BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B70 12081

SUBJECT: MSFN Coverage From Insertion Through Injection Burn for Apollo 15 - Case 320

DATE: December 30, 1970

FROM: J. P. Maloy

ABSTRACT

This memorandum details the Earth orbital coverage provided for an Apollo 15 (J-type) mission by a 12 station MSFN (including an Insertion Ship) for launch azimuths of 72°, 80°, 84°, 86°, 90°, 94°, 96°, 98°, and 100°. An Earth orbital altitude of 90 nautical miles is assumed until the injection burn. The coverage obtained is compared with the requirements outlined in the Apollo Program Specification, (Revision B, 5/1/69).

The first requirement examined is for 3 minutes of continuous tracking above 5° elevation from the MSFN station after insertion into Earth Orbit. It appears that this can be achieved by the judicious placement of the Insertion Ship, particularly if the launch azimuth range were reduced to about 20°.

A second requirement for two contacts for the first three revolutions of at least 4 minutes above the 5° masking of the MSFN station was not met for the complete range of launch azimuths. For azimuths greater than 85°, the 4-minute contact requirement was not met on the third revolution and on the second revolution for azimuths greater than 95°. In all cases, however, there was at least one contact greater than 3.0 minutes on each revolution.

The third requirement is for one contact of 4 minutes above 5° elevation between ninety and thirty minutes before injection. This requirement is not met for those cases at launch azimuths of 96° or greater for the second injection opportunity over the Pacific. However, in each case, (96°, 98° and 100° launch azimuths) there was a contact of between 3 and 4 minutes at Texas in the interval of 90 to 30 minutes before the start of injection burn. For Atlantic injections this requirement is not met for 6 times out of 18 opportunities. In each of these cases, with the exception of the second Atlantic injection opportunity at 90°, 94° and 96°, there is a station contact of greater than 3 minutes in the required time period. In the case of the exceptions, Texas has a contact of about 4.0 minutes which is no later than 93.2 minutes before injection.

BELLCOMM. INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 12081

SUBJECT: MSFN Coverage From Insertion Through Injection Burn for Apollo 15 - Case 320

DATE: December 30, 1970

FROM: J. P. Maloy

MEMORANDUM FOR FILE

INTRODUCTION

The possibility of changing the launch azimuth range for Apollo Missions from 84° ± 12° to 90° ± 10° and the possible use of an Atlantic injection opportunity prompted a review of tracking and communication coverage provided by the current Apollo MSFN for these launch azimuths.

The current MSFN coverage requirements (Apollo Program Specification, Revision B, dated 5/1/69) are as follows:

(1) Three minutes of tracking coverage above 5° elevation from the MSFN station after insertion into Earth orbit.

(2) Two contacts per revolution for the initial three Earth revolutions of at least four minutes above 5° elevation.

(3) One contact of four minutes above 5° elevation between ninety and thirty minutes before injection.

(4) Partial coverage during the injection burn.

The ALTER 1 computer program was used to calculate the coverage contacts of the Apollo MSFN for the twelve stations listed in Table I, for the first three revolutions at an orbital altitude of 90 nm using a constant 5° elevation masking angle about each station. Antenna keyhole affects, except for the insertion ship, were included where appropriate (6° half-angle for 30' antenna MSFN stations in a N-S direction and 15° half-angle for 85' antennas in the E-W direction). Other masking above 5° elevation was not included. The procedure was repeated for seven launch azimuths (72°, 80°, 84°, 86°, 90°, 96°, 98°, and 100°) using the insertion points as derived from previous mission data as starting points for coverage calculations.

PROCEDURE:

The resultant data is shown in Table II where contacts for each station of the network is shown for the first three revolutions by launch azimuth. The start time (referenced to insertion) and the length of each contact is shown. Contacts 4.0 minutes and greater are underlined. By displaying the data in this manner, it can readily be seen which revolutions have the required size and number of contacts to meet requirements.

