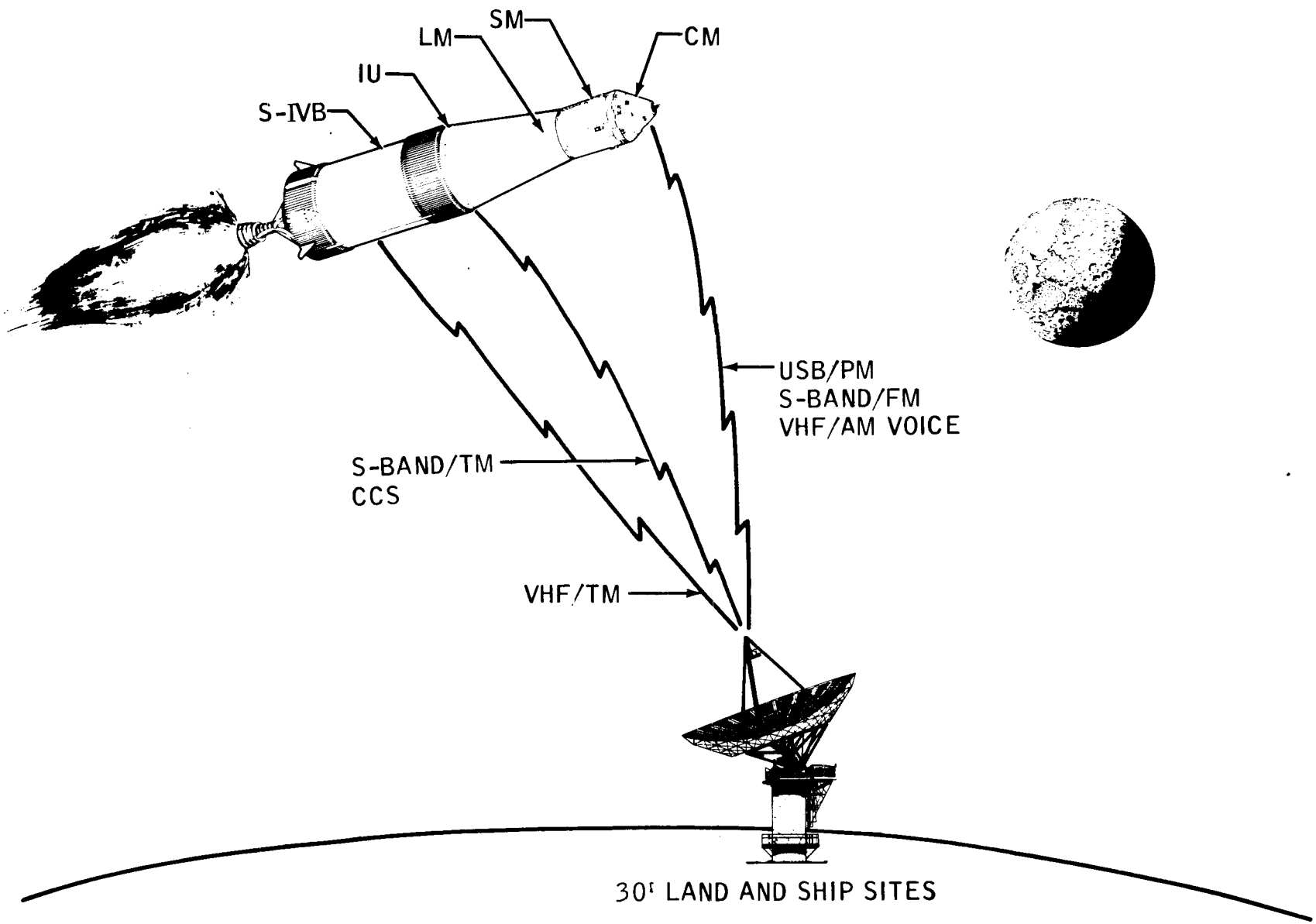
S/C TO MSFN		MSFN TO S/C
CSM:	LM:	
PM1 - 51.2 TM, VOICE, CW	PM1 - 51.2 TM, VOICE, CW	2 - VOICE, CW
PM2 - 51.2 TM, VOICE, PRN, CW	PM2 - 51.2 TM, VOICE, PRN, CW	4 - VOICE, PRN, CW
PM3 - 1.6 TM, VOICE, PRN, CW	PM4 - 1.6 TM, BACKUP VOICE, CW	6 - VOICE, CMD, PRN, CW
PM6 - KEY, CW	PM6 - KEY, CW	7 - VOICE, CMD, CW
PM8 - 1.6 TM, BACKUP VOICE, CW	PM7 - 1.6 TM, VOICE, CW	
FM1 - 51.2 TM, VOICE (D.D., 1:1)	FM-10 - 51.2 TM, VOICE, TV	
FM2 - 1.6 TM, VOICE (D.D., 32:1)		
FM3 - LM/CSM 1.6 TM (D.D., 32:1)		

D.D. - Data Dump

OPERATIONS REQUIREMENTS FOR COMMUNICATIONS

- OPERATIONS CRITERIA FOR CHANNEL PERFORMANCE (VOICE, TELEMETRY, UPDATA, AND RANGING) FOR ALL CSM & LM SYSTEMS
- CONSIDERED AGAINST LUNAR LANDING MISSION MODEL, BY PHASES:
  1. POWERED FLIGHT TO EARTH ORBIT AND EARTH ORBIT
  2. TRANSLUNAR INJECTION TO END OF TRANSPOSITION AND DOCKING
  3. LUNAR PHASE (INCLUDING LUNAR ORBIT, LM LANDING, LUNAR STAY, LM LAUNCH, AND RENDEZVOUS TO TRANS EARTH INJECTION
  4. EARTH REENTRY TO LANDING AND RECOVERY.
- CONSIDERED FOR ALL SPACECRAFT (CSM - LM), AND EVA SYSTEM CONFIGURATIONS
- CONSIDERED ALL GROUND (MSFN) INTERFACES
- CONSIDERED FOR SOME CONTINGENCY CONDITIONS

POWERED FLIGHT THROUGH EARTH ORBIT INSERTION AND EARTH ORBIT



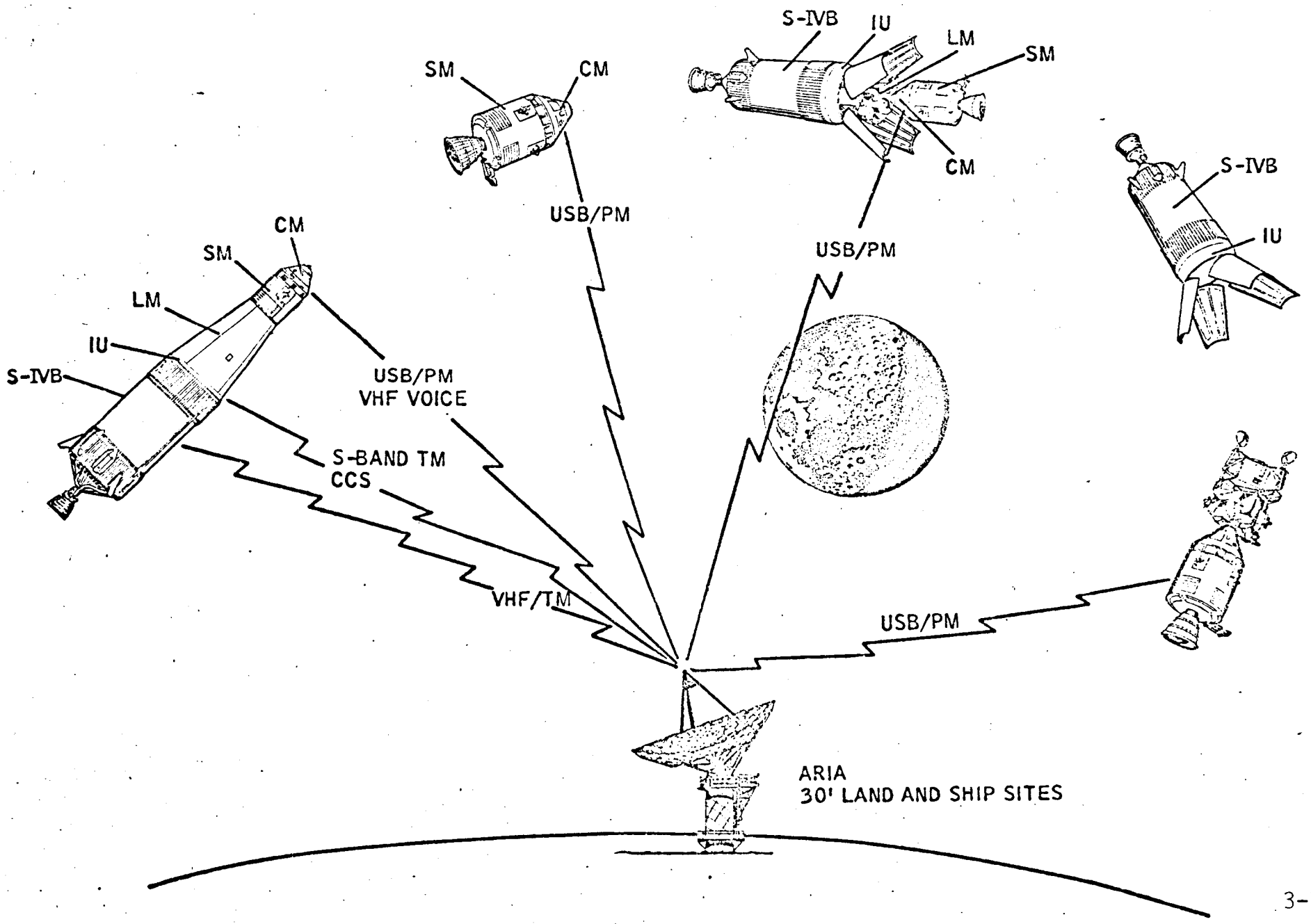
COMMUNICATION SYSTEM	POWERED FLIGHT THROUGH EO INSERTION AND EO SUPPORT REQUIREMENT								USB MODE		S/C CONFIG.	GROUND INTERFACE	
	TM		CMD	V	G. TRK		D.D.	TV					
	DR	BER		INT.	PRN	CW	BER		DN	UP		SITE	S/R
CSM-USB	51.2	10^{-6}		90%	X	X			PM 2	4	OMNI-PA/TX	30'	1K
	51.2	10^{-6}	X	90%	X	X			PM 2	6	OMNI-PA/TX	30'	1K
	1.6	10^{-6}		90%	X	X			PM 3	4	OMNI-PA/TX	30'	1K
	1.6	10^{-6}	X	90%	X	X			PM 3	6	OMNI-PA/TX	30'	1K
CSM-S-BAND/FM				70%			10^{-4}		FM 1	–	OMNI-PA	30'	1K
				70%			10^{-4}		FM 2	–	OMNI-PA	30'	1K
CSM-VHF/AM				90%							OMNI	L/S	1K

DATA SHEET

PRN - Pseudo Random Noise Ranging
CW - Range Rate Tracking

D.R. - Data Rate in Kilobits/Sec.
D.D. - Data Dump
INT. - Word Intelligibility

TLI THROUGH TRANSPOSITION AND DOCKING



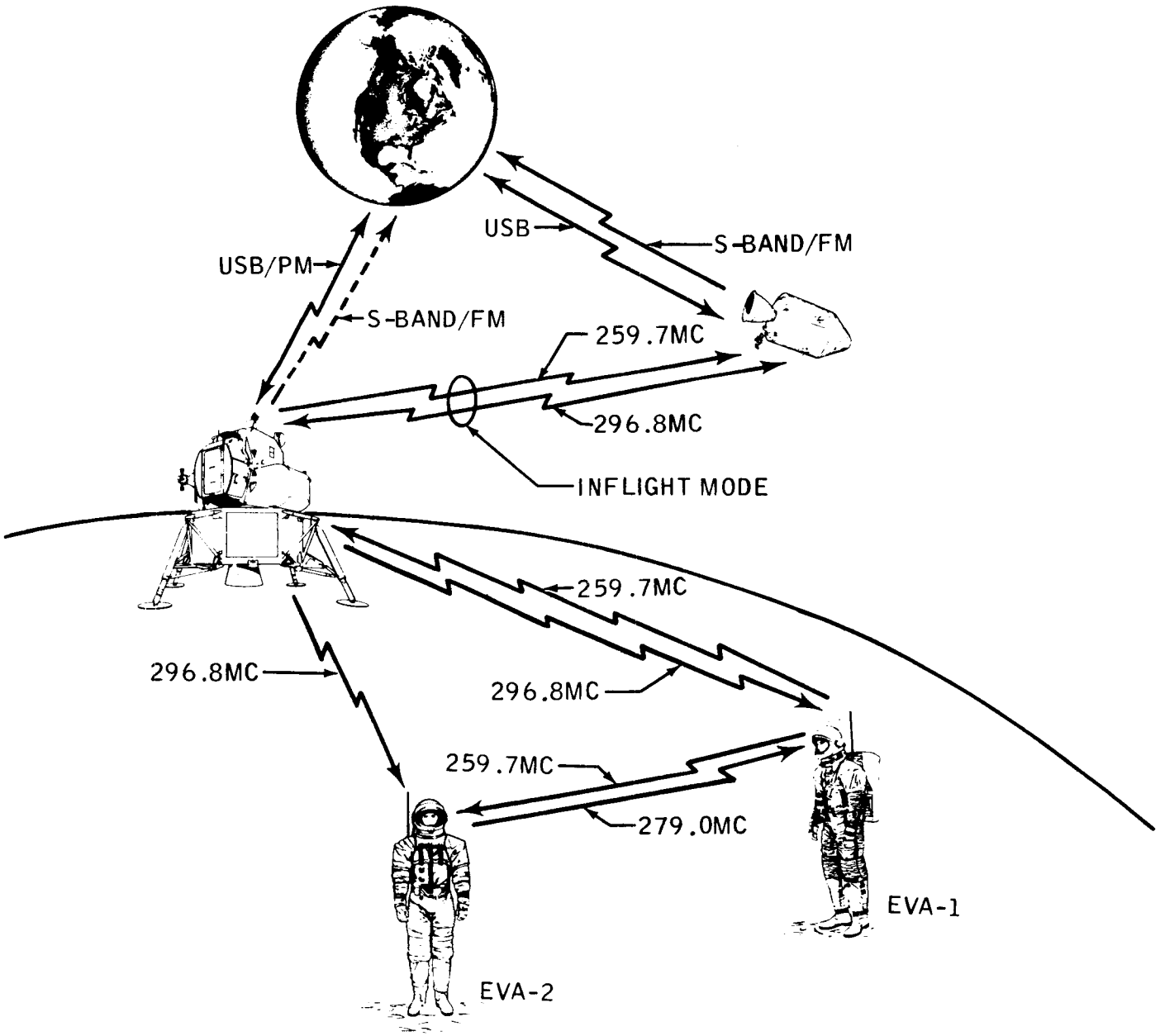
COMMUNICATION SYSTEM	TLI THROUGH TRANSPOSITION AND DOCKING SUPPORT REQUIREMENT								USB MODE		S/C CONFIGURATION	GROUND INTERFACE	
	TM		CMD	V	G. TRK		D.D.	TV					
	DR	BER		INT	PRN	CW	BER		DN	UP		SITE	S/R
CSM-USB	51.2*▽	10^{-4}		90%		X			PM 1	2	OMNI-PA	ARIA	750
	51.2*▽	10^{-4}		90%		X			PM 2	–	OMNI-PA	ARIA	750
	1.6*	10^{-4}		90%		X			PM 3	–	OMNI-PA	ARIA	750
	1.6*	10^{-4}		90%		X			PM 4	2	OMNI-PA	ARIA	750
	1.6	10^{-6}	X	90%		X			PM 3	7	OMNI-PA	30'	12K
	51.2	10^{-6}	X	90%	X	X			PM 2	6	OMNI-PA	30'	10K
	51.2	10^{-6}	X	90%	X	X			PM 2	6	HG(W)-PA	30'	15K
CSM-VHF/AM				70%		X					OMNI	ARIA	750

