Internal Note 69-FM-76

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 69-FM-76

April 7, 1969

CONSUMABLES ANALYSIS FOR THE APOLLO 10 (MISSION F) SPACECRAFT OPERATIONAL TRAJECTORY

Guidance and Performance Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

(NASA-TM-X-69384) CONSUMABLES ANALYSIS FOR THE APOLLO 10 (MISSION F) SPACECRAFT OPERATIONAL TRAJECTORY (NASA) 64 p

N74-70735

Unclas
00/99 16454

MSC INTERNAL NOTE NO. 69-FM-76

PROJECT APOLLO

CONSUMABLES ANALYSIS FOR THE APOLLO 10 (MISSION F) SPACECRAFT OPERATIONAL TRAJECTORY

By Martin L. Alexander, Sam A. Kamen, Arnold J. Loyd,
Samuel O. Mayfield, Dwight G. Peterson,
and Walter Scott, Jr.
Guidance and Performance Branch

April 7, 1969

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

Approved: [signature] for
Marlowe D. Cassetti, Chief
Guidance and Performance Branch

Approved: [signature] for
John P. Mayer, Chief
Mission Planning and Analysis Division

FOREWORD

The following table summarizes the consumables requirements for the Apollo 10 mission. Percentages refer to nominal usage only and do not include dispersions and contingencies.

Consumable	Percentage of available consumable used for mission planning
CM RCS	15
SM RCS	60
SPS	
May 18 launch	92
May 17 launch	89
LM RCS	65
DPS	5
APS	100
CSM O_2	66
CSM H_2	77
LM descent battery	36
LM ascent battery	73

These results were obtained from detailed consumables analyses performed on the Apollo 10 RCS, SPS, APS, DPS, and EPS. A time history of total consumables weight loss is also presented. The ECS analysis will be supplied when the detailed operational trajectory time line is available.

The principal sources of data were the data books (refs. 1, 2, and 3). The RCS and EPS analyses were based on the Apollo 10 rough draft preliminary flight plan (ref. 4). The operational procedures described in this study are not intended to define mission rules or crew procedures but are merely an attempt to establish an estimate of the consumables requirements.

Support was obtained from TRW Systems Group, from North American Rockwell, from Grumman Aircraft Engineering Corporation, from the Apollo Spacecraft Program Office, and from the Instrumentation and Electronics Systems Division.

CONTENTS

Section		Page
1.0	THE CM RCS ANALYSIS	1
2.0	THE SM RCS ANALYSIS	2
3.0	THE SPS ANALYSIS	23
4.0	THE LM RCS PROPELLANT ANALYSIS	27
5.0	THE DPS ANALYSIS	33
6.0	THE APS ANALYSIS	35
7.0	ASSUMPTIONS AND RESULTS OF THE EPS ANALYSIS	36
8.0	THE CSM ECS ANALYSIS	43
9.0	THE LM EPS ANALYSIS	44
10.0	THE LM ECS ANALYSIS	47
11.0	TIME HISTORY OF CONSUMABLES WEIGHT LOSS	48
12.0	REFERENCES	51

TABLES

Table		Page
1-I	CM RCS PROPELLANT SUMMARY	1
2-I	GROUND RULES AND ASSUMPTIONS FOR THE SM RCS ANALYSIS	2
2-II	SM RCS PROPELLANT LOADING AND USAGE SUMMARY	3
2-III	SM RCS PROPELLANT BUDGET	4
3-I	ASSUMPTIONS FOR THE SPS ANALYSIS	24
3-II	SPS PROPELLANT SUMMARY	
	(a) May 17 launch, 72° launch azimuth, first opportunity injection	25
	(b) May 18 launch, 72° launch azimuth, first opportunity injection	26
4-I	GROUND RULES AND ASSUMPTIONS	27
4-II	LM RCS PROPELLANT SUMMARY	27
4-III	LM RCS PROPELLANT BUDGET	28
5-I	ASSUMPTIONS FOR THE DPS ANALYSIS	33
5-II	DPS PROPELLANT SUMMARY	34
6-I	ASSUMPTIONS FOR THE APS ANALYSIS	35
6-II	APS PROPELLANT SUMMARY	35
7-I	ASSUMPTIONS FOR THE CSM EPS ANALYSIS	37
7-II	CRYOGENICS SUMMARY	38
9-I	ASSUMPTIONS FOR THE LM EPS ANALYSIS	44
11-I	TIME HISTORY OF CONSUMABLES WEIGHT LOSS	48

FIGURES

Figure		Page
2-1	SM RCS propellant profile	
	(a) Total	20
	(b) Quads A and C	21
	(c) Quads B and D	22
7-1	Total spacecraft current versus time	39
7-2	Hydrogen remaining for mission for one tank versus time	40
7-3	Oxygen remaining for mission for one tank versus time	41
7-4	Total DC energy profile versus time	42
9-1	Descent electrical power profile for an F mission flight plan	45
9-2	Ascent electrical load analysis for an F mission flight plan	46
11-1	Spacecraft weight versus ground elapsed time	49

ABBREVIATIONS

AGS	abort guidance system
APS	ascent propulsion system
CDH	constant differential height
CM	command module
COAS	crew optical alinement sight
CSI	concentric sequence initiation
CSM	command and service modules
DB	deadband
DAP	digital autopilot
DOI	descent orbit insertion
DPS	descent propulsion system
ECS	environmental control system
EECOM	electrical, environmental, and communications
EPS	electrical power system
F.T.P.	full throttle position
H_2	hydrogen
IMU	inertial measurement unit
I_{fc}	fuel cell current
I_{sp}	specific impulse
LM	lunar module
LOI	lunar orbit insertion
LOS	line of sight

LPO	lunar parking orbit
MCC	midcourse correction
MI	minimum impulse
MPAD	Mission Planning and Analysis Division
MSFN	Manned Spaceflight Network
NR	North American Rockwell
ORDEAL	orbital rate display, earth and lunar
O_2	oxygen
PGNCS	primary guidance and navigation control subsystem
PTC	passive thermal control
RCS	reaction control system
REV	revolution
RR	rendezvous radar
SCS	stabilization and control subsystem
SEP	separation
SLA	spacecraft/LM adapter
SM	service module
SPS	service propulsion system
SPS-n	number of the SPS burn; n = 1, ..., 8
T, D, and E	transposition, docking, and extraction
TEC	transearth coast
TEI	transearth injection
TLC	translunar coast
TLMC	translunar midcourse correction

TPI	terminal phase initiation (of rendezvous)
TPF	terminal phase finalization (of rendezvous)
t	time
WT	weight

CONSUMABLES ANALYSIS FOR THE APOLLO 10 (MISSION F)

SPACECRAFT OPERATIONAL TRAJECTORY

By Martin L. Alexander, Sam A. Kamen, Arnold J. Loyd,
Samuel O. Mayfield, Dwight G. Peterson,
and Walter Scott, Jr.