Table III lists the translunar injection times (as measured from insertion) for the second revolution by launch azimuth and by date of launch. Times for injection opportunities on the third revolution can be derived by adding one orbital period, 87.8 minutes, to the times shown in this table. The basic injection data from which these times were derived was provided by Miss Sue Caldwell of Department 2013. The times were converted to minutes from insertion by allowing 11.7 minutes for the launch phase. The minimum and maximum times for first opportunity Pacific injection are asterisked and form the bounds for Pacific injection. Atlantic first injection opportunities are also marked (ϕ). This table in conjunction with Table II can be used to determine whether the coverage requirement prior to injection is fulfilled.

Figure 1 represents a graphical analysis of tracking coverage after insertion to determine a ship location that could best provide post insertion tracking coverage. Three minutes of continuous contact above 5° elevation is required. The figure was basically traced from the Apollo Earth Orbit Chart (AEO) prepared by the Air Force for Apollo Mission 13. 5° elevation coverage circles at 90 nm were drawn about MLA, BDA, and 2 ship locations as an approximation. In addition, tracks for an 80° and 100° launch azimuth were dubbed in. No launch trajectory profile for Apollo 15 was available for a more detailed analysis of coverage during and immediately after launch.

DISCUSSION

FIRST REQUIREMENT:

Figure 1 shows that the ship at its Apollo 13 location (49°W; 28°N) would not fulfill the requirement for coverage of the launch azimuth range of 72-96° without some pre-launch maneuvering. However, at the second location (50°W; 24°N) it appears possible that from that one location three minutes of tracking could be provided for the launch azimuth range of 80° to 100°. At the worst, it appears that a minimum of maneuvering may be required to satisfy post insertion coverage requirements at this location for that range of launch azimuths without interrupting launch coverage with a gap between BDA and the ship.

Also it should be remembered that particularly in the case of a ship with no obstructions on the horizon, good communications may be received below 5°. At 3° elevation, coverage is increased by 0.4 minutes in these cases.

SECOND REQUIREMENT:

The second requirement for two contacts of four minutes above 5° elevation is of particular interest for the first two revolutions in this study. This requirement on the third revolution is for the case of an abort - where injection was not possible at the second opportunity. It can easily be seen from the coverage summary of Table II that this criteria is not fulfilled during the second revolution with azimuths 96° to 100°. In each case, however, there are five contacts in the revolution with at least three exceeding 3.0 minutes.

On the third revolution there are two or more 4.0 minute contacts for launch azimuths up to and including 84°, only one contact > 4.0 minutes on launch azimuths 86° through 96° and only two contacts (<4.0 minutes) on azimuths 98° and 100°.

THIRD REQUIREMENT:

The third requirement calls for one contact of 4.0 minutes above 5° elevation between ninety and thirty before injection. The fulfillment of this requirement is more complex to analyze since the time and, consequently, location of injection varies with launch opportunity which in turn is dependent on one of four selected lunar landing sites. How translunar injection (TLI) times vary with launch azimuth and landing site is shown in Table III. Desired Atlantic injection opportunities are limited to the Hadley landing site. All other times shown are for Pacific injection (first opportunity). Times for injection opportunities on the third revolution (second opportunity) can be derived by adding one orbital period, 87.8 minutes, to the times in the table. The columns of minimum and maximum times are asterisked and form a bound for injection opportunities on each of the azimuths. By comparing these times with the coverage times of Table II it can be determined if there is a 4.0 minute or greater contact within the ninety to thirty minute period before the start of injection burn.

These results are summarized in Table IV. The requirement was not met for those cases at 96° launch azimuth or greater for the second injection opportunity over the Pacific. Although at 100° launch azimuth some opportunities comply with the requirement while others do not. However, in each case (96°, 98° and 100° launch azimuth) there was a contact of between 3 and 4 minutes from TEX in the interval of ninety to thirty minutes

before the start of injection burn. Atlantic injection opportunities fail to meet this requirement 6 times out of 18. In each case there is a contact between 3.1 and 3.6 minutes in the required interval or there is a contact close to or greater than 4.0 minutes overlapping the 90 minute boundary.

Atlantic injection at the end of the first revolution would have the advantage of better coverage over third revolution injection in all cases except for launch azimuths between 72° and 84°. This is due to contact by Ascension (ACN) several minutes after injection burn for azimuths 86° to 100°. It is estimated from the Operational Trajectory document for the Apollo 14 mission that the altitude at the end of burn for this mission starting at a lower altitude (90 vs 100 nm) would be approximately 150 nm and would rise steeply after that. (When comparing the duration of a contact at 150 nm with the equivalent one at 90 nm a factor of 1.38 can be used as an approximation.) However, it may not be possible for the spacecraft to be fully checked out for injection that early in orbital flight.