DATA SHEET

S/R - Slant Range in Nautical Miles
Shaded Area Denotes Backup modes

* POST MISSION REQUIREMENT
▽ PERFORMANCE PROBLEM

LUNAR PHASE


USB
S-BAND/FM
USB/PM
S-BAND/FM
259.7MC
296.8MC
INFLIGHT MODE
259.7MC
296.8MC
296.8MC
259.7MC
279.0MC
EVA-1
EVA-2

COMMUNICATION SYSTEM	LUNAR PHASE SUPPORT REQUIREMENT								USB MODE		S/C CONFIGURATION	GROUND INTERFACE	
	TM		CMD	V	G. TRK		D.D.	TV					
	DR	BER		INT	PRN	CW	BER		DN	UP		SITE	S/R
CSM - USB	51.2	10^{-6}	X	90%	X	X			PM 2	6	HG(N)-PA	85'	215K
	51.2	10^{-6}		90%	X	X			PM 2	4	HG(N)-PA	85'	215K
	1.6	10^{-6}	X	90%	X	X			PM 3	6	HG(N)-PA	85'	215K
▼	1.6	10^{-6}		90%	X	X			PM 3	4	HG(N)-PA	85'	215K
▼	1.6	10^{-4}		70%		X			PM 8	2	OMNI-PA	85'	215K
▼	1.6	10^{-4}	X	70%		X			PM 8	7	OMNI PA	85'	215K
	(VOICE	UP -	KEY	DOWN)					PM 6	2	OMNI-TX	85'	215K
	(FOR	3-WAY	DOP	PLER)		X			PM 2	–	HG(N)-PA	30'	215K
	(FOR	3-WAY	DOP	PLER)		X			PM 3	–	HB(N)-PA	30'	215K
CSM - S-BAND/FM ▼				70%			10^{-4}		FM 1	–	HG(N)-PA	85'	215K
▼				70%			10^{-4}		FM 2	–	HG(N)-PA	85'	215K
							10^{-4}		FM 3	–	HG(N)-PA	85'	215K

DATA SHEET

▼ PERFORMANCE PROBLEM

Shaded Area Denotes Backup Modes

COMMUNICATION SYSTEM	LUNAR PHASE SUPPORT REQUIREMENT								USB MODE		S/C CONFIGURATION	GROUND INTERFACE	
	TM		CMD	V	G. TRK		D.D.	TV					
	DR	BER		INT	PRN	CW	BER		DN	UP		SITE	S/R
LM - USB	51.2	10^{-6}	X	90%	X	X			PM 2B	6	HG(S)-PA	85'	215K
	51.2	10^{-6}		90%	X	X			PM 2B	4	HG(S)-PA	85'	215K
	51.2	10^{-6}		90%		X			PM 1B	2	HG(E)-PA	85'	215K
	51.2	10^{-6}	X	90%		X			PM 1B	7	HG(E)-PA	85'	215K
	1.6	10^{-6}	X	90%		X			PM 7A	7	HG(E)-TX	85'	215K
▼	1.6	10^{-4}		70%		X			PM 4B	2	OMNI-PA	85'	215K
	(VOICE	UP-	KEY	DOWN)					PM 6	2	OMNI-TX	85'	215K
	(FOR	3-WAY	DOP	PLER)		X			PM 2B	-	HG(S)-PA	30'	215K
	51.2	10^{-6}	X	90%		X		X	FM 10B	7	HG(E)-PA	85'	215K

DATA SHEET

▼ PERFORMANCE PROBLEM

Shaded Area Denotes Backup Mode

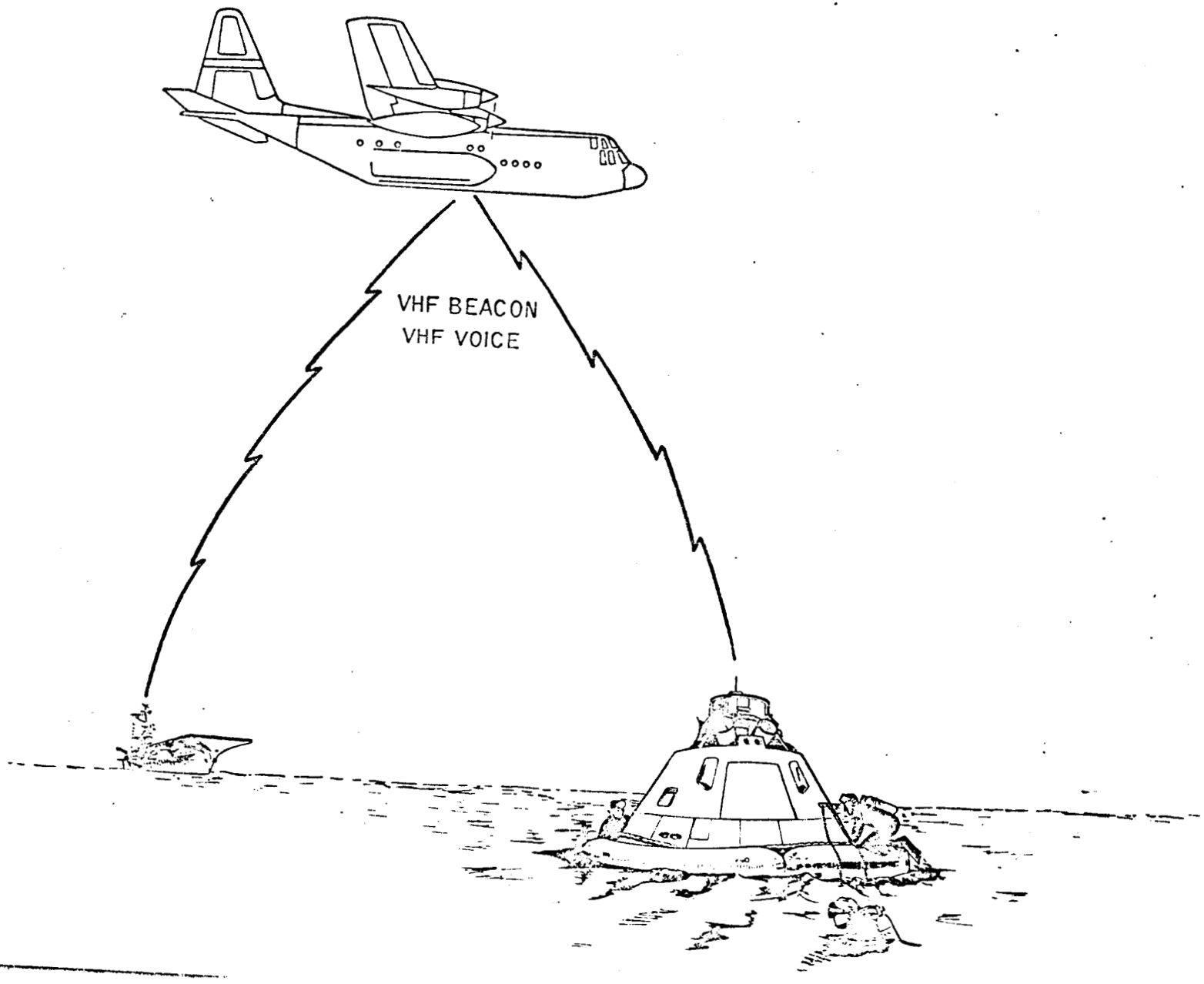
HG(s) - High Gain Antenna - Steerable

HG(e) - High Gain Antenna - Erectable

COMMUNICATION SYSTEM	LUNAR PHASE SUPPORT REQUIREMENT								USB MODE		S/C CONFIGURATION	GROUND INTERFACE	
	TM		CMD	V	G. TRK		D.D.	TV					
	DR	BER		INT	PRN	CW	BER		DN	UP		SITE	S/R
LM/CSM - VHF/AM	1.6	10^{-6}				X					OMNI		320
▼				70%							OMNI		550
EVA/LM/MSFN/CSM-USB				90%/70%		X			(REL MO	AY DE)	HG(N)-PA HG(E)-PA	85'	215K
EVA/LM - VHF/AM				90%									1.0
EVA/LM/MSFN-USB	51.2	10^{-6}	X	90%/70%		X			PM 9B	7	HG(E)-PA	85'	215K
	1.6	10^{-6}	X	90%/70%		X			PCM 7B/A	7	HG(E)-PA/TX	85'	215K
EVA/EVA - VHF/AM				90%									0.5
EVA/EVA - VHF/~~FM~~ PAM/FM	(BIO	MED DA	TA)										0.5

DATA SHEET ▼ PERFORMANCE PROBLEM

RECOVERY PHASE



COMMUNICATION SYSTEM	REENTRY AND RECOVERY PHASE SUPPORT REQUIREMENT								USB MODE		S/C CONFIGURATION	GROUND INTERFACE	
	TM		CMD	V	G. TRK		D.D.	TV					
	DR	BER		INT	PRN	CW	BER		DN	UP		SITE	S/R
CM - USB						X			PM 1	–	OMNI-PA	A/C	300
						X			PM 2	–	OMNI-PA	A/C	300
						X			PM 3	–	OMNI-PA	A/C	300
CM - VHF/AM				90%		X					1/4λ ANT.	ARIA	300
▼				70%		X					1/4λ ANT.	A/C	200
CM - VHF (R)						X					1/4λ ANT.	A/C	300
CM-SURVIVAL BEACON						X					1/4λ ANT.	A/C	195
				70%							1/4λ ANT.	A/C	75

DATA SHEET ▼ PERFORMANCE PROBLEM

Powered Flight through Earth Orbit Insertion and Earth Orbit Support Requirements
CSM - MSFN Ranging Links

MSFN Configuration	CSM Configuration	Mode Description MSFN to CSM	Range nmi	Margins at CSM N	Margins at CSM W	Mode Description CSM to MSFN	Range nmi	Margins at MSFN N	Margins at MSFN W
30'	Omni - PA	PM Mode 4	1K			PM Mode 2	1K	db.	db.
		Carrier		47.6	47.6	Carrier		32.8	32.0
		PRN Ranging		--	--	PRN Ranging		24.0	24.0
		Voice		11.7	11.3	Voice		13.5	12.9
						51.2Kbps TLM		12.7	12.2
30'	Omni - TX	PM Mode 4	1K			PM Mode 2	1K		
		Carrier		47.6	47.6	Carrier		22.4	21.6
		PRN Ranging		--	--	PRN Ranging		13.6	13.6
		Voice		11.7	11.3	Voice		3.1	2.5
						51.2Kbps TLM		2.3	1.8
30'	Omni - PA	PM Mode 6	1K			PM Mode 2	1K		
		Carrier		51.8	51.8	Carrier		32.8	32.2
		PRN Ranging		--	--	PRN Ranging		27.1	27.1
		Voice		7.0	6.6	Voice		13.5	12.9
		Updata		4.0	3.7	51.2Kbps TLM		12.4	12.0
30'	Omni - TX	PM Mode 6	1K			PM Mode 2	1K		
		Carrier		51.8	51.8	Carrier		22.3	21.5
		PRN Ranging		--	--	PRN Ranging		16.6	16.6
		Voice		7.0	6.6	Voice		3.0	2.4
		Updata		4.0	3.7	51.2Kbps TLM		2.2	1.7
30'	Omni - PA	PM Mode 4	1K			PM Mode 3	1K		
		Carrier		47.6	47.6	Carrier		32.8	32.0
		PRN Ranging		--	--	PRN Ranging		24.0	24.0
		Voice		11.7	11.3	Voice		19.5	18.9
						1.6Kbps TLM		21.7	21.3

Powered Flight through Earth Orbit Insertion and Earth Orbit Support Requirements
CSM - MSFN Ranging Links
(continued)