1.0 THE CM RCS ANALYSIS

The CM RCS propellant data were taken from reference 1. Usage data were taken from reference 5. The CM RCS propellant summary is presented in table 1-I.

TABLE 1-I.- CM RCS PROPELLANT SUMMARY

Item	RCS propellant used, lb	RCS propellant remaining, lb
Loaded	--	245.0
Trapped	36.4	208.6
Available for mission planning	--	208.6
Nominal usage	30.8	177.8
Margin	--	177.8

2.0 THE SM RCS ANALYSIS

TABLE 2-I.- GROUND RULES AND ASSUMPTIONS FOR THE SM RCS ANALYSIS

The following ground rules were used to calculate the SM RCS budget.
1. The transposition and docking phase of the mission includes an SPS evasive maneuver.
2. The first and third MCC's (translunar) are executed as SPS burns with the third MCC followed by an RCS trim.
3. Passive thermal control is assumed to be in the PGNCS wide deadband control mode and to require 1 lb/hr, compared with 1.1 to 1.7 lb/hr requirement on Apollo 8 in the SCS control mode, except for the test periods under manual control which required ≈ 5 lb/hr on the Apollo 8 mission.
4. The sixth MCC (transearth) is executed as an RCS burn of 5 fps.
5. The SM RCS propellant allocation for a CSM-active rescue of the LM is currently under study. The data is to be included in revision 1 to this document.
6. The propellant profiles shown in figure 2-1 are based on usable propellant remaining as a function of mission time.

TABLE 2-II.- SM RCS PROPELLANT LOADING AND USAGE SUMMARY

Nominal loaded propellant, lb	1342.4
Initial outage caused by loaded mixture ratio, lb	15.6
Total trapped propellant, lb	26.4
Gaging inaccuracy, lb	80.4
Deliverable SM RCS propellant, lb	1220
Nominal propellant used, lb	730
Propellant used for translunar phase, lb	334
Propellant used for transposition and docking, lb	90
Propellant used for midcourse corrections, lb	35
Propellant used for passive thermal control, lb	106
Propellant used for other items, lb	103
Propellant used for lunar orbital phase (LOI-TEI inclusive), lb	221
Propellant used for docked CSM activities, lb	96
Propellant used for undocked CSM activities, lb	125
Propellant used for transearth phase, lb	134
Propellant used for midcourse corrections, lb	24
Propellant used for passive thermal control, lb	74
Propellant used for other items, lb	36
Outage caused by mission duty cycle mixture ratio, lb	41
Nominal propellant remaining, lb	490