FOURTH REQUIREMENT:

The fourth requirement calls for partial coverage during the injection burn period (approx. 5.5 minutes). In some cases for the azimuths looked at, this period may occur over a ground station of the MSFN. In other cases, the burn period would get no coverage from a ground station and the requirement of partial coverage would have to be provided by Apollo Range Instrumentation Aircraft (ARIA). This study did not explore the ARIA coverage.

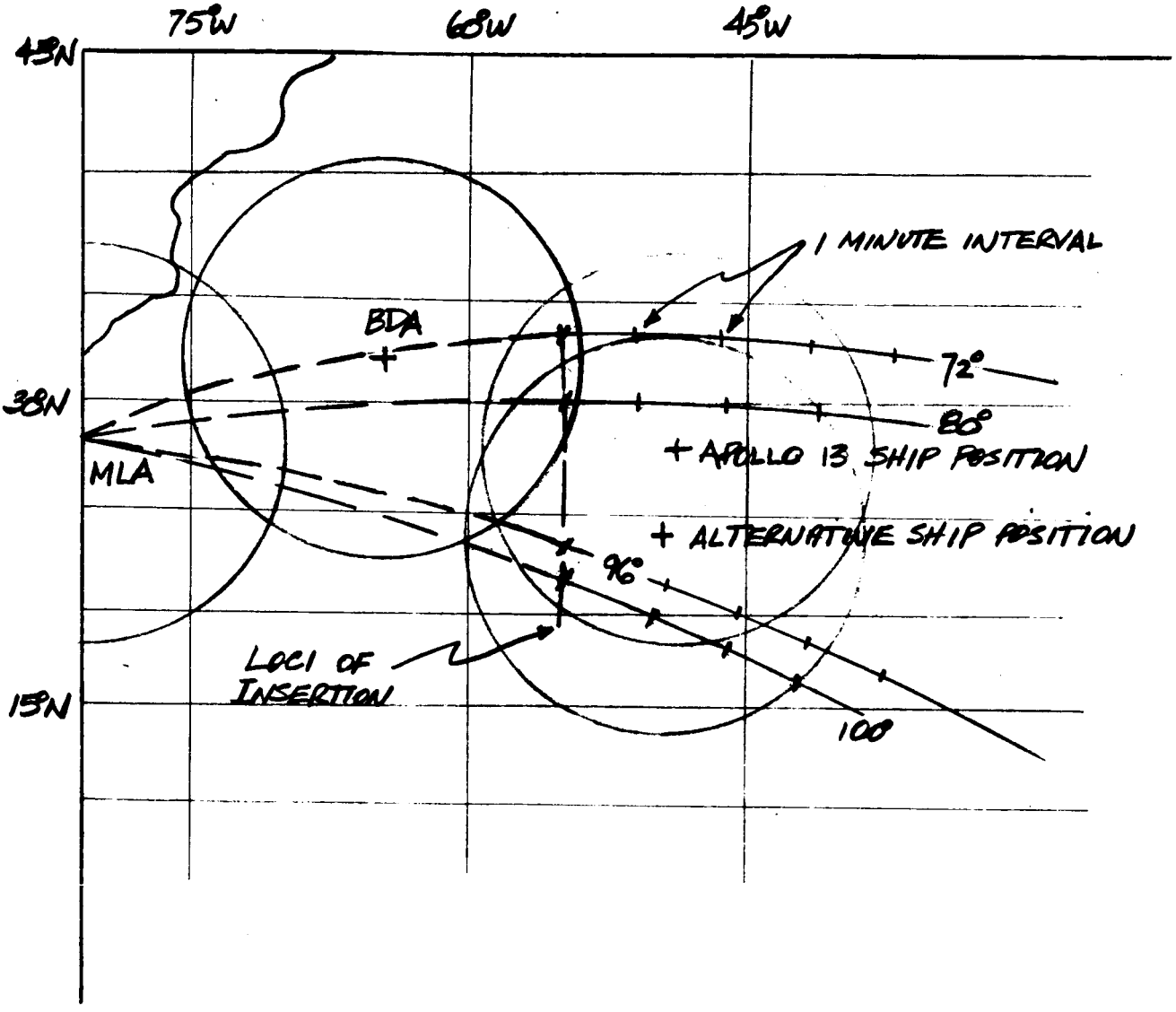
CONCLUSIONS:

Although it is reasonably certain that the first requirement concerning post insertion coverage can be met in all cases studied here, the second requirement of the number and size of contacts per revolution and the third requirement for pre-injection coverage are not fully met as written in the Apollo Program Specification. However, in the case of these latter requirements, considerable coverage is provided, and it may be of sufficient quantity to be considered adequate in view of the maturity of the program.

J. P. Maloy

2034-JPM

Attachments
Figure 1
Tables 1-4



TRACKING COVERAGE AFTER INSERTION

INSERTION ALTITUDE = 90 NM

5° STATION MASK

FIGURE 1

TABLE I

NETWORK

	STATION	SYMBOL	LATITUDE°	LONGITUDE°
1.	MILA	MLA	28.5083N	80.6934W
2.	BDA	BDA	32.3506N	64.6581W
*3.	SHIP (POSITION 1)	---	28.0000N	49.0000W
	SHIP (POSITION 2)	---	26.0000N	49.0000W
4.	CANARY IS.	CYI	27.7644N	15.6347W
5.	ASCENSION	ACN	7.9547S	14.3272W
6.	MADRID	MAD	40.4550N	4.1694W
7.	CARNARVON	CRO	24.9066S	113.7255E
8.	GUAM	GWM	13.3106N	144.7369E
9.	HONEYSUCKLE	HSK	35.5837S	148.9783E
10.	HAWAII	HAW	22.1264N	159.6656E
11.	GOLDSTONE	GDS	35.3417N	116.8733W
12.	TEXAS	TEX	27.6539N	97.3783W

*There will be only one ship but two locations for insertion were tried - Position 1 for azimuths 72 to 90°; Position 2 for azimuths 90 to 100°.

TABLE II

ORBITAL COVERAGE (MINUTES)

(90 NM ALTITUDE; 5° MASKING)

LAUNCH AZ		72°		80°		84°		86°		90°		94°		96°		98°		100°	
		START*	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH
REV 1	SHIP LOC 1	0.0	4.6	0.0	3.3	0.0	3.3	0.0	3.2	0.0	3.0	0.0	2.6	0.0	2.3	0.0	2.0	0.0	1.5
	SHIP LOC 2	0.0	2.4	0.0	3.2	0.0	3.9	0.0	3.4	0.0	3.3	0.0	3.1	0.0	2.9	0.0	2.7	0.0	2.4
	CYI	6.0	4.6	6.8	2.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	ACN	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11.6	2.3	11.0	3.4
	CRO	42.1	2.5	41.5	4.0	41.4	4.4	41.4	4.5	41.3	4.6	41.3	4.6	41.3	4.6	41.3	4.5	41.4	4.3
	GWM	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	HSK	49.1	3.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	HAW	--	--	--	--	--	--	68.1	1.1	66.7	3.6	66.2	4.4	66.1	4.6	66.1	4.6	66.1	4.5
	GDS	--	--	--	--	78.0	1.7	77.7	2.1	77.2	2.8	76.9	3.3	76.7	3.5	76.6	3.7	76.5	3.8
	TEX	80.5	4.5	80.5	4.6	80.6	4.6	80.6	4.6	80.6	4.7	80.6	4.7	80.6	4.7	80.6	4.7	80.6	4.7
	MLA	84.4	4.2	84.3	4.6	84.3	4.8	84.3	4.7	84.4	4.5	84.4	4.3	84.5	4.1	84.5	3.9	84.6	3.7
	BDA	87.7	4.7	88.0	4.1	88.4	3.2	88.7	2.5	--	--	--	--	--	--	--	--	--	--
	SHIP LOC 1	91.4	4.5	91.6	4.2	92.1	3.1	92.6	2.0	--	--	--	--	--	--	--	--	--	--
	SHIP LOC 2	91.7	4.2	91.6	4.5	91.9	3.9	92.1	3.3	--	--	--	--	--	--	--	--	--	--