MSFN Configuration	CSM Configuration	Mode Description MSFN to CSM	Range nmi	Margins at CSM		Mode Description CSM to MSFN	Range nmi	Margins at MSFN	
				N	W			N	W
30'	Omni - TX	PM Mode 4	1K			PM Mode 3	1K		
		Carrier		47.6	47.6	Carrier		22.4	21.6
		PRN Ranging		--	--	PRN Ranging		13.6	13.6
		Voice		11.7	11.3	Voice		9.1	8.5
						1.6Kbps TLM		11.3	10.9
30'	Omni - PA	PM Mode 6	1K			PM Mode 3	1K		
		Carrier		51.8	51.8	Carrier		32.8	32.0
		PRN Ranging		--	--	PRN Ranging		27.1	27.1
		Voice		7.0	6.6	Voice		19.4	18.8
		Updata		4.0	3.7	1.6Kbps TLM		21.7	21.3
30'	Omni - TX	PM Mode 6	1K			PM Mode 3	1K		
		Carrier		51.8	51.8	Carrier		22.3	21.5
		PRN Ranging		--	--	PRN Ranging		16.6	16.6
		Voice		7.0	6.6	Voice		9.0	8.4
		Updata		4.0	3.7	1.6Kbps TLM		11.2	10.8

Powered Flight through Earth Orbit Insertion and Earth Orbit Support Requirements
CSM - MSFN One-Way Links

MSFN Configuration	CSM Configuration	Mode Description MSFN to CSM	Range nmi	Margins at CSM		Mode Description CSM to MSFN	Range nmi	Margins at MSFN	
				N	W			N	W
30'	Omni - PA					FM Mode 1 1:1 Playback of Voice and 51.2 Kbps TLM Mode-as-a-Whole	1K	13.3	12.7
30'	Omni - PA					FM Mode 2 32:1 Playback of Voice and 1.6 Kbps TLM Mode-as-a-Whole	1K	13.3	12.7

Trans-Lunar Injection thru Transposition and Docking
CSM - MSFN Range Links

MSFN Configuration	CSM Configuration	Mode Description MSFN to CSM	Range nmi	Margins at CSM N	Margins at CSM W	Mode Description CSM to MSFN	Range nmi	Margins at MSFN N	Margins at MSFN W
30'	Omni - PA	PM Mode 6	10K			PM Mode 2	10K		
		Carrier		37.6	37.4	Carrier		21.8	21.0
		PRN Ranging		--	--	PRN Ranging		16.0	16.0
		Voice		6.9	6.5	Voice		2.1	1.5
		Updata		4.0	3.6	51.2Kbps TLM		1.4	0.9
30'	Omni - PA	PM Mode 6	15K			PM Mode 3	15K		
		Carrier		34.1	33.9	Carrier		18.9	18.1
		PRN Ranging		--	--	PRN Ranging		12.8	12.8
		Voice		6.8	6.4	Voice		5.5	4.9
		Updata		3.8	3.4	1.6Kbps TLM		7.5	7.1
30'	HGA(W) - PA	PM Mode 6	15K			PM Mode 2	15K		
		Carrier		36.8	36.7	Carrier		26.0	24.6
		PRN Ranging		--	--	PRN Ranging		20.3	19.6
		Voice		6.5	6.5	Voice		6.7	5.5
		Updata		3.6	3.6	51.2Kbps TLM		5.9	4.8

Trans-Lunar Injection through Transposition and Docking Support Requirements
CSM - MSFN One-Way Links

MSFN Configuration	CSM Configuration	Mode Description MSFN to CSM	Range nmi	Margins at CSM N	Margins at CSM W	Mode Description CSM to MSFN	Range nmi	Margins at MSFN N	Margins at MSFN W
ARIA	Omni - PA					PM Mode 1	750		
						Carrier		23.3	20.6
						Voice		4.2	1.9
						51.2Kbps TLM		- 2.3	- 4.3
ARIA	Omni - PA	(Listen only)				PM Mode 2	750		
						Carrier		22.5	19.8
						PRN Ranging		--	--
						Voice		3.3	1.0
						51.2Kbps TLM		- 2.7	- 4.9
ARIA	Omni - PA	(Listen only)				PM Mode 3	750		
						Carrier		22.5	19.8
						PRN Ranging		--	--
						Voice		9.5	7.2
						1.6Kbps TLM		5.2	3.1
ARIA	Omni - PA					PM Mode 4	750		
						Carrier		23.3	20.6
						Voice		10.2	7.9
						1.6Kbps TLM		5.9	3.8
ARIA	Omni	PM Mode 2	750						
		Carrier		12.8	11.4				
		Voice		8.9	7.5				

Lunar Phase Support Requirements
CSM - MSFN Ranging Links

MSFN Configuration	CSM Configuration	Mode Description MSFN to CSM	Range nmi	Margins at CSM		Mode Description CSM to MSFN	Range nmi	Margins at MSFN	
				N	W			N	W
85'	HG(N) - PA	PM Mode 6	215K			PM Mode 2	215K		
		Carrier		42.1	40.0	Carrier		40.6	38.3
		PRN Ranging		--	--	PRN Ranging		23.5	21.2
		Voice		7.0	6.6	Voice		9.9	7.0
		Updata		4.1	3.6	51.2Kbps TLM		9.0	6.2
85'	HG(N) - PA	PM Mode 4	215K			PM Mode 2	215K		
		Carrier		33.9	31.6	Carrier		40.7	38.4
		PRN Ranging		--	--	PRN Ranging		20.5	18.2
		Voice		11.8	11.2	Voice		10.0	7.1
						51.2Kbps TLM		9.1	6.3
85'	HG(N) - PA	PM Mode 6	215K			PM Mode 3	215K		
		Carrier		42.1	40.0	Carrier		40.6	38.3
		PRN Ranging		--	--	PRN Ranging		23.5	21.2
		Voice		7.0	6.6	Voice		15.8	12.9
		Updata		4.1	3.6	1.6Kbps TLM		18.1	15.4
85'	HG(N) - PA	PM Mode 4	215K			PM Mode 3	215K		
		Carrier		33.9	31.6	Carrier		40.7	38.4
		PRN Ranging		--	--	PRN Ranging		20.5	18.2
		Voice		11.8	11.2	Voice		15.9	13.0
						1.6Kbps TLM		18.2	15.5

Lunar Phase Support Requirements
CSM - MSFN One-Way Links

MSFN Configuration	CSM Configuration	Mode Description MSFN to CSM	Range nmi	Margins at CSM		Mode Description CSM to MSFN	Range nmi	Margins at MSFN	
				N	W			N	W
85'	Omni - PA					[illegible]	215K		
						Carrier		17.7	15.2
						[illegible]		2.1	- 0.8
						[illegible]		2.1	- 0.8
85'	Omni - TX					[illegible]	[illegible]		
						[illegible]		6.3	3.8
						[illegible]		5.7	2.8
30'	HGA(N) - PA	(Listen only)				PM Mode 2	215K		
						Carrier		35.6	32.6
						PRN Ranging			
						Voice		4.6	1.2
						51.2Kbps TLM		4.0	0.5
30'	HGA(N) - PA	(Listen only)				PM Mode 3	215K		
						Carrier		35.6	32.6
						PRN Ranging			
						Voice		10.8	7.2
						1.6Kbps TLM		13.0	9.6
85'	HGA(N) - PA					FM Mode 1	215K		
						1:1 Playback of Voice and 51.2 Kbps TLM			
						Mode-as-a-Whole		2.6	- 1.4
85'	HGA(N) - PA					FM Mode 2	215K		
						32:1 Playback of Voice and 1.6 Kbps TLM			
						Mode-as-a-Whole		2.6	- 1.4

Lunar Phase Support Requirements
CSM - MSFN One-Way Links
(continued)

MSFN Configuration	CSM Configuration	Mode Description MSFN to CSM	Range nmi	Margins at CSM		Mode Description CSM to MSFN	Range nmi	Margins at MSFN	
				N	W			N	W
85'	HGA(N) - PA					FM Mode 3 32:1 Playback of LM 1.6Kbps TLM Mode-as-a-Whole	215K	8.6	4.6
85'	Omni	PM Mode 2 Carrier Voice	215K	 14.8 10.8	 12.6 8.2				
85'	Omni	PM Mode 7 Carrier Voice Updata	215K	 19.2 6.1 6.1	 17.0 3.5 3.5				

Lunar Phase Support Requirements
LM - MSFN Ranging Links

MSFN Configuration	LM Configuration	Mode Description MSFN to LM	Range nmi	Margins at LM		Mode Description LM to MSFN	Range nmi	Margins at MSFN	
				N	W			N	W
85'	HGA(S) - PA	PM Mode 6	215K			PM Mode 2B	215K		
		Carrier		37.1	32.9	Carrier		37.9	34.5
		PRN Ranging		--	--	PRN Ranging		20.8	17.5
		Voice		9.8	6.3	Voice/H.L.			
		Updata		6.9	3.4	Biomed		9.7	5.7
						51.2Kbps TLM		7.3	3.5
85'	HGA(S) - PA	PM Mode 4	215K			PM Mode 2B	215K		
		Carrier		28.6	24.6	Carrier		37.9	34.5
		PRN Ranging		--	--	PRN Ranging		17.8	14.5
		Voice		11.6	11.1	Voice/H.L.			
						Biomed		9.8	5.9
						51.2Kbps TLM		7.3	3.5

Lunar Phase Support Requirements
LM - MSFN One-Way Links

MSFN Configuration	LM Configuration	Mode Description MSFN to LM	Range nmi	Margins at LM		Mode Description LM to MSFN	Range nmi	Margins at MSFN	
				N	W			N	W
85'	HGA(E) - PA					PM Mode 1B	215K		
						Carrier		46.6	43.7
						Voice/H.L.			
						Biomed		18.4	14.9
						51.2Kbps TLM		16.0	12.7
85'	HGA(E) - TX					PM Mode 7A	215K		
						Carrier		31.2	28.3
						Voice/H.L.			
						Biomed		5.5	1.9
						1.6Kbps TLM		8.6	5.3
85'	Omni - PA					[illegible]	215K		
						[illegible]		17.4	13.7
						[illegible]		3.8	- 0.3
						[illegible]		2.9	- 1.2
85'	Omni - TX					[illegible]	215K		
						[illegible]		6.7	5.4
								10.5	7.1
30'	HGA(S) - PA	(Listen only)				PM Mode 2B	215K		
						Carrier		30.8	29.9
						PRN Ranging		13.7	12.9
						Voice/H.L.			
						Biomed		2.6	1.1
						51.2Kbps TLM		0.2	- 1.1

Lunar Phase Support Requirements
LM - MSFN One-Way Links
(continued)

MSFN Configuration	LM Configuration	Mode Description MSFN to LM	Range nmi	Margins at LM		Mode Description LM to MSFN	Range nmi	Margins at MSFN	
				N	W			N	W
85'	HGA(E) - PA					FM Mode 10B Voice/H.L. Biomed 51.2Kbps TLM TV Mode-as-a-Whole	215K	8.8	4.3
85'	Omni	PM Mode 2 Carrier Voice	215K	13.1 10.5	9.1 7.4				
85'	HGA(E)	PM Mode 2 Carrier Voice	215K	41.1 38.5	38.0 36.2				
85'	HGA(E)	PM Mode 7 Carrier Voice Updata	215K	43.2 31.5 31.5	40.8 30.0 30.0				

Lunar Stay Phase Relay Links
EVA_2-EVA_1-LM-MSFN-CSM

MSFN Configuration	Spacecraft Configuration	Mode Description	Range nmi	Margins N	Margins W	Mode Description	Range nmi	Margins N	Margins W
		EVA_2 to EVA_1				EVA_1 to LM			
		Voice	0.5	15.6	--	Voice	1.0	12.3	--
		EMU				EMU		11.1	--
85'	LM: HGA(E)-PA CSM: HGA(N)	LM to MSFN				MSFN to CSM			
		PM Mode 1B	215K			PM Mode 7	215K		
		Carrier		46.7	43.7	Carrier		41.2	39.1
		Voice/H.L.				Voice		28.2	25.6
		Biomed/EMU		15.1	11.6	Updata		28.2	25.6
		51.2Kbps TLM		16.0	12.7				
		EVA_2 to EVA_1				EVA_1 to LM			
		Voice	0.5	15.6	--	Voice	1.0	12.3	--
		EMU		--	--	EMU		11.1	--
85'	LM: HGA(E)-TX CSM: HGA(N)	LM to MSFN				MSFN to CSM			
		PM Mode 7A				PM Mode 7	215K		
		Carrier		31.2	28.3	Carrier		41.2	39.1
		Voice/H.L.				Voice		28.2	25.6
		Biomed/EMU		4.2	0.6	Updata		28.2	25.6
		1.6Kbps TLM		8.6	5.3				

Lunar Stay Phase Relay Links
EVA_2-EVA_1-LM-MSFN-CSM

MSFN Configuration	Spacecraft Configuration	Mode Description	Range nmi	Margins N	Margins W	Mode Description	Range nmi	Margins N	Margins W
85'	LM: HGA(E)-PA CSM: HGA(N)	EVA_2 to EVA_1				EVA to LM			
		Voice	0.5	15.6	--	Voice	1.0	12.7	--
		EMU		--	--	EMU		14.9	--
		LM to MSFN				MSFN to CSM			
		PM Mode 7B	215K			PM Mode 7	2.5K		
		Carrier		46.6	43.7	Carrier		41.2	39.1
		Voice/H.L.				Voice		28.2	25.6
		Biomed/EMU		15.1	11.6	Updata		28.2	25.6
		1.6Kbps TLM		31.0	27.7				
85'	LM: HGA(E)-PA CSM: HGA(N)-PA	EVA_2 to EVA_1				EVA_1 to LM			
		Voice	0.5	15.6	--	Voice	1.0	12.3	--
		EMU		--	--	EMU		10.6	--
		LM to MSFN				MSFN to CSM			
		FM Mode 9B	215K			PM Mode 7	2.5K		
		Voice/EMU				Carrier		41.3	39.1
		51.2Kbps TLM				Voice		28.2	25.6
		Mode-as-a-Whole		4.5	0.0	Updata		28.2	25.6