TABLE 2-III.- SM RCS PROPELLANT BUDGET

TIME (HR)	EVENT	S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
.0	MISSION F	65887.	.0	1342.4	100.
.0	SM-RCS CHECKOUT NON PROPULSIVE	65887.	.0	1342.4	100.
3.1	TRANSPOSITION AND DOCKING +X .8 FPS,NULL .3	65877.	10.5	1331.9	99.
3.1	PITCH TO ACQUIRE SIVB PITCH 180 DEG 1.5DEG/SEC	65875.	2.4	1329.6	99.
3.1	ROLL CSM AT 0.5 DEG/SEC	65874.	.4	1329.2	99.
3.1	X AXIS TRANSLATIONS	65860.	14.3	1314.9	98.
3.1	PHOTOGRAPHY AND SYSTEMS FAMILIARIZAT ION	65830.	29.8	1285.1	96.
3.3	INDEX AND DOCK LANGLEY STUDY	65804.	26.0	1259.1	94.
3.3	LM EJECTION	95836.	.0	1259.1	94.
4.3	SPS BURN TO EVADE SIVB 3 AXIS ORIENT PGNCS	95831.	4.2	1254.8	93.
4.3	ATTITUDE HOLD	95831.	.4	1254.5	93.
4.3	SPS BURN BUILD UP	95828.	.0	1254.5	93.
4.3	STEADY STATE BURN 11	95793.	.1	1254.4	93.
4.3	TAILOFF	95751.	.8	1253.6	93.
4.3	DAMP SHUTDOWN TRANSIENT	95750.	1.1	1252.5	93.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
4.4	ORIENT TO MONITOR SLINGSHOT 0.2 DEG/SEC PGNCS	95746.	4.3	1248.2	93.
5.0	P52 IMU ALIGN	95742.	4.2	1244.0	93.
5.5	ORIENT FOR NAV SIGHTINGS	95738.	4.3	1239.7	92.
5.6	ORIENT FOR NAV SIGHTINGS	95733.	4.2	1235.5	92.
5.7	ORIENT FOR NAV SIGHTINGS	95729.	4.3	1231.2	92.
5.8	ORIENT FOR NAV SIGHTINGS	95725.	4.2	1227.0	91.
5.9	ORIENT FOR NAV SIGHTINGS	95721.	4.2	1222.7	91.
5.9	MINIMUM IMPULSE MARKING FOR STGS	95715.	5.2	1217.6	91.
6.0	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC	95711.	3.9	1213.7	90.
6.0	ATTITUDE HOLD 0.2 DEG DB SCS	95711.	.8	1212.9	90.
6.0	EST. 0.3 DEG/SEC ROLL	95710.	.4	1212.5	90.
6.0	PITCH AND YAW CONTROL	95708.	2.7	1209.8	90.
8.7	P52 IMU ALIGN	95705.	2.4	1207.4	90.
9.2	MIDCOURSE CORRECTION NO 1 3 AXIS ORIENT PGNCS	95701.	4.3	1203.1	90.
9.2	ATTITUDE HOLD 5 DEG DB	95701.	.4	1202.7	90.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT		S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
9.2	SPS BURN BUILD UP		95698.	.0	1202.7	90.
9.2	STEADY STATE BURN	11	95662.	.1	1202.6	90.
9.2	TAILOFF		95621.	.8	1201.9	90.
9.2	DAMP SHUT.DOWN TRANSIENT		95620.	1.1	1200.8	89.
10.1	P52 IMU ALIGN		95618.	2.3	1198.5	89.
10.4	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC		95614.	3.9	1194.6	89.
10.4	ATTITUDE HOLD 0.2 DEG DB	SCS	95613.	.8	1193.8	89.
10.4	EST. 0.3 DEG/SEC ROLL		95612.	.4	1193.4	89.
10.4	PITCH AND YAW CONTROL		95603.	9.6	1183.8	88.
20.0	P52 IMU ALIGN		95599.	4.2	1179.6	88.
20.4	ORIENT FOR NAV SIGHTINGS		95594.	4.2	1175.4	88.
20.8	ORIENT FOR NAV SIGHTINGS		95590.	4.2	1171.1	87.
21.2	ORIENT FOR NAV SIGHTINGS		95586.	4.2	1166.9	87.
21.6	ORIENT FOR NAV SIGHTINGS		95582.	4.2	1162.7	87.
21.6	MINIMUM IMPULSE MARKING		95578.	3.4	1159.3	86.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT		S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
21.8	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC		95574.	3.9	1155.4	86.
21.8	ATTITUDE HOLD 0.2 DEG DB	SCS	95574.	.8	1154.6	86.
21.8	EST. 0.3 DEG/SEC ROLL		95573.	.4	1154.2	86.
21.8	PITCH AND YAW CONTROL		95570.	3.6	1150.6	86.
25.4	P52 IMU ALIGN		95565.	4.3	1146.3	85.
26.5	MIDCOURSE CORRECTION NO 2 MNVR TO BURN ATT		95561.	4.2	1142.2	85.
26.5	ATT HOLD .5 DEG DB PGNCS		95561.	.3	1141.9	85.
26.5	DELTA VEL = NOMINALLY ZERO		95561.	.0	1141.9	85.
27.0	ORIENT FOR S-BAND TEST		95557.	4.2	1137.7	85.
27.6	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC		95553.	4.0	1133.7	84.
27.6	ATTITUDE HOLD		95552.	.4	1133.3	84.
27.6	EST. 0.3 DEG/SEC ROLL		95552.	.4	1132.9	84.
32.0	PITCH AND YAW CONTROL		95543.	8.7	1124.2	84.
38.0	PITCH AND YAW CONTROL		95535.	8.7	1115.5	83.
45.0	P52 IMU ALIGN		95530.	4.2	1111.2	83.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT		S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
47.0	PTC TEST W/O ATT CONTROL		95518.	12.0	1099.2	82.
49.0	PTC TEST W/O ATT CONTROL		95506.	12.0	1087.2	81.
51.0	PTC TEST W/O ATT CONTROL		95494.	12.0	1075.2	80.
53.0	P52 IMU ALIGN		95490.	4.2	1071.0	80.
54.1	MIDCOURSE CORRECTION NO 3 MNVR TO BURN ATT		95486.	4.2	1066.8	79.
54.1	ATTITUDE HOLD		95486.	.4	1066.4	79.
54.1	SPS BURN BUILD UP		95483.	.0	1066.4	79.
54.1	STEADY STATE BURN	11	95457.	.0	1066.4	79.
54.1	TAILOFF		95416.	.9	1065.5	79.
54.1	DAMP SHUT.DOWN TRANSIENT		95414.	1.1	1064.4	79.
54.1	RCS TRIM 1 FPS		95403.	11.0	1053.5	78.
54.5	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC		95399.	4.0	1049.4	78.
54.5	ATTITUDE HOLD 0.2 DEG DB	SCS	95399.	.8	1048.7	78.
54.5	EST. 0.3 DEG/SEC ROLL		95398.	.4	1048.3	78.
54.5	PITCH AND YAW CONTROL		95390.	7.8	1040.5	78.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT		S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
62.0	PITCH AND YAW CONTROL		95383.	7.8	1032.7	77.
70.1	P52 IMU ALIGN		95378.	4.2	1028.4	77.
71.1	MIDCOURSE CORRECTION NO 4 MNVR TO BURN ATT		95374.	4.2	1024.2	76.
71.1	ATT HOLD 0.5 DEG DB	PGNCS	95374.	.4	1023.8	76.
71.1	DEL VEL = NOM ZERO		95374.	.0	1023.8	76.
71.5	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC		95370.	4.0	1019.8	76.
71.5	ATTITUDE HOLD 0.2 DEG DB	SCS	95369.	.8	1019.0	76.
71.5	EST. 0.3 DEG/SEC ROLL		95369.	.4	1018.6	76.
71.5	PITCH AND YAW CONTROL		95368.	1.0	1017.6	76.
71.5	REORIENT		95365.	2.4	1015.2	76.
71.5	REORIENT		95363.	2.4	1012.8	75.
75.4	P52 IMU ALIGN		95359.	4.2	1008.6	75.
75.4	SEXTANT STAR CHECKING,MIN IMPULSE		95358.	.4	1008.2	75.
76.2	LUNAR ORBIT INSERTION BURN 1 3-AXIS ORIENT	PGNCS	95354.	4.2	1004.0	75.
76.2	ATTITUDE HOLD		95354.	.4	1003.6	75.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
76.2	START TRANSIENT CONTROL	95352.	1.3	1002.3	75.
76.5	LOI BURN BUILD UP	95349.	.0	1002.3	75.
76.5	STEADY STATE BURN 11	71766.	.6	1001.7	75.
76.5	TAILOFF	71725.	.0	1001.7	75.
76.5	DAMP SHUT DOWN TRANSIENT	71724.	1.1	1000.6	75.
76.5	ORIENT TO TRACKING ATTITUDE PITCH TO ORDEAL	71721.	3.4	997.2	74.
76.5	HOLD ATTITUDE	71715.	5.2	992.0	74.
76.5	TV ALLOWANCE	71711.	4.0	988.0	74.
79.6	P52 IMU ALIGN	71708.	3.5	984.5	73.
79.6	STAR CHECK ,MIN IMP CONTROL	71708.	.4	984.1	73.
80.6	LOI 2 LPO CIRC MNVR TO BURN ATT	71704.	3.5	980.6	73.
80.6	ATTITUDE HOLD	71704.	.4	980.3	73.
80.6	ULLAGE 2 JET B AND D QUADS 2	71688.	15.3	965.0	72.
80.9	SPS BURN BUILD UP	71686.	.0	965.0	72.
80.9	STEADY STATE BURN14.5 FPS PGNCS	70708.	.2	964.8	72.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
80.9	TAILOFF	70668.	.0	964.8	72.
80.9	DAMP SHUTDOWN TRANSIENT	70667.	1.1	963.7	72.
81.0	REORIENT FOR MSFN ACQUISITION	70663.	3.4	960.3	72.
83.5	P52 IMU ALIGN	70660.	3.4	956.9	71.
83.5	REORIENT	70657.	3.4	953.4	71.
83.5	REORIENT	70653.	3.4	950.0	71.
83.5	MINIMUM IMPULSE MARKING	70653.	.4	949.6	71.
84.5	ORIENT FOR MSFN	70649.	3.4	946.2	70.
85.5	MANEUVER TO ORBITAL SLEEP MODE ASSUME SAME AS PTC	70646.	3.4	942.8	70.
85.5	PITCH AND YAW CONTROL	70641.	4.5	938.3	70.
90.0	PITCH AND YAW CONTROL	70637.	4.5	933.8	70.
95.5	P52 IMU ALIGN	70633.	3.4	930.4	69.
95.5	REORIENT	70632.	1.8	928.6	69.
95.5	REORIENT	70630.	1.8	926.8	69.
97.0	ORIENTATION MANEUVERS	70627.	2.5	924.3	69.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
98.0	ORIENT TO UNDOCKING ATT	70624.	3.4	920.9	69.
98.5	UNDOCK	40588.	4.9	915.9	68.
98.5	STATION KEEP FOR LM PHOTOGRAPHY	40578.	10.0	905.9	67.
98.8	REORIENT FOR MSFN ACQUISITION	40576.	1.7	904.3	67.
98.9	ORIENT FOR SEP BURN	40575.	.8	903.5	67.
99.2	RCS SEPARATION BURN 1 FPS	40570.	4.9	898.5	67.
99.2	REORIENT	40570.	.5	898.1	67.
99.4	REORIENT	40569.	.5	897.6	67.
99.6	REORIENT	40569.	.5	897.1	67.
99.8	REORIENT	40568.	.5	896.6	67.
99.8	MINIMUM IMPULSE CONTROL	40565.	3.4	893.1	67.
102.0	P52 IMU ALIGN	40563.	1.7	891.5	66.
102.5	2 MANEUVERS TO ACQUISITION ATT	40560.	2.7	888.8	66.
102.9	MNVR TO BURN ATT	40559.	1.7	887.1	66.
102.9	ATTITUDE HOLD WITH MI	40558.	.3	886.8	66.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
103.2	P52 IMU ALIGN	40557.	1.7	885.1	66.
103.8	MNVR TO BURN ATT	40555.	1.7	883.5	66.
103.8	ATT HOLD	40553.	1.7	881.7	66.
104.0	REORIENT SPACECRAFT 4 TIMES	40548.	5.0	876.7	65.
104.0	MINIMUM IMPULSE CONTROL	40545.	3.0	873.7	65.
105.4	MANEUVER TO TPI ATTITUDE	40544.	1.7	872.0	65.
105.4	ATT HOLD	40543.	.9	871.2	65.
106.0	FOUR MANEUVERS TO ATTITUDE	40538.	5.0	866.1	65.
106.0	MINIMUM IMPULSE CONTROL	40536.	1.3	864.8	64.
106.5	REORIENT FOR MSFN	40535.	1.7	863.2	64.
106.5	TV ALLOWANCE	40531.	4.0	859.2	64.
106.9	ORIENT TO DOCKING ATTITUDE	40529.	1.7	857.5	64.
107.0	MAINTAIN BORESIGHT	40527.	1.7	855.8	64.
107.0	DOCKING	46189.	2.5	853.3	64.
108.5	MNVR TO JETTISON ATT	46188.	1.2	852.1	63.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
108.6	ORIENT FOR SEP BURN	46186.	1.2	850.9	63.
108.7	JETTISON LM 1 FPS	40517.	5.9	845.0	63.
110.0	ESTABLISH SLEEP MODE	40516.	.7	844.3	63.
112.0	PITCH AND YAW CONTROL	40512.	4.0	840.3	63.
115.0	PITCH AND YAW CONTROL	40508.	4.0	836.3	62.
118.0	REORIENT FOR MSFN ACQUISITION	40506.	1.7	834.6	62.
122.0	REV 24 IMU ALIGN	40505.	.8	833.9	62.
122.5	REORIENT FOR LANDMARKS 3 TIMES PER REV	40502.	3.8	830.1	62.
122.5	ROLL TO ACQUIRE MSFN	40501.	.3	829.8	62.
122.5	MINIMUM IMPULSE MARKING	40501.	.4	829.3	62.
124.0	REV 25 IMU ALIGN	40500.	.8	828.5	62.
124.5	REORIENT FOR LANDMARKS 3 TIMES PER REV	40496.	3.8	824.8	61.
124.5	ROLL TO ACQUIRE MSFN	40496.	.3	824.5	61.
124.5	MINIMUM IMPULSE MARKING	40496.	.4	824.1	61.
126.0	REV 26 IMU ALIGN	40495.	.8	823.3	61.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
126.5	REORIENT FOR LANDMARKS 3 TIMES PER REV	40491.	3.8	819.5	61.
126.5	ROLL TO ACQUIRE MSFN	40491.	.3	819.2	61.
126.5	MINIMUM IMPULSE MARKING	40490.	.4	818.8	61.
128.0	REV 27 IMU ALIGN	40490.	.8	818.0	61.
128.5	REORIENT FOR LANDMARKS 3 TIMES PER REV	40486.	3.8	814.2	61.
128.5	ROLL TO ACQUIRE MSFN	40485.	.3	813.9	61.
128.5	MINIMUM IMPULSE MARKING	40485.	.4	813.5	61.
128.5	P52 IMU ALIGN	40483.	1.7	811.8	60.
128.5	REORIENT 3X FOR PHOTOGRAPHY	40480.	3.8	808.0	60.
128.5	AUTO ORB RATE	40478.	1.7	806.3	60.
129.0	P52 IMU ALIGN	40476.	1.7	804.7	60.
129.0	SXT STAR CHECK	40476.	.4	804.2	60.
129.8	TRANS-EARTH INJECTION MNVR TO BURN ATT	40474.	1.7	802.6	60.
129.8	- ATTITUDE HOLD	40474.	.4	802.2	60.
129.8	ULLAGE 2 JET B AND D	40460.	14.0	788.2	59.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT	S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
129.8	SPS BURN BUILD UP	40457.	.0	788.2	59.
129.8	STEADY STATE BURN 136 SEC PGNCS	31293.	.2	788.0	59.
129.8	TAILOFF	31252.	.0	788.0	59.
129.8	DAMP SHUTDOWN TRANSIENT	31251.	1.1	786.9	59.
130.0	MANEUVER FOR MSFN ACQUISITION	31250.	1.5	785.4	59.
131.7	P52 IMU ALIGN	31248.	1.5	783.9	58.
132.0	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC	31248.	.7	783.2	58.
132.0	ATTITUDE HOLD 0.2 DEG DB SCS	31247.	.8	782.4	58.
132.0	EST. 0.3 DEG/SEC ROLL	31247.	.2	782.2	58.
132.0	PITCH AND YAW CONTROL	31236.	11.0	771.2	57.
143.0	P52 IMU ALIGN	31234.	1.5	769.7	57.
143.5	CISLUNAR NAVIGATION STAR/LUNAR HORIZON ORIENT	31228.	6.2	763.6	57.
143.5	MIN. IMPULSE MARKING	31226.	2.2	761.4	57.
144.8	MIDCOURSE CORRECTION NO 5 MNVR TO BURN ATT	31224.	1.5	759.9	57.
144.8	ATTITUDE HOLD WITH MI	31224.	.3	759.7	57.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT		S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
144.8	DEL VEL = NOM ZERO		31224.	.0	759.7	57.
146.0	PTC TEST W/O ATT CONTROL		31215.	9.0	750.7	56.
148.0	PTC TEST W/O ATT CONTROL		31206.	9.0	741.7	55.
150.0	PTC TEST W/O ATT CONTROL		31197.	9.0	732.7	55.
150.0	TV ALLOWANCE		31193.	4.0	728.7	54.
156.0	P52 IMU ALIGN		31192.	1.5	727.2	54.
156.5	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC		31191.	.7	726.5	54.
156.5	ATTITUDE HOLD 0.2 DEG DB	SCS	31190.	.8	725.7	54.
156.5	EST. 0.3 DEG/SEC ROLL		31190.	.2	725.5	54.
156.5	PITCH AND YAW CONTROL		31176.	14.0	711.5	53.
171.0	P52 IMU ALIGN		31174.	1.5	710.0	53.
173.5	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC		31174.	.7	709.3	53.
173.5	ATTITUDE HOLD 0.2 DEG DB	SCS	31173.	.8	708.5	53.
173.5	EST. 0.3 DEG/SEC ROLL		31173.	.2	708.3	53.
173.5	PITCH AND YAW CONTROL		31169.	4.0	704.3	52.