*Start time given in minutes from insertion

TABLE II (CONTINUED)

ORBITAL COVERAGE (MINUTES)

(90 NM ALTITUDE; 5° MASKING)

LAUNCH AZ		72°		80°		84°		86°		90°		94°		96°		98°		100°	
		START*	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH
REV 2	CYI	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	ACN	--	--	--	--	--	--	104.5	2.3	103.5	4.1	103.2	4.6	103.2	4.5	103.4	4.2	103.7	3.6
	CRO	134.7	3.4	134.2	4.6	134.3	4.5	134.4	4.3	134.7	3.5	135.6	1.4	--	--	--	--	--	--
	GWM	--	--	--	--	--	--	--	--	--	--	--	--	146.9	2.3	146.2	3.5	145.8	4.1
	HSK	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	HAW	160.1	2.7	159.2	4.3	159.0	4.6	159.0	4.6	159.0	4.5	159.3	4.2	159.4	3.8	159.7	3.4	160.0	2.9
	GDS	169.6	4.1	169.7	3.6	169.7	3.4	169.7	3.2	169.7	3.0	169.8	2.6	169.8	2.4	169.8	2.3	169.9	2.0
	TEX	173.7	3.9	173.5	4.6	173.5	4.7	173.5	4.6	173.5	4.5	173.7	4.1	173.7	3.9	173.9	3.5	174.0	3.1
	MLA	177.3	4.4	177.2	4.6	177.4	4.1	177.6	3.6	178.3	2.0	--	--	--	--	--	--	--	--
	BDA	180.6	4.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SHIP LOC 1		184.4	3.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SHIP LOC 2		184.4	4.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

*Start time given in minutes from insertion

TABLE II (CONTINUED)

ORBITAL COVERAGE (MINUTES)

(90 NM ALTITUDE; 5° MASKING)

LAUNCH AZ		72°		80°		84°		86°		90°		94°		96°		98°		100°	
		START*	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH	START	LENGTH
REV 3	CYI	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	ACN	197.7	1.7	196.2	4.5	196.2	4.5	196.3	4.3	196.9	3.0	--	--	--	--	--	--	--	--
	CRO	227.0	4.6	227.7	3.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	GWM	--	--	--	--	239.8	2.3	239.1	3.4	238.6	4.4	238.4	4.6	238.6	4.4	238.8	3.9	239.1	3.2
	HSK	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	HAW	251.8	4.5	252.2	4.2	252.3	4.0	252.5	3.8	252.7	3.5	253.0	3.1	253.2	2.9	253.4	2.6	253.6	2.4
	GDS	261.9	4.5	262.4	3.4	262.9	2.1	--	--	--	--	--	--	--	--	--	--	--	--
	TEX	266.4	4.4	266.4	4.5	266.7	3.8	267.0	3.1	--	--	--	--	--	--	--	--	--	--
	MLA	269.9	4.5	271.5	1.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	BDA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

*Start time given in minutes from insertion

TABLE III[1]

TRANSLUNAR INJECTION TIMES FOR 2ND REVOLUTION[2]

(MEASURED FROM INSERTION IN MINUTES)

DATE OF LAUNCH **LANDING SITE		7/26/71 (H)	8/24/71 (H)	9/23/71* (H)	10/22/71 (H)	10/23/71(ϕ) (H)	1/18/72 (D)	2/18/72 (D)
LAUNCH AZ	72°	163.2	166.7	169.5	166.8	188.3	150.2	144.7
	80	161.2	165.4	168.9	165.6	184.1	146.8	140.7
	84	159.9	164.4	168.3	164.5	182.0	145.0	138.5
	86	159.0	163.7	167.9	163.9	180.9	144.1	137.5
	90	157.4	162.2	166.5	162.3	178.9	142.3	135.6
	94	155.6	160.2	164.3	160.3	177.4	140.6	134.0
	96	154.6	159.2	163.0	159.3	176.6	139.8	133.3
	98	153.7	158.1	161.6	158.2	176.1	139.0	132.7
	100	152.7	156.9	160.2	157.0	175.5	138.3	132.2

*Maximum time for that azimuth for Pacific injection
**(H) Hadley
(D) Descarte
ϕAtlantic injection

Note 1: Basic data for this table was procured from Department 2013. The times were converted to minutes from insertion by allowing 11.7 minutes for the launch phase.