Lunar Stay Phase Relay Links
EVA_2-EVA_1-LM-MSFN-CSM

MSFN Configuration	Spacecraft Configuration	Mode Description	Range nmi	Margins N	Margins W	Mode Description	Range nmi	Margins N	Margins W
		EVA_2 to EVA_1				EVA to LM			
		Voice	0.5	15.6	--	Voice	1.0	12.3	--
		EMU		--	--	EMU		10.6	--
85'	LM: HGA(E)-PA	LM to MSFN				MSFN to CSM			
	CSM: HGA(N)-PA	FM Mode 10B	215K			PM Mode 7	2.5K		
		Voice/EMU				Carrier		41.3	39.1
		51.2Kbps TLM				Voice		28.2	25.6
		TV				Updata		28.2	25.6
		Mode-as-a-Whole		4.5	0.0				

Lunar Stay Phase Relay Link
CSM-MSFN-LM-EVA

MSFN Configuration	Spacecraft Configuration	Mode Description	Range nmi	Margins N	Margins W	Mode Description	Range nmi	Margins N	Margins W
85'	CSM: HGA(N)-PA	CSM to MSFN	215K			MSFN to LM	215K		
	LM: HGA(E)	PM Mode 1				PM Mode 2			
		Carrier		41.0	38.9	Carrier		41.1	38.0
		Voice		10.3	7.6	Voice		38.5	36.2
		LM to EVA_1 or 2							
		Voice	1.0	17.6	15.0				

Lunar Stay Phase
EVA_1-EVA_2

MSFN Configuration	Spacecraft Configuration	Mode Description	Range nmi	Margins		Mode Description	Range nmi	Margins	
				N	W			N	W
		EVA_1 to EVA_2							
		Voice	0.5	29.8db	--				

Reentry and Recovery Support Requirements
CM - MSFN One-Way Links

MSFN Configuration	CM Configuration	Mode Description MSFN to CM	Range nmi	Margins at CM N	Margins at CM W	Mode Description CM to MSFN	Range nmi	Margins at MSFN N	Margins at MSFN W
Recovery A/C	Omni - PA	(Tracking only)				PM Mode 1	300		
						Carrier		2.7	2.7
						Voice		--	--
						51.2Kbps TLM		--	--
Recovery A/C	Omni - PA	(Tracking only)				PM Mode 2	300		
						Carrier		0.9	0.9
						PRN Ranging		--	--
						Voice		--	--
						51.2Kbps TLM		--	--
Recovery A/C	Omni - PA	(Tracking only)				PM Mode 3	300		
						Carrier		0.9	0.9
						PRN Ranging		--	--
						Voice		--	--
						1.6Kbps TLM		--	--

FM CHANNEL PERFORMANCE

PROBLEM: THE FOLLOWING CSM FM MODES EXHIBIT NEGATIVE CIRCUIT MARGINS AT LUNAR DISTANCE FOR WORST CASE CONDITIONS.

MODE	SERVICE(S)	ANTENNA		SC TRANSMIT POWER	CRITERIA
		SC	MSFN		
CSM FM Mode 1	1:1 Playback of: 51.2Kbps TLM Voice	High-gain NBW	85-foot	High	10^{-4} BER TLM 70% Word Intelligibility
CSM FM Mode 2	32:1 Playback of: 1.6Kbps TLM Voice	High-gain NBW	85-foot	High	10^{-4} BER TLM 70% Word Intelligibility

BACKGROUND

- THE CSM EFFECTIVE RADIATED POWER FOR FM MODES WAS BASED ON A REQUIRED INPUT SIGNAL-TO-NOISE RATIO OF 8db IN THE MSFN FM CARRIER FREQUENCY DEMODULATOR. PREDETECTION NOISE BANDWIDTH FOR ACCEPTABLE OUTPUT PERFORMANCE.

- BASED ON MSFN CHARACTERISTICS ESTABLISHED EARLY IN THE PROGRAM A RECEIVED SIGNAL LEVEL OF -102dbm AT THE MSFN PARAMP OUTPUT INTERFACE SHOULD PROVIDE AN INPUT SIGNAL-TO-NOISE RATIO OF 8db IN THE FM DEMODULATOR PREDETECTION BANDWIDTH.

PRESENT STATUS

A TOTAL RECEIVED SIGNAL POWER LEVEL OF -102dbm AT THE MSFN PARAMP OUTPUT INTERFACE PROVIDES AN INPUT SIGNAL-TO-NOISE RATIO OF APPROXIMATELY 6.6db IN THE PREDETECTION BANDWIDTH OF THE FM CARRIER FREQUENCY DEMODULATOR. THIS RESULTS IN AN FM CHANNEL MODE-AS-A-WHOLE CIRCUIT MARGIN OF -1.4db.

4-19

RECOMMENDED SOLUTIONS

- INCREASE SPACECRAFT RADIATED POWER.
    - SPACECRAFT POWER AMPLIFIERS EXCEED OUTPUT POWER SPECIFICATION BY APPROXIMATELY 0.5db.
    - NAA IS INVESTIGATING WAYS OF REDUCING SPACECRAFT CABLE LOSSES.
- INCREASE THE WORST CASE MSFN 85-FOOT ANTENNA GAIN.

FM CHANNEL PERFORMANCE

PROBLEM: THE MSFN APOLLO FM DEMODULATORS DO NOT MEET SPECIFIED PERFORMANCE CHARACTERISTICS.

BACKGROUND

THE APOLLO CSM FM SIGNAL DESIGN IS PREDICATED ON FM DEMODULATOR THRESHOLD AT OR BELOW AN INPUT SIGNAL-TO-NOISE RATIO OF 8db FOR ALL INPUT SIGNAL CONDITIONS.

IF THRESHOLD REQUIREMENT IS MET THE CSM SIGNAL DESIGN IS SUCH THAT AN 8db SIGNAL-TO-NOISE INTO THE DEMODULATOR WILL RESULT IN A MINIMUM VOICE CHANNEL OUTPUT SIGNAL-TO-NOISE RATIO OF 14db (GREATER THAN 70% WORD INTELLIGIBILITY) AND A MAXIMUM BIT ERROR RATE OF 10^{-4} FOR 51.2Kbps TLM.

PRESENT STATUS

- TEST DATA OBTAINED AT MSC INDICATES THAT FM DEMODULATOR INPUT SIGNAL-TO-NOISE RATIOS OF 9 - 10.5db* ARE NECESSARY TO OBTAIN THE REQUIRED VOICE CHANNEL OUTPUT SIGNAL-TO-NOISE RATIO OF 14db.

- AN INPUT SIGNAL-TO-NOISE RATIO OF 8.5 - 10db* IN THE PREDETECTION BANDWIDTH IS REQUIRED FOR A TELEMETRY BIT ERROR RATE OF 10^{-4}.

*PERFORMANCE OF THE MSFN DEMODULATOR UNITS TESTED AT MSC VARIES SIGNIFICANTLY BETWEEN INDIVIDUAL UNITS.

RECOMMENDED TECHNIQUES FOR OPTIMIZATION

OF THE MSFN CARRIER FREQUENCY DEMODULATOR

1. AUTOMATIC FREQUENCY CONTROL (AFC) OF THE 50 MHz IF.

2. IMPLEMENTATION OF PRE-MISSION ALIGNMENT PROCEDURES FOR THE MSFN CARRIER FREQUENCY DEMODULATOR TO ASSURE THAT THE PHASE LOCK LOOP VCO STRESS IS MINIMIZED.

3. IMPULSE NOISE SUPPRESSION.

OMNI MODE PERFORMANCE AT LUNAR DISTANCE

PROBLEM: WORST CASE THEORETICAL CIRCUIT MARGIN FOR CSM MODE 8 AND LM MODE 4 (1.6Kbps TLM AND BACKUP VOICE) ARE NEGATIVE AT LUNAR DISTANCE WHEN USING THE SPACECRAFT OMNI ANTENNA.

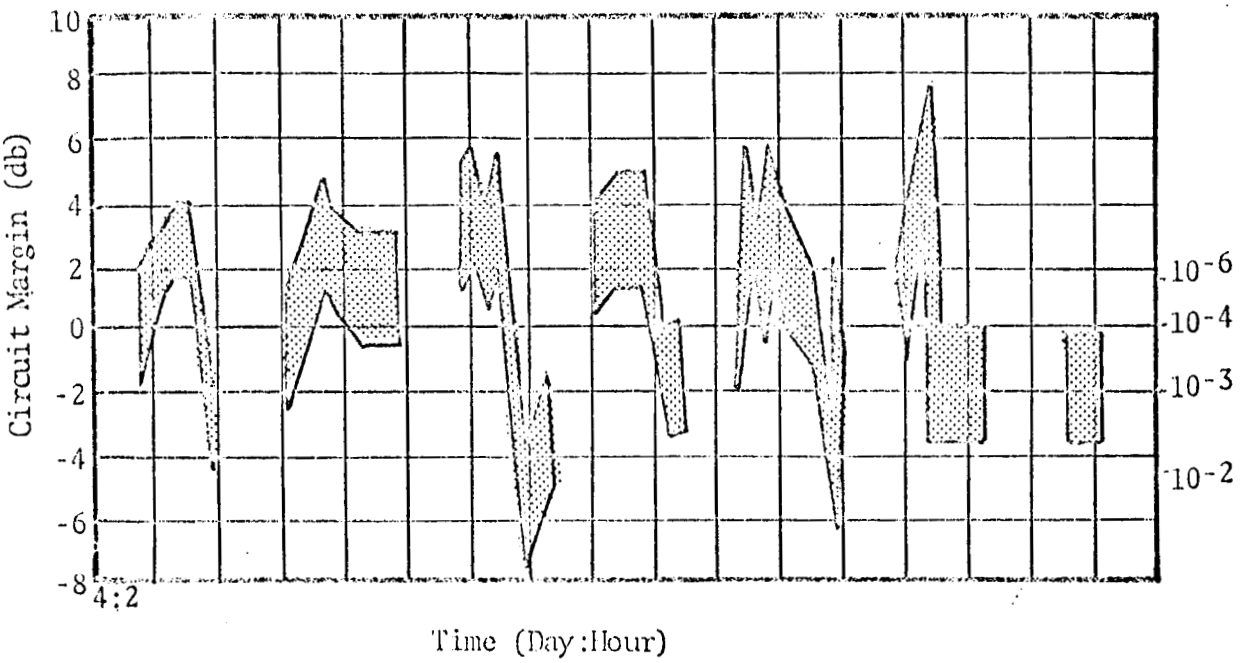
- THE THEORETICAL MARGINS ARE BASED ON SPECIFIED SYSTEMS PARAMETERS AND DO NOT REFLECT ANY PERFORMANCE DEGRADATION DUE TO EFFECTS SUCH AS:

  (1) INCIDENTAL PHASE MODULATION (IPM).

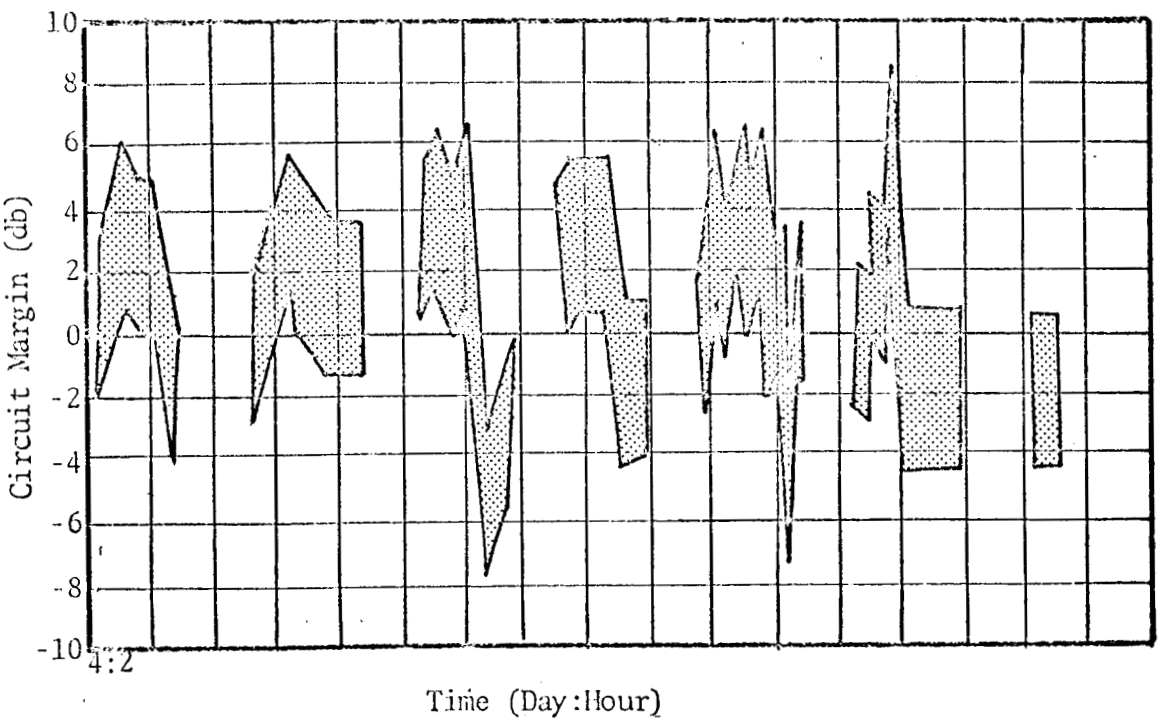
  (2) FINITE TRANSMITTED SIGNAL-TO-NOISE RATIOS.

  (3) MODULATION INDEX TOLERANCES.