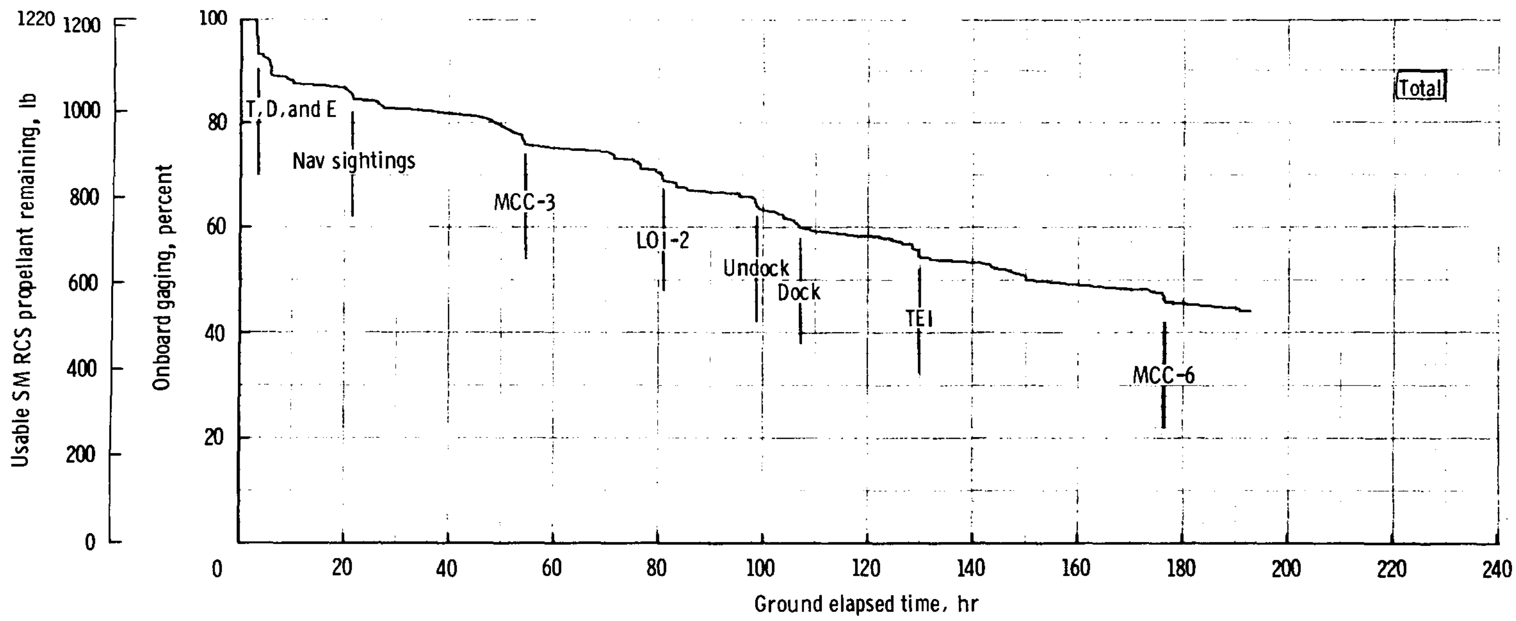
TABLE 2-III.- SM RCS PROPELLANT BUDGET - Continued