Note 2: Times for injection opportunities on the third revolution can be derived by adding one orbital period, 87.8 minutes, to the times shown in this table.

TABLE III[1] (CONTINUED)

TRANSLUNAR INJECTION TIMES FOR 2ND REVOLUTION[2]

(MEASURED FROM INSERTION IN MINUTES)

DATE OF LAUNCH **LANDING SITE		3/17/72* (D)	6/16/72 (C)	6/19/72 (M)	7/16/72 (C)	7/19/72 (M)	8/14/72 (C)	8/17/72 (M)
LAUCHH AZ	72°	141.7	160.9	166.7	165.8	168.6	167.8	165.7
	80	136.7	158.7	165.4	164.2	167.7	166.8	164.2
	84	134.1	157.3	164.3	163.1	166.9	165.9	163.1
	86	132.9	156.6	163.7	162.4	166.4	165.4	162.4
	90	130.8	154.9	162.1	160.8	164.9	163.9	160.8
	94	129.4	153.1	160.2	158.9	162.9	161.8	158.9
	96	128.8	152.1	159.1	157.8	161.7	160.7	157.9
	98	128.4	151.2	158.0	156.8	160.4	159.5	156.8
	100	128.1	150.2	156.8	155.7	159.2	158.2	155.7

*Minimum time for that azimuth for Pacific injection
**(D) Descarte
(M) Marius Hills
(C) Copernicus

Note 1: Basic data for this table was procured from Department 2013. The times were converted to minutes from insertion by allowing 11.7 minutes for the launch phase.

Note 2: Times for injection opportunities on the third revolution can be derived by adding one orbital period, 87.8 minutes, to the times shown in this table.

TABLE IV

STATION INJECTION COVERAGE

(EXCLUSIVE OF ARIA)

REQUIREMENT: AT LEAST ONE CONTACT $\geq$ 4 MINS. ABOVE 5° ELEV. BETWEEN -90° AND -30 MINUTES BEFORE INJECTION

LAUNCH AZ°	ATLANTIC OPPORTUNITY 1	ATLANTIC OPPORTUNITY 2	PACIFIC OPPORTUNITY 1	PACIFIC OPPORTUNITY 2
72	NO (CRO-3.4)	YES	YES	YES
80	YES	YES	YES	YES
84	YES	YES	YES	YES
86	YES	YES	YES	YES
90	YES	NO *(TEX-4.5 START-93.2)	YES	YES
94	YES	NO *(TEX-4.1 START-91.5)	YES	YES
96	YES	NO *(TEX-3.9 START-90.7)	YES	NO (TEX-3.9)
98	YES	NO (TEX-3.9)	YES	NO (TEX-3.5)
100	NO (ACN-3.6)	NO (TEX-3.1)	YES	YES AND NO (TEX-3.1)

( ) Station with largest contact within required time interval.

*( ) TEX in these cases has good contact but just beyond 90 min. limit.

BELLCOMM, INC.

Subject: MSFN Coverage From Insertion Through Injection Burn for Apollo 15 - Case 320

From: J. P. Maloy

DISTRIBUTION LIST

NASA Headquarters
W. B. Evans/MLO
E. Harkleroad/MLO
J. K. Holcomb/MAO
A. S. Lyman/MR
J. T. McClanahan/MAO
L. M. Robinson/OTDA/TS
M. Savage/MLT
J. D. Stevenson/MO

Bellcomm, Inc.
G. M. Anderson
R. A. Bass
W. J. Benden
A. P. Boysen, Jr.
S. F. Caldwell
R. K. Chen
J. P. Downs*
L. A. Ferrara
D. R. Hagner
J. J. Hibbert
J. E. Johnson
H. Kraus
K. E. Martersteck
J. Z. Menard
J. T. Raleigh
I. M. Ross
N. W. Schroeder
W. Strack
J. W. Timko
R. L. Wagner
A. G. Weygand
M. P. Wilson
W. D. Wynn
Department 1024 File
Central Files
Library

*Abstract Only