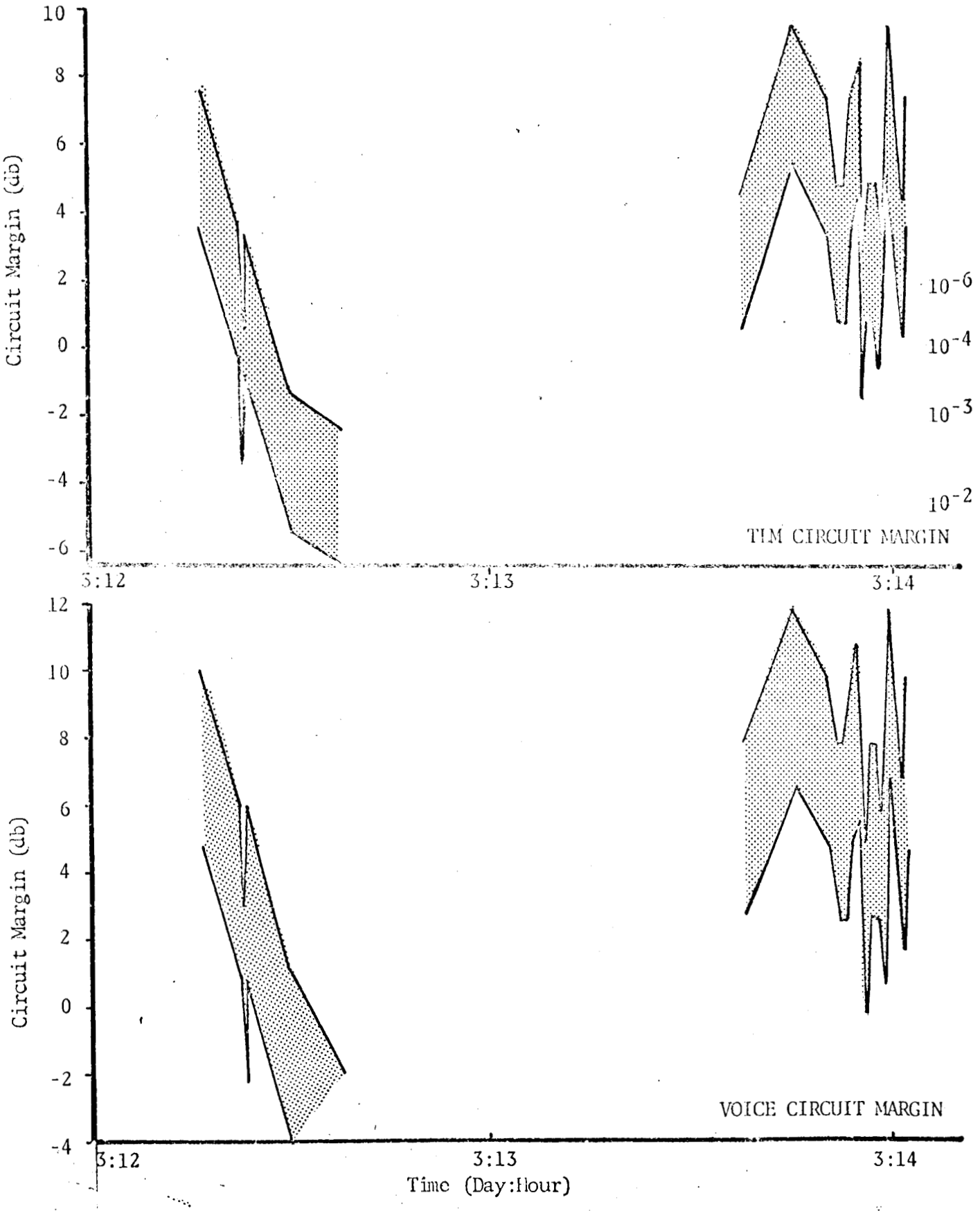
DOWN-LINK BLOCK II CIRCUIT MARGINS
CSM Mode 8 (Backup Voice and 1.6Kbps TIM)
TIM Circuit Margin



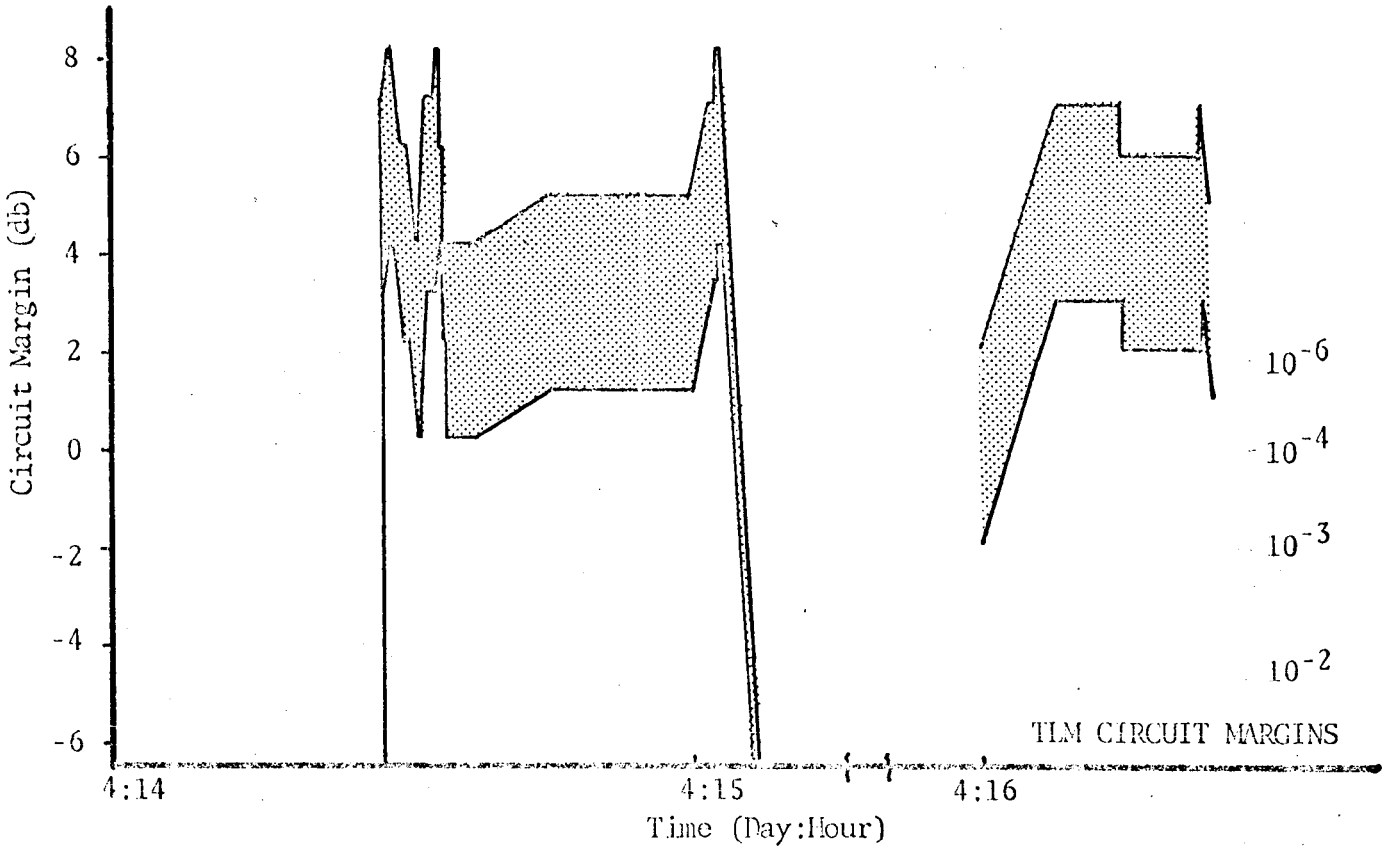
DOWN-LINK BLOCK II CIRCUIT MARGINS
CSM Mode 8 (Backup Voice and 1.6Kbps TIM)
Voice Circuit Margin

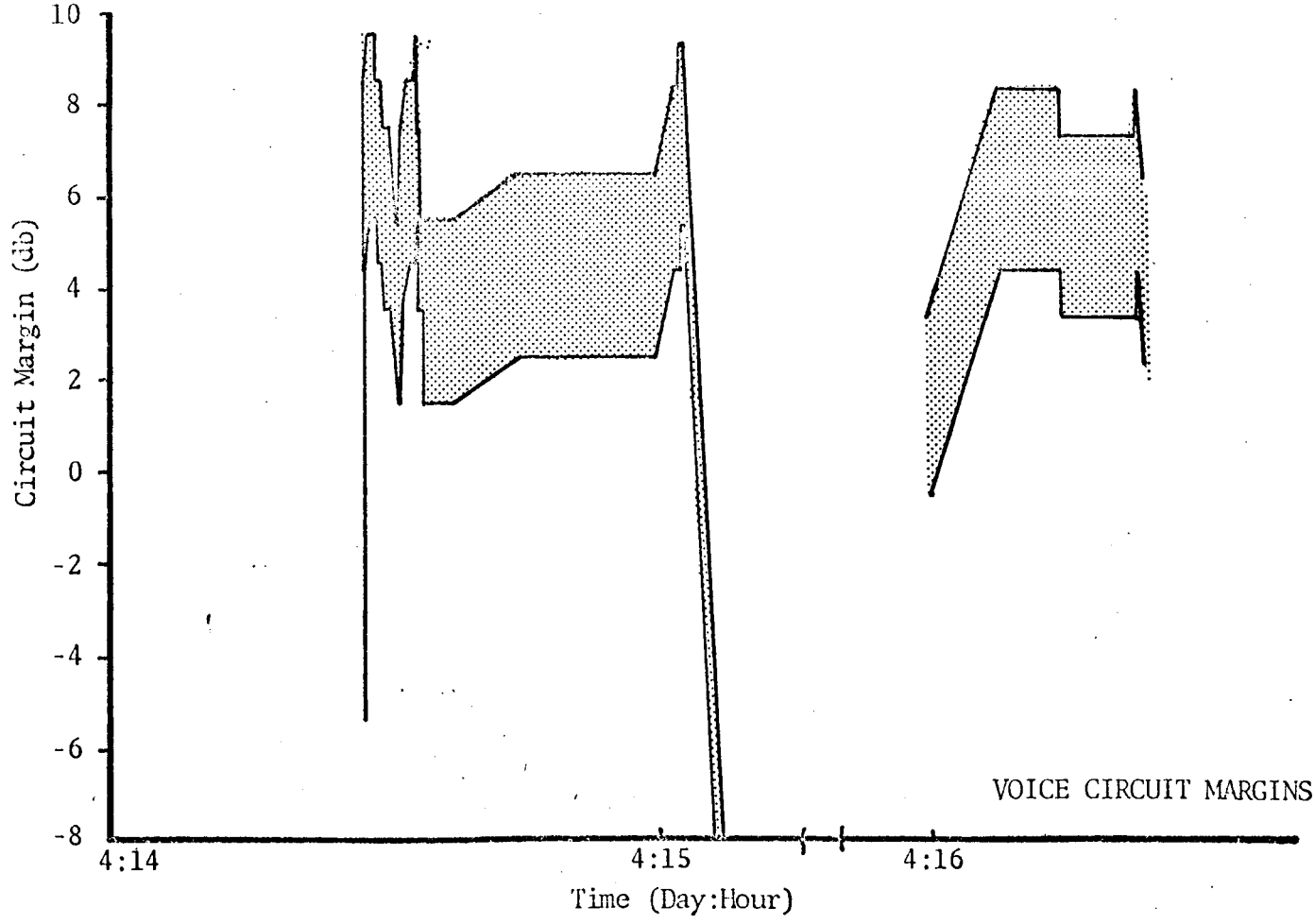


DOWN-LINK LM DESCENT CONFIGURATION CIRCUIT MARGINS, OMNI 1
MODE 4 (BACKUP VOICE AND 1.6Kbps TLM)



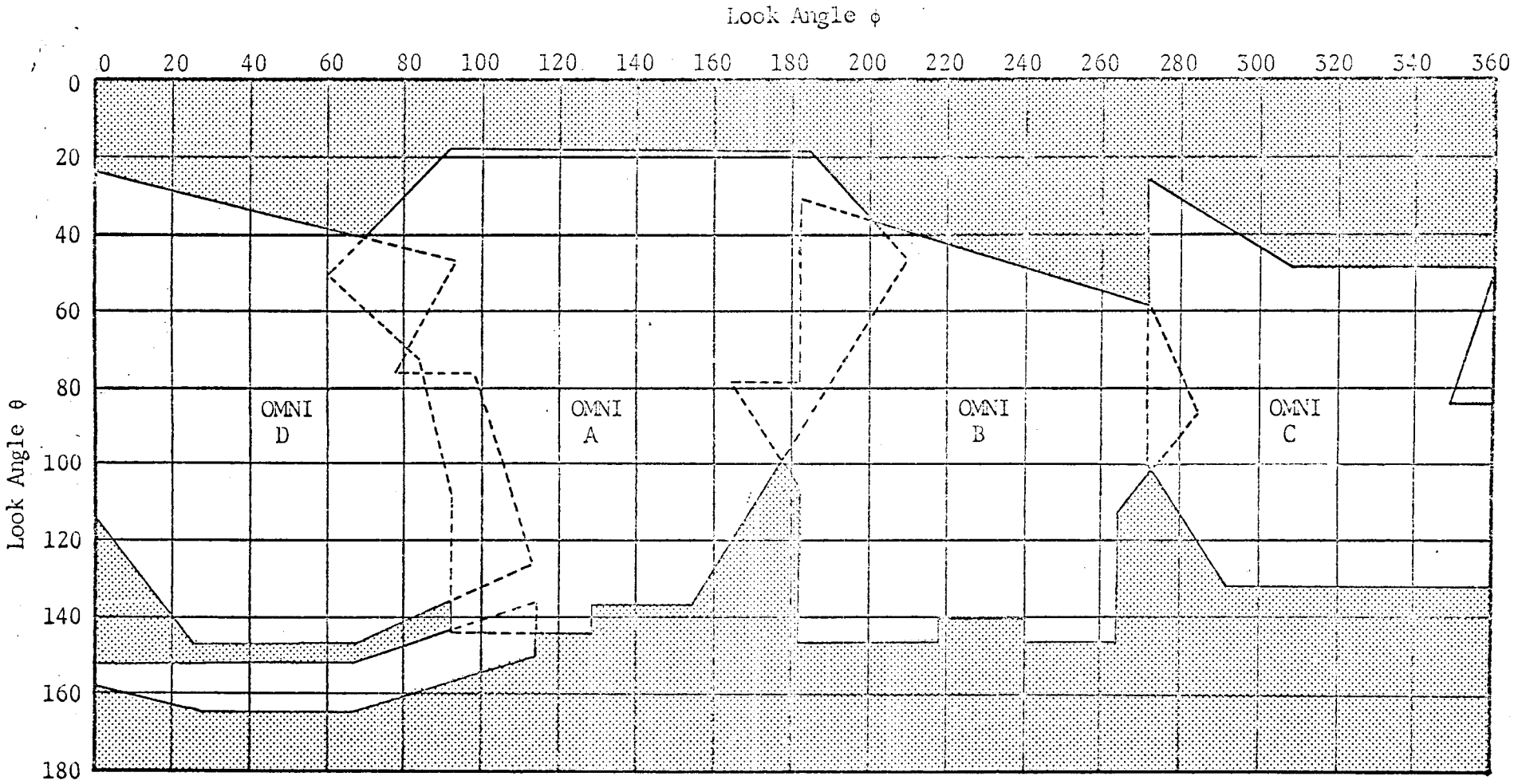
DOWN-LINK LM ASCENT CONFIGURATION CIRCUIT MARGINS, OMNI
MODE 4 (BACKUP VOICE AND 1.6Kbps TLM)