TIME (HR)	EVENT		S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
175.0	P52 IMU ALIGN		31167.	1.5	702.8	52.
176.2	MIDCOURSE CORRECTION NO 6 MNVR TO BURN ATT		31166.	1.5	701.3	52.
176.2	ATT HOLD .5 DEG DB PGNCS		31165.	.4	701.0	52.
176.2	RCS -X TRANS 5 FPS		31147.	18.1	682.8	51.
176.7	ORIENT FOR PTC 3AXIS 0.2 DEG/SEC		31146.	.7	682.1	51.
176.7	ATTITUDE HOLD 0.2 DEG DB	SCS	31146.	.8	681.3	51.
176.7	EST. 0.3 DEG/SEC ROLL		31146.	.2	681.1	51.
176.7	PITCH AND YAW CONTROL		31137.	9.0	672.1	50.
187.0	P52 IMU ALIGN		31135.	1.5	670.6	50.
188.3	MIDCOURSE CORRECTION NO 7 MNVR TO BURN ATT		31133.	1.5	669.1	50.
188.3	ATT HOLD .5 DEG DB PGNCS		31133.	.3	668.9	50.
188.3	DEL VEL = NON ZERO		31133.	.0	668.9	50.
189.6	P52 IMU ALIGN		31132.	1.5	667.3	50.
191.0	MANEUVER TO REENTRY ATTITUDE		31130.	1.5	665.8	50.
191.0	ATTITUDE HOLD 0.2 DEG DB	SCS	31129.	.8	665.0	50.