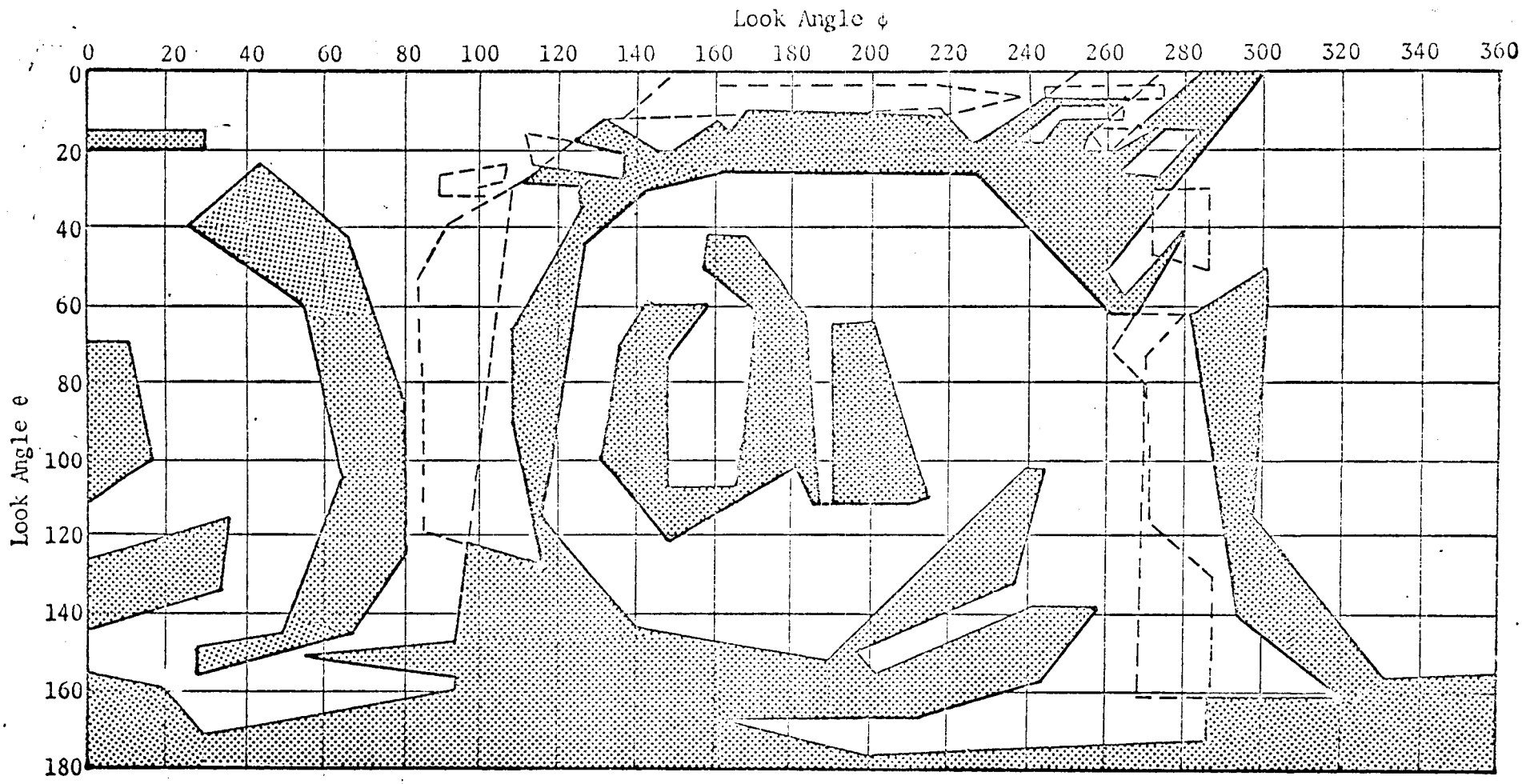
POSSIBLE SOLUTIONS

- REDUCE SPACECRAFT RF CIRCUIT LOSSES.
- INCREASE SPACECRAFT POWER AMPLIFIER OUTPUT.
- INCREASE THE WORST CASE MSFN 85-FOOT ANTENNA GAIN.
- CONSTRAIN CSM ATTITUDE SO THAT OMNI ANTENNA PROVIDES A GAIN OF 2.0db.
- CONSTRAIN LM ATTITUDE SO THAT OMNI ANTENNA PROVIDES A GAIN OF -1.0db.



LOOK-ANGLE COMBINATIONS[1] WHICH
PROVIDE POSITIVE CIRCUIT MARGINS
FOR CSM MODE 8 AT LUNAR DISTANCE

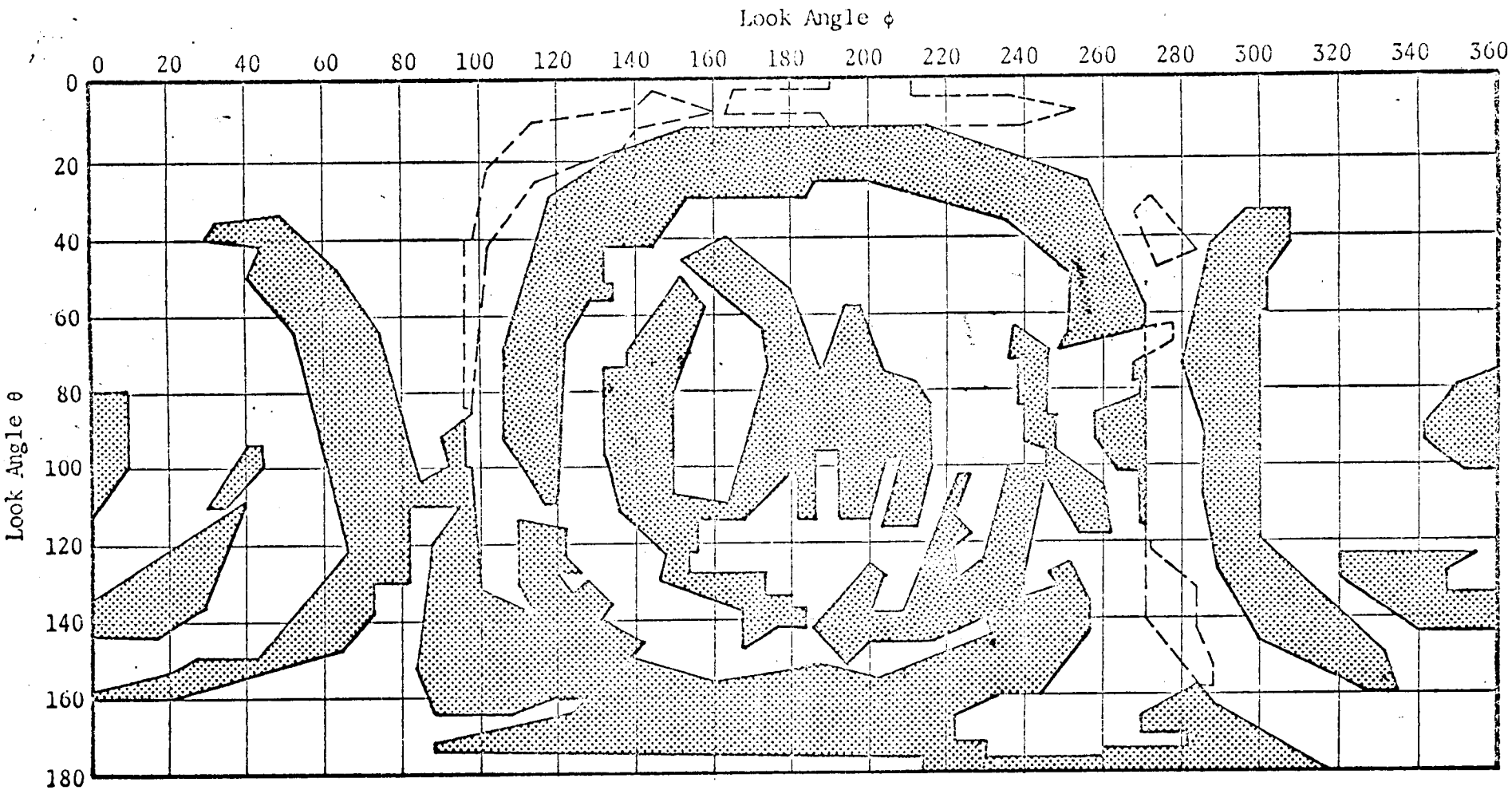
NOTE 1
PERCENT COVERAGE ≐ 60%



LOOK-ANGLE COMBINATIONS[1] WHICH
PROVIDE POSITIVE CIRCUIT MARGINS
FOR LM MODE 4 AT LUNAR DISTANCE
(DESCENT CONFIGURATION)

NOTE 1

PERCENT COVERAGE = 66%



LOOK ANGLE COMBINATIONS[1] WHICH
PROVIDE POSITIVE CIRCUIT MARGINS
FOR LM MODE 4 AT LUNAR DISTANCE
(ASCENT CONFIGURATION)

NOTE 1

PERCENT COVERAGE = 63%

OMNI MODE PERFORMANCE AT LUNAR DISTANCE

PROBLEM: THE MODULATION TECHNIQUE EMPLOYED ON BOTH CSM AND LM FOR TRANSMISSION OF BACKUP VOICE AND 1.6Kbps TLM IS INCOMPATIBLE WITH THE MSFN RECEIVER.

- 1.6Kbps TLM PERFORMANCE IS DEGRADED DUE TO INTERFERENCE FROM THE BACKUP VOICE CHANNEL.
- TEST RESULTS INDICATE THAT TLM PERFORMANCE IS LIMITED BY THE PEAK MODULATION ON THE S-BAND CARRIER.
- FOR PEAK CARRIER PHASE DEVIATIONS GREATER THAN 0.85 RADIANS, THE DEGRADATION IS INTOLERABLE.
- THE PRESENTLY SPECIFIED VALUE FOR IPM OF 28° RMS (0.49 RMS RADIANS; ESTIMATED 1.0 RADIAN PEAK) EXCEEDS THIS LIMIT.
- DECREASING THE BACKUP VOICE MODULATION INDEX TO COMPENSATE FOR THE PRESENCE OF IPM FORCES THE ALREADY NEGATIVE VOICE MARGIN MORE NEGATIVE.

PRESENT STATUS

- DETAILED THEORETICAL ANALYSIS HAS FAILED TO IDENTIFY THE SOURCE OF THE TOTAL DEGRADATION.

- INSUFFICIENT TEST DATA EXISTS TO DETERMINE IF MODIFICATION CAN BE MADE TO THE PRESENT MSFN RECEIVER WHICH WILL IMPROVE PERFORMANCE TO AN ACCEPTABLE LEVEL.

- TESTS ARE NOW BEING DEFINED TO:

  A. VERIFY OPERATING CHARACTERISTICS OF THE MSFN RECEIVER CARRIER TRACKING LOOP.

  B. VERIFY OPERATING CHARACTERISTICS OF THE MSFN TELEMETRY DEMODULATOR.

  C. DETERMINE THE EFFECTS OF REDUCING THE CARRIER LOOP BANDWIDTH BELOW 50 Hz.

POSSIBLE SOLUTIONS

- RESTRICTION OF THE BACKUP VOICE MODULATION INDEX TO 0.85 RADIANS (EFFECTIVE ONLY IF IPM IS MODERATE).

- MODIFY THE PRESENT MSFN OPERATING CONFIGURATION.
    - ELIMINATION OF THE INTERFERENCE BY REDUCTION OF THE CARRIER TRACKING LOOP BANDWIDTH.
    - MODIFICATION OF THE TLM SUBCARRIER DEMODULATOR REFERENCE LOOP.

- IMPLEMENTATION OF A NEW SPACECRAFT MODULATION TECHNIQUE TO INSURE THAT THE VOICE CHANNEL POWER SPECTRUM IS OUTSIDE THE CARRIER TRACKING LOOP AND TLM DEMODULATOR REFERENCE LOOP BANDWIDTHS.

ALTERNATIVES

- USE OF CSM MODE 10 OR LM MODE 5 (BACKUP VOICE ONLY) FOR VOICE COMMUNICATIONS.

- USE OF CSM MODE 5 OR LM MODE 3 (1.6Kbps TLM ONLY) TO ACQUIRE LOW BIT RATE TLM.

PROBLEM

- INSUFFICIENT MEASURED PERFORMANCE DATA ON THE MSFN

BACKGROUND

COMMUNICATION SYSTEM PERFORMANCE ANALYSES FOR MISSIONS AS-501, AS-502, AND AS-204/LM-1 WERE ACCOMPLISHED USING MEASURED SPACECRAFT PARAMETERS AND MSFN PARAMETERS AS GIVEN IN THE PERFORMANCE AND INTERFACE SPECIFICATION.