TABLE 2-III.- SM RCS PROPELLANT BUDGET - Concluded

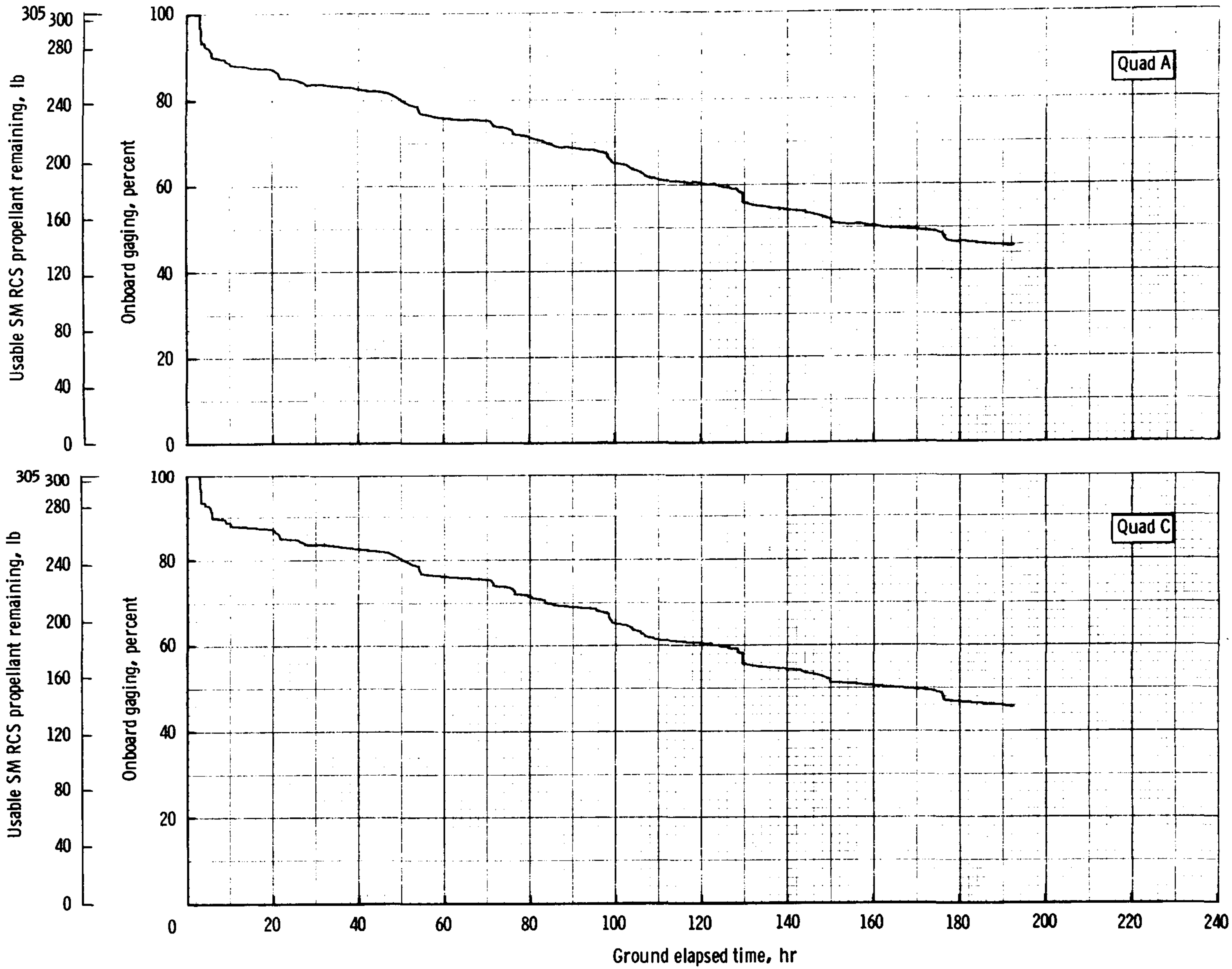
TIME (HR)	EVENT	S/C WT (LBS)	SM RCS USED (LBS)	SM RCS LEFT (LBS)	SM RCS LEFT (%)
191.0	PITCH TO ACQUIRE HORIZON	34129.	.7	664.3	49.
191.0	YAW 45 DEG	34128.	.7	663.6	49.
191.0	ATT HOLD .5 DEG DB PGNCS	34128.	.4	663.2	49.
193.0	CM/SM SEPARATION DELTA VEL=3 FPS	18107.	10.1	[a]653.2	49.

[a]This is the total propellant remaining and does not account for mission duty cycle mixture ratio shift or other unusables. Usable propellant remaining is 490 pounds as shown in table 2-II.



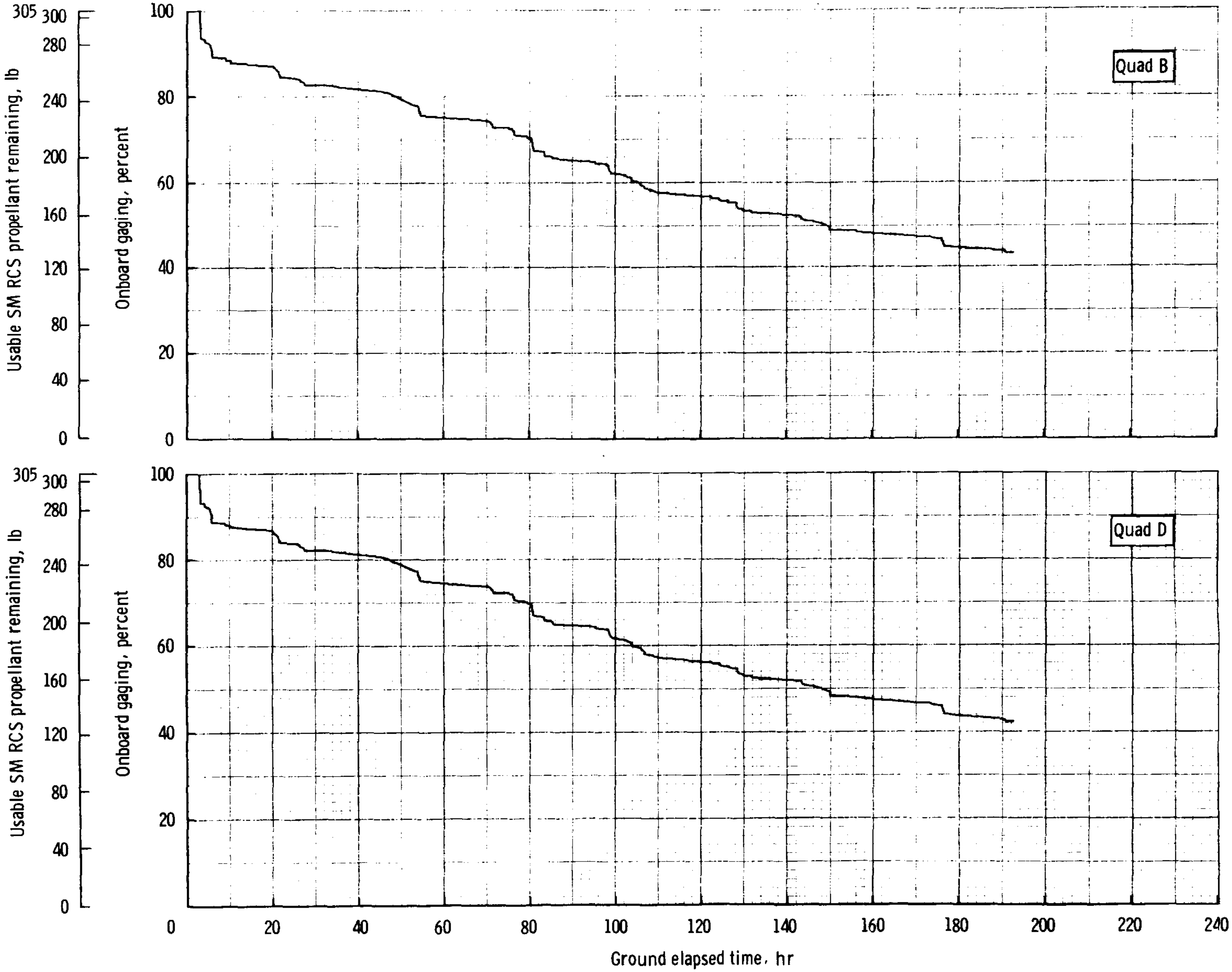
(a) Total.