MEASURED VALUES FOR CERTAIN MSFN PARAMETERS ARE NEEDED IN ORDER TO PREDICT THE USB SYSTEM PERFORMANCE MORE ACCURATELY.

A SET OF DATA REQUIREMENTS WHICH WILL PROVIDE THE DESIRED INFORMATION HAS BEEN MUTUALLY AGREED ON BY GSFC AND MSC.

STATUS

MEASURED MSFN PARAMETERS ARE UNAVAILABLE AT THIS TIME.

PERFORMANCE AND INTERFACE SPECIFICATION OPEN ITEMS

1. MSFN 30' ANTENNA GAIN - THE GAIN WAS ORIGINALLY STATED BY GSFC AND PLACED IN THE P&I SPECIFICATION AS 43db MINIMUM ON TRANSMIT AND 44db MINIMUM ON RECEIVE. LATER INPUTS FROM GSFC INDICATE A GAIN OF 41db MINIMUM ON TRANSMIT AND 42db MINIMUM ON RECEIVE.

2. EVA-LM INTERFACE - THE CHARACTERISTICS AND PERFORMANCE REQUIREMENTS FOR THIS INTERFACE ARE NOT CURRENTLY IN THE PERFORMANCE AND INTERFACE SPECIFICATION.

3. CSM-MSFN-LM RELAY INTERFACE - THE CHARACTERISTICS AND PERFORMANCE REQUIREMENTS FOR THIS INTERFACE ARE NOT CURRENTLY IN THE PERFORMANCE AND INTERFACE SPECIFICATION.

4. JPL BACK-UP SITE PARAMETERS - THE VALUES FOR THE JPL BACK-UP SITES HAVE BEEN OBTAINED FROM JPL AND ARE NOT OFFICIAL. ACTION IS UNDERWAY TO OBTAIN OFFICIAL VALUES FOR GSFC.

5. LM PCM BIT TRANSITION - THE NUMBER AND DENSITY OF PCM BIT TRANSITIONS REQUIRED FOR PROPER PCM BIT SYNCHRONIZER OPERATION IS NOT CURRENTLY IN THE PERFORMANCE AND INTERFACE SPECIFICATION.

6. MSFN LM UP-DATA LINK - THE CHARACTERISTICS AND PERFORMANCE REQUIREMENTS FOR THIS INTERFACE ARE NOT CURRENTLY IN THE PERFORMANCE AND INTERFACE SPECIFICATION.

LM STEERABLE ANTENNA STATUS

LM ANTENNA

QUALIFICATION TEST STATUS

QUALIFICATION TESTS COMPLETED FEBRUARY 18, 1967

NO SIGNIFICANT PROBLEMS ENCOUNTERED DURING QUAL TESTS

MODIFICATION TO LM STEERABLE ANTENNA

PURPOSE: NEW MPAD COVERAGE REQUIREMENTS

THE MODIFICATION WILL CONSIST OF THE FOLLOWING:

a. ROTATE ELECTRONICS ASSEMBLY -30° ABOUT THE Xg AXIS

b. CHANGE ANTENNA STOW POSITION

c. ALTER POWER AMPLIFIER CIRCUIT TO PROVIDE MORE TORQUE TO DRIVE MOTORS

d. INCREASE Xg AXIS TRAVEL FROM $\pm 75^{\circ}$ to $\pm 87^{\circ}$

e. TILT ANTENNA BY 45° IN THE LM XY PLANE

EFFECT OF MODIFICATION ON PRESENT MISSION PLAN:

a. COOL DOWN PERIOD REQUIRED WITH RADIATION AXIS POSITIONED TOWARD LOCAL ZENITH

b. DECREASE VEHICLE ROTATION RATES TO 5°/SEC AT Xg ANGLES GREATER THAN 81°

NEW ENDURANCE QUALIFICATION TEST WILL BE REQUIRED ON MODIFIED ANTENNAS

LM STEERABLE DELIVERY SCHEDULE

MODEL	DESTINATION	DELIVERY DATE
PP3	GAEC ESI - RCA INT LM 1	AT KSC ON LM 1
PP4	VENDOR DFI MSC INT.	AT MSC
PP5	GAEC LTA-1 LTA-8	ON LTA 8 AT GAEC
PP6	RCA INT VENDOR OP SPARE	AT VENDOR
P7	VENDOR ENDUR. & D. L. QUAL	
	MSC INT.	AT MSC
P8	GAEC LM 2	AT GAEC IN OCP
P9	GAEC LM 3	9-25-67
P10	DV SPARE	10-10-67
P11	GAEC LM 4	2-15-68
P12	QUAL UNIT	3-25-68
P13	GAEC LM 5	5-1-68
P14	SPARE	5-25-68
P15	GAEC LM 6	6-15-68
P16	GAEC LM 7	6-28-68
P17	GAEC LM 8	7-15-68

CSM APOLLO HGA

PROGRAM STATUS REPORT

CSM ANTENNA

QUAL-UNIT DEVIATIONS

PARAMETERS	SPEC. REQ.	GRANTED DEV.	ACTUAL PER.
RECEIVE VSWR	1.7:1.0	2.0:1.0	1.72:1.0
NARROW BEAM GAIN			
ON AXIS	27 db	26.2 db	26.4 db
PRI. STA. NORMAL	26.8 db	26.0 db	26.0 db
PRI STA. TRANSIENT (10 RPH)	25.6 db	24.8 db	25.2 db
BEAM WIDTH MEDIUM (TRANSMIT)	11.3^{o}	7.5^{o}	7.75^{o}
MANUAL POSITION ACCURACY	5°	10°	6.25^{o}

CSM ANTENNA

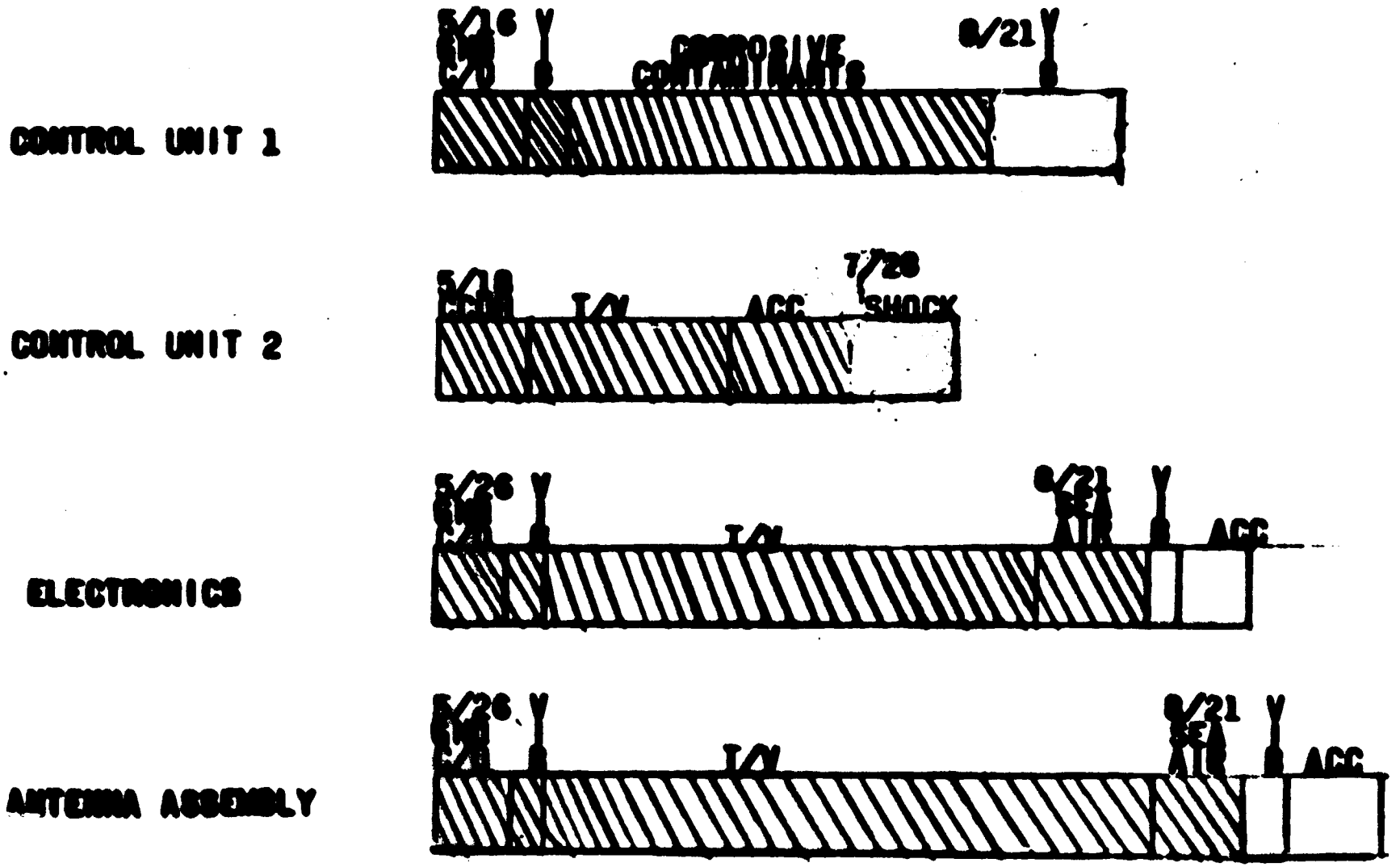
REASONS FOR QUAL TESTING UNIT WITH DEVIATIONS

1. EXPECTED PROBLEM AREAS WHICH WERE NOT ENCOUNTERED DURING LIMITED DEVELOPMENT TESTING. THESE PROBLEM AREAS WOULD BECOME APPARENT AS SOON AS POSSIBLE TO ALLOW REDESIGN AND DELTA QUAL TESTING.

2. ELIMINATING DEVIATIONS ON QUAL UNITS WOULD COST $340,000 AND THREE MONTHS SCHEDULE SLIP ON BEGINNING QUAL TESTS.

CSM ANTENNA

QUAL TEST STATUS



CSM ANTENNA

SIGNIFICANT OPEN QUAL TEST FAILURES

FAILURES	CORRECTION ACTIONS
ANTENNA ASSEMBLY	
DIODE HOUSING SHORTS & OPENS	DIODE HOUSING DESIGN MOD. PROCEDURES & INLINE TESTS UPDATED
W/B HORN & COAX CABLE FRACTURES	INSTALLATION REDESIGN & COAX SUPPORT CHANGED
MICROWAVE PERFORMANCE CHANGES VSWR SEC. STA. GAIN ELLIPTICITY BEAMWIDTH	PERFORM TESTS AND INSPECTION ON MICROWAVE SUBASSEMBLIES TO ISOLATE PROBLEMS
CONTROL	
HOUSING (RESOLVER) CORROSION	PAINT AND NICKEL PLATE RESOLVER HOUSINGS

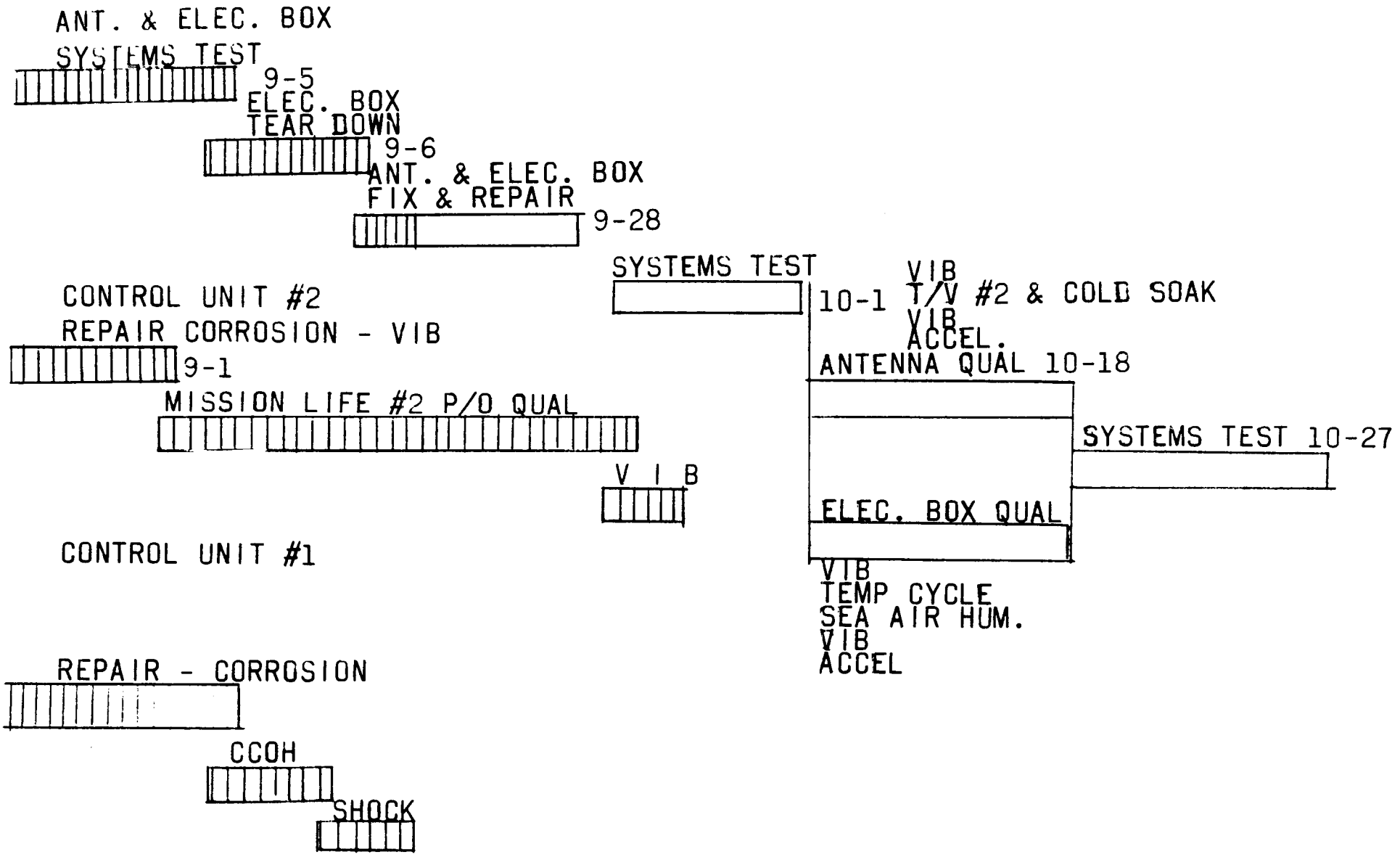
CSM ANTENNA

SIGNIFICANT OPEN QUAL TEST FAILURES CONT.

FAILURES	CORRECTIVE ACTIONS
ELECTRONICS BOX	
C-AXIS PHASE ANGLE	DETERMINE TEMP. SENSITIVE COMPS.
A&B AXIS GAIN	DETERMINE TEMP. SENSITIVE COMPS.
W/B - N/B SWITCH	SWITCHING CIRCUIT MODIFICATION INCORP.
PITCH & YAW INSTR. SERVO (BRUSH CONTACT)	MECH. MEASUREMENTS MADE DURING ASSEMBLY CONTROLLING BRUSH PRESSURE

CSM ANTENNA

DELTA - QUAL PLAN



SCHEDULES

NAA DATES AS OF 7/21/67

S/C	NAA DATES	D.V. PREDICTED	ANTENNA UNIT
*2 TV			
101	DELETED	---	XDV - 3
103	11/15/67	10/16/67	XDV - 5
104	1/15/68	11/10/67	XDV - 6
106	2/1/68	12/8/67	XDV - 7
107	2/15/68	1/12/68	XDV - 8
108	3/1/68	2/9/68	XDV - 9
109	3/29/68	3/8/68	XDV - 10
110	5/17/68	4/5/68	XDV - 11
111	6/21/68	5/3/68	XDV - 12
112	8/9/68	5/31/68	XDV - 13
102	9/29/68	6/29/68	XDV - 14
113	11/15/68	7/26/68	XDV - 15

*S/C 101 ANTENNA WILL BE USED FOR S/C 2TV-1 AND COMPATIBILITY TESTING AT MSC.

STATUS OF CSM & LM STEERABLE ANTENNA RF

TRACKER COMPATIBILITY TESTING AT MSC

LM STEERABLE ANTENNA

RF TRACKER COMPATIBILITY TEST RESULTS INDICATE THE FOLLOWING PROBLEMS:

a. INTRODUCTION OF UPLINK SUBCARRIERS & PRN CAUSES EXCESSIVE BORESIGHT SHIFT

b. INTRODUCTION OF UPLINK SUBCARRIERS & PRN RESULTS IN EXCESSIVE DYNAMIC TRACKING ERROR

TEST RESULTS VERIFIED TWO SOLUTIONS FOR THE RF TRACK PROBLEMS:

a. IMPLEMENT NONCOHERENT DETECTOR

b. REDUCE UPLINK MODULATION INDICES

REDUCED UPLINK MODULATION INDICES WERE RECOMMENDED DUE TO:

a. NO SCHEDULE IMPACT

b. NO HARDWARE MODS.

c. NO SIGNIFICANT COST

d. MARGINS ALLOW THIS

ADDITIONAL RF TRACKER TESTS ARE REQUIRED TO VERIFY PERFORMANCE OF ANTENNA AFTER MODIFICATION FOR INCREASED COVERAGE.

CSM STEERABLE ANTENNA

TRACKER COMPATIBILITY TEST WILL BE CONDUCTED AT MSC ON S/C 101 ANTENNA TO ANALYZE THE FOLLOWING POTENTIAL PROBLEM AREAS:

a. INTRODUCTION OF UPLINK SUBCARRIERS AND PRN CAUSES EXCESSIVE BORESIGHT SHIFT

b. INTRODUCTION OF UPLINK SUBCARRIERS AND PRN CAUSES RESULTS IN EXCESSIVE DYNAMIC TRACKING ERROR

PRESENT ANALYSIS RESULTS INDICATE ABOVE PROBLEMS WILL NOT BE AS SEVERE AS THOSE ON LM ANTENNA.

TEST STATUS:

RECEIVED S/C 101 ANTENNA AT MSC 8-1-67.

FAILED TO AUTO TRACK

ELECTRONICS BOX SHIPPED TO D. V. FOR ANALYSIS AND REPAIR 9-1-67

LM COMMUNICATIONS CORONA PROBLEM

COMM. UNIT	RF CORONA		AC CORONA		DC CORONA	
	AREA	FIX	AREA	FIX	AREA	FIX
S-BAND PA	UNKNOWN	-	HIGH VOLTAGE RECT.	COPPER-CLAD DIELEC-TRIC	HIGH VOLTAGE MODULE & HV LEAD	IMPREGNATE W/LOW VIS-COSITY POT-TING COMP.
S-BAND XCVR	RF X5 MPR (ATP ONLY)	POTTING OF MODULE	NONE	-	NONE	-
VHF XCVR	POSSIBLE POWER AMP	POT OR EPOXY COAT	NONE	-	NONE	-

LM COMMUNICATIONS CHANGES

1. CHANGE - SPA - ADD REDUNDANT REGULATOR AND SHORT CIRCUIT PROTECTION

   EFFECTIVITY - LM-4 AND SUBSEQUENT

   REMARKS - REQUIRED TO REMOVE SINGLE POINT FAILURE AND TO MEET SPECIFICATION REQUIREMENTS

2. CHANGE

   A. CHANGE VHF CLIPPING LEVEL
   B. PROVIDE HOT MIKE INTERCOM
   C. REDUCE VHF A OUTPUT 9 DB

   EFFECTIVITY

   A. LM-3 AND SUBSEQUENT
   B. LM-2 AND SUBSEQUENT
   C. LM-2 AND SUBSEQUENT

   REMARKS - REQUIRED TO CORRECT DEFICIENCIES IN VOICE LINKS

3. CHANGE - ADD S-BAND UP-DATA LINK INCLUDING BACKUP UP-VOICE CAPABILITY

   EFFECTIVITY - LM-4 AND SUBSEQUENT

   REMARKS - NEW REQUIREMENT

4. CHANGE - ROTATE VHF ANTENNA

   EFFECTIVITY - LM-2 AND SUBSEQUENT

   REMARKS - REQUIRED TO ELIMINATE SPS NOZZLE INTERFERENCE

5. CHANGE - MODIFY S-BAND STEERABLE ANTENNA MOUNT AND GIMBAL LIMITS

   EFFECTIVITY - LM-4 AND SUBSEQUENT

   REMARKS - NEW REQUIREMENT. TO PROVIDE BETTER COVERAGE DURING DESCENT

6. CHANGE

ADD S-BAND SQUELCH

EFFECTIVITY

LM-4 AND SUBSEQUENT

REMARKS

NEW REQUIREMENT TO PRECLUDE LOSS OF UP-LINK INTERFERING WITH EVA-EVA LINK

CSM COMMUNICATIONS CHANGES

1. CHANGE - DELETE HF RECOVERY SYSTEM

   EFFECTIVITY - ALL BLOCK II

   REMARKS - REQUIREMENT DELETED

2. CHANGE - RELOCATE VHF RECOVERY ANTENNAS

   EFFECTIVITY - ALL BLOCK II

   REMARKS - REQUIRED BECAUSE OF UPPER DECK CHANGES (ELS MODS)

EXTRA-VEHICULAR COMMUNICATIONS SYSTEM SCHEDULE

CONTRACT - JULY 24, 1967

CRITICAL DESIGN REVIEW - NOVEMBER 23, 1967

DESIGN FREEZE - MARCH 15, 1968

QUAL TEST - JUNE 1 THROUGH JULY 31, 1968

DELIVER 16 FLIGHT UNITS - OCTOBER 15, 1968 THROUGH
SEPTEMBER 15, 1969

LM S-BAND VOICE SINGLE POINT FAILURES

1. RF CABLE - S-BAND TRANSPONDER TO S-BAND POWER AMPLIFIER
2. RF CABLE - S-BAND POWER AMPLIFIER TO ANTENNA SWITCH
3. S-BAND DIPLEXER
4. RF CABLE - DIPLEXER TO S-BAND TRANSPONDER

VHF SPACE/GROUND LINKS						
CONFIGURATION		RANGE	UPLINK MARGIN		DOWNLINK MARGIN	
TERMINAL 1	TERMINAL 2	REQUIREMENT	NOMINAL	WORST CASE	NOMINAL	WORST CASE
CSM VHF/AM	MSFN	1000 N.M.	14.92 DB	8.72 DB	13.32 DB	9.32 DB
CSM VHF/AM	ARIA	750 N.M.	4.90	(-0.50)	11.55	7.75
CM VHF/AM	ARIA	300 N.M.	13.20	5.40	20.25	13.45
CM VHF/AM	AIRCRAFT	200 N.M.	4.10	(-3.56)	2.47	(-1.33)
CM BEACON	AIRCRAFT PRIMARY RCVR	300 N.M.	----	----	12.66	8.86
CM BEACON	AIRCRAFT SECONDARY RCVR	300 N.M.	----	----	(-3.34)	(-7.14)
CM SURVIVAL BEACON	AIRCRAFT PRIMARY RCVR	195 N.M.	----	----	12.92	6.50
CM SURVIVAL BEACON	AIRCRAFT SECONDARY RCVR	195 N.M.	----	----	(-4.08)	(-10.48)
CM SURVIVAL VHF/AM	AIRCRAFT	75 N.M.	6.82	(-3.60)	2.38	(-4.92)

NOTE: 1. MSFN & ARIA MARGINS BASED ON 90% WORD INTELLIGIBILITY

2. RECOVERY AIRCRAFT VOICE MARGINS BASED ON 70% WORD INTELLIGIBILITY

3. WORST CASE MARGINS CONSIDER EQUIPMENT TOLERANCES AND WORST CASE ANTENNA GAINS.

CSM/LM VHF INTERSPACECRAFT LINKS							
MODE	RANGE	CSM TO LM MARGINS			LM TO CSM MARGINS		
		NOM. MISSION ATTITUDES		RANDOM ATTITUDES	NOM. MISSION ATTITUDES		RANDOM ATTITUDES
		BEST CASE	WORST CASE	WORST CASE	BEST CASE	WORST CASE	WORST CASE
VHF/AM VOICE	550 N.M.	15.8	3.9	(-12.5)	15.4	3.6	(-13.0)
VHF/AM PCM	320 N.M.	--	--	--	10.6	(-1.4)	(-18.9)

NOTES

1. VOICE MARGIN BASED ON 70% WORD INTELLIGIBILITY.
2. PCM MARGIN BASED ON 1×10^{-6} BER.
3. NOMINAL MISSION ATTITUDES CONSIDER ANTENNA GAIN PRODUCTS FOR THE NOMINAL DESIGN REFERENCE MISSION.
4. RANDOM ATTITUDES CONSIDER THE MINIMUM ANTENNA GAIN PRODUCT OVER 80% OF THE SPHERE.
5. WORST CASES CONSIDER WORST CASE EQUIPMENT TOLERANCES AND ANTENNA GAINS.

VHF SYSTEM PROBLEMS

1. CM - VHF/AM:

   A. MODIFICATIONS TO THE CM LANDING SYSTEM MAY AFFECT CM 1/4 WAVE STUB ANTENNA PERFORMANCE.

2. RECOVERY AIRCRAFT VHF/AM:

   A. POSSIBLE PERFORMANCE IMPROVEMENTS ARE UNDER CONSIDERATION BY ISD & LRD.

   B. CONSIDERATION IS BEING GIVEN TO A NEW SURVIVAL KIT TRANSCEIVER DESIGN.

3. LM/CSM PCM:

   A. PRELIMINARY TESTS REVEAL THAT 6 DB SNR IN THE CSM 20 KHz BANDWIDTH MEETS DSE RECORD REQUIREMENTS. HOWEVER, PRECISE SNR REQUIREMENTS CANNOT BE DETERMINED UNTIL SYSTEM TESTS USING THE DSE ARE CONDUCTED.

COMMUNICATION SYSTEM	TLI THROUGH TRANSPOSITION AND DOCKING SUPPORT REQUIREMENT								USB MODE		S/C CONFIGURATION	GROUND INTERFACE	
	TM		CMD	V	G. TRK		D.D.	TV					
	DR	BER		INT	PRN	CW	BER		DN	UP		SITE	S/R
CSM-USB	51.2*▽	10^{-4}		90%		X			PM 1	2	OMNI-PA	ARIA	750
	51.2*▽	10^{-4}		90%		X			PM 2	–	OMNI-PA	ARIA	750
	1.6*	10^{-4}		90%		X			PM 3	–	OMNI-PA	ARIA	750
	1.6*	10^{-4}		90%		X			PM 4	2	OMNI-PA	ARIA	750
	1.6	10^{-6}	X	90%		X			PM 3	7	OMNI-PA	30'	12K
	51.2	10^{-6}	X	90%	X	X			PM 2	6	OMNI-PA	30'	10K
	51.2	10^{-6}	X	90%	X	X			PM 2	6	HG(W)-PA	30'	15K
CSM-VHF/AM				70%		X					OMNI	ARIA	750

DATA SHEET

S/R - Slant Range in Nautical Miles
Shaded Area Denotes Backup modes

* POST MISSION REQUIREMENT
▽ PERFORMANCE PROBLEM

BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: MSC Review of Requirements and Expected Performance of Communications Systems For the Apollo Spacecraft on 25 September 1967
Case 320

DATE: November 6, 1967

FROM: J. J. Hibbert

ABSTRACT

The current requirements and expected performance of the communication systems to be carried by the Apollo spacecraft during lunar missions were reviewed by representatives of MSC for the Apollo Program Director on September 25, 1967. This memorandum records major conclusions of the review and of the discussions that followed. Copies of the presentation slides are also attached.

AUG 1977
RECEIVED
NASA STI FACILITY
INPUT BRANCH