Figure 2-1.- SM RCS propellant profile.



(b) Quads A and C.

Figure 2-1. - Continued.



(c) Quads B and D.

Figure 2-1. - Concluded.

3.0 THE SPS ANALYSIS

Weight assumptions for the SPS analysis are shown in table 3-I (ref. 3, amendment 41); SPS performance parameters were taken from reference 1.

The SPS propellant budget for a May 17 launch, 72° launch azimuth, first opportunity injection is presented in table 3-II(a). The propellant budget for a May 18 launch with a 72° launch azimuth, first opportunity injection, 61-hour lunar orbit time, and 2-day return is shown in table 3-II(b). Both budgets include a contingency ΔV of 900 fps to provide the capability to perform a worst case LM rescue, to return by use of the SCS, or to return from any lunar orbit.

The May 18 launch has two other sets of ΔV associated with it, one which assumes a 51-hour lunar stay (TEI of 3198.8 fps), and the other which assumes a 61-hour lunar stay and 3-day return (TEI of 2818.8 fps). The propellant margins associated with these trajectories are shown in table 3-II(b). The contingency ΔV of 900 fps would be used for a quick earth return or for a LM rescue in the last case. Propellant margin for the May 17 launch [table 3-II(a)] is 1837 pounds, and for the May 18 launch, fast return [table 3-II(b)] is 818 pounds.

TABLE 3-I.- ASSUMPTIONS FOR THE SPS ANALYSIS

1. Each SPS engine start used 14.4 lb of propellant in nonpropulsive losses.

2. Spacecraft weights

CM, lb	12 276.8
SM, lb	10 641.8
SLA ring, lb	98.0
Tanked SPS, lb	40 633.7
LM (unmanned), lb	30 848.8
Spacecraft at TLC, lb	94 499.1

3. SM RCS, EPS, and ECS weight losses

Mission Period	Incremental weight loss, lb
Lift-off to MCC-1	89.4
MCC-1 to LOI-1	185.5
LOI-1 to LOI-2	30.5
LOI-2 to TEI	234.8

TABLE 3-II.- SPS PROPELLANT SUMMARY

(a) May 17 launch, 72° launch azimuth, first opportunity injection

Item	Propellant required, lb	Propellant remaining, lb
Loaded	--	40 836.0
Trapped and unavailable	441.4	40 394.6
Outage	78.5	40 316.1
Unbalanced meter bias	100.0	40 216.1
Available for ΔV	--	40 216.1
Required for ΔV		
TLMC (120 fps)	1 128.4	39 087.7
LOI-1 (2866.3 fps)	23 004.0	16 083.7
LOI-2 (137.7 fps)	962.9	15 120.8
TEI (3252.2 fps)	10 507.8	4 613.0
Nominal remaining	--	4 613.0
Contingency ΔV (900 fps)	2 238.7	2 374.3
Dispersions (-3σ)	537.6	1 836.7
Propellant margin		1 836.7

TABLE 3-II.- SPS PROPELLANT SUMMARY - Concluded

(b) May 18 launch, 72° launch azimuth, first opportunity injection

Item	Propellant required, lb	Propellant remaining, lb
Loaded	--	40 836.0
Trapped and unavailable	441.4	40 394.6
Outage	78.5	40 316.1
Unbalanced meter bias	100.0	40 216.1
Available for ΔV	--	40 216.1
Required for ΔV		
TLMC (120 fps)	1 128.4	39 087.7
LOI-1 (2856 fps)	22 932.5	16 155.2
LOI-2 (137.4 fps)	961.8	15 193.4
TEI (3693.5 fps)	11 711.6	3 481.8
Nominal remaining	--	3 481.8
Contingency ΔV (900 fps)	2 123.4	1 358.4
Dispersions (-3σ)	540.0	818.4
Propellant margin[a]	--	818.4

[a]For a 51-hour lunar orbit time and a TEI ΔV of 3199 fps, propellant margin is 1884.3 lb. For a 61-hour lunar orbit time and a TEI ΔV of 2819 fps (3-day return), the propellant margin is 2852.9 lb.

4.0 THE LM RCS PROPELLANT ANALYSIS

TABLE 4-I.- GROUND RULES AND ASSUMPTIONS

1. Data for the LM RCS engine performance and propellant requirements were obtained from reference 2.

2. All orientation maneuvers were assumed to be made at 2.0 deg/sec.

3. All orientation maneuvers were assumed to be 3-axis maneuvers.

4. Line-of-sight with the CSM was assumed to be maintained in the minimum impulse mode.

TABLE 4-II.- LM RCS PROPELLANT SUMMARY

Description	Propellant weight, lb
Loaded	633.0
Trapped	40.6
Nominal deliverable	592.4
Gaging inaccuracy and loading tolerance	39.5
Mixture ratio uncertainty	17.0
Usable	535.9
Nominal mission requirement	359.7
Nominal remaining	176.2

TABLE 4-III.- LM RCS PROPELLANT BUDGET

TIME HR	M	EVENT TITLE	S/C WT (LBS)	LM RCS USED (LBS)	LM RCS LEFT (LBS)	LM RCS LEFT (%)
0	0	OUTPUT PROPELLANT LOADINGS	94959.	.0	633.0	100.
96	58	RCS HOT FIRE	94954.	5.0	628.0	99.
98	15	AGS ACCELERATION AND GYRO CALIBRATIONS	94952.	2.0	626.0	99.
98	33	UNDOCKING	31307.	.0	626.0	99.
98	47	MNVR FOR INSP AND FOR FLY	31297.	10.0	616.0	97.
99	20	P20 RR LOCK ON	31293.	4.1	611.9	97.
99	28	MAINTAIN RR TRACKING 8 MIN	31292.	.8	611.1	97.
99	29	IMU REALIGN SINGLE STAR	31288.	4.1	607.1	96.
99	29	IMU REALIGN SINGLE STAR	31284.	4.1	603.0	95.
99	29	IMU REALIGN SINGLE STAR	31280.	4.1	598.9	95.
99	54	MNVR TO BURN ATTITUDE	31276.	4.1	594.8	94.
99	54	ATTITUDE HOLD	31276.	.0	594.8	94.
99	54	ATTITUDE HOLD	31276.	.2	594.6	94.
99	54	2 JET ULLAGE	31270.	5.9	588.7	93.
99	54	DESCENT ORBIT INSERT. BURN	31036.	.0	588.7	93.
99	54	MOMENT CONTROL	31029.	7.0	581.7	92.
99	54	ATTITUDE HOLD	31028.	.5	581.2	92.
100	20	RR LOCK ON	31024.	4.1	577.2	91.
100	50	MAINTAIN RR TRACKING 25 MIN	31022.	2.5	574.7	91.
100	50	PITCH DOWN 90 DEG.	31020.	1.7	573.0	91.
100	50	YAW LEFT 180 DEG.	31019.	1.5	571.5	90.
100	50	YAW RIGHT 180 DEG.	31017.	1.5	570.0	90.
100	50	PITCH UP 90 DEG.	31017.	.1	570.0	90.
100	59	MNVR TO BURN ATTITUDE	31013.	4.0	565.9	89.

TABLE 4-III.- LM RCS PROPELLANT BUDGET - Continued

TIME HR	M	EVENT TITLE	S/C WT (LBS)	LM RCS USED (LBS)	LM RCS LEFT (LBS)	LM RCS LEFT (%)
100	59	ATTITUDE HOLD	31013.	.0	565.9	89.
100	59	ATTITUDE HOLD	31013.	.2	565.7	89.
100	59	2 JET ULLAGE	31007.	5.9	559.8	88.
101	6	DPS PHASING BURN	30394.	.0	559.8	88.
101	6	MOMENT CONTROL	30392.	1.5	558.3	88.
101	6	ATTITUDE HOLD	30392.	.5	557.8	88.
101	6	YAW	30391.	1.4	556.4	88.
101	6	PITCH	30389.	1.7	554.7	88.
101	10	RR LOCK ON	30385.	4.0	550.7	87.
101	28	MAINTAIN RR TRACKING	30383.	1.8	548.9	87.
101	28	IMU REALIGN SINGLE STAR	30379.	4.0	544.9	86.
101	28	IMU REALIGN SINGLE STAR	30375.	4.0	540.9	85.
101	28	COAS CALIBRATION	30371.	4.0	536.9	85.
101	34	RR LOCK ON	30367.	4.0	532.9	84.
102	53	MAINTAIN TRACKING	30359.	7.6	525.3	83.
102	53	ORIENT FOR STAGING	30355.	4.0	521.3	82.
102	53	STAGING	8364.	.0	521.3	82.
102	53	START STAGING	8362.	1.9	519.5	82.
102	53	COMPLETE STAGING	8361.	1.9	517.6	82.
102	53	MNVR TO BURN ATTITUDE	8360.	.8	516.8	82.
102	53	ATTITUDE HOLD	8360.	.2	516.6	82.
102	53	ATTITUDE HOLD	8359.	.9	515.7	81.
102	53	4 JET ULLAGE	8353.	5.7	510.0	81.
103	4	MOMENT CONTROL INSERTION BURN	8176.	1.3	508.8	80.
103	4	NULL DVEL 1FPS XAXIS	8175.	.9	507.9	80.

TABLE 4-III.- LM RCS PROPELLANT BUDGET - Continued

TIME HR	M	EVENT TITLE	S/C WT (LBS)	LM RCS USED (LBS)	LM RCS LEFT (LBS)	LM RCS LEFT (%)
103	4	NULL DVEL 1FPS YAXIS	8174.	1.1	506.7	80.
103	4	NULL DVEL 1FPS ZAXIS	8173.	1.0	505.7	80.
103	4	ATTITUDE HOLD	8170.	2.3	503.4	80.
103	4	IMU REALIGN SINGLE STAR	8170.	.8	502.5	79.
103	4	IMU REALIGN SINGLE STAR	8169.	.8	501.7	79.
103	4	IMU REALIGN SINGLE STAR	8168.	.8	500.9	79.
103	22	RR LOCK ON	8167.	.8	500.0	79.
103	22	MAINTAIN RR TRACKING 25 MIN	8163.	4.2	495.9	78.
103	22	MNVR TO BURN ATTITUDE	8162.	.8	495.0	78.
103	22	ATTITUDE HOLD	8162.	.2	494.9	78.
103	22	ATTITUDE HOLD	8161.	.9	494.0	78.
103	54	CSI RCS BURN	8116.	14.2	479.8	76.
103	54	ATTITUDE HOLD	8113.	2.4	477.4	75.
103	54	RR LOCK ON	8112.	.8	476.6	75.
103	54	MAINTAIN RR TRACKING	8108.	4.8	471.7	75.
104	23	PLANE CHANGE	8106.	2.0	469.7	74.
104	53	MAINTAIN RR TRACKING	8101.	4.2	465.6	74.
104	53	MNVR TO BURN ATTITUDE	8101.	.8	464.7	73.
104	53	ATTITUDE HOLD	8100.	.2	464.6	73.
104	53	ATTITUDE HOLD	8100.	.9	463.7	73.
104	53	CDH +Z BURN	8094.	5.7	458.0	72.
104	53	ATTITUDE HOLD	8091.	2.4	455.6	72.
104	53	UPDATE AGS WITH RR DURING ATTI TUDE HOLD	8079.	12.3	443.3	70.
105	23	MNVR TO BURN ATTITUDE	8078.	.8	442.5	70.
105	23	ATTITUDE HOLD	8078.	.2	442.3	70.

TABLE 4-III.- LM RCS PROPELLANT BUDGET - Concluded

TIME HR M	EVENT TITLE	S/C WT (LBS)	LM RCS USED (LBS)	LM RCS LEFT (LBS)	LM RCS LEFT (%)
105 23	ATTITUDE HOLD	8077.	.9	441.4	70.
105 29	TPI RCS BURN	8055.	14.2	427.2	67.
105 29	ATTITUDE HOLD	8053.	2.4	424.8	67.
105 51	ORIENT TO ATTITUDE	8052.	.8	424.0	67.
105 51	ATTITUDE HOLD	8034.	17.8	406.2	64.
106 12	MNVR TO BURN ATTITUDE	8033.	.8	405.4	64.
106 12	ATTITUDE HOLD	8033.	.2	405.2	64.
106 12	ATTITUDE HOLD	8032.	.9	404.3	64.
106 12	TPF +Z BURN	7982.	49.7	354.7	56.
106 12	ATTITUDE HOLD	7980.	2.4	352.3	56.
106 12	ATTITUDE MNVRS AND LOS CONTROL	7954.	26.0	326.3	52.
106 38	FORM. FLYING	7942.	12.0	314.3	50.
106 55	DOCKING	71546.	41.0	273.3	43.

NOTE: The APS propellant used through the RCS for moment control during the APS burn to depletion (assumes $Z_{c.g.}$ = 2.1 in. at burnout) is 139 lb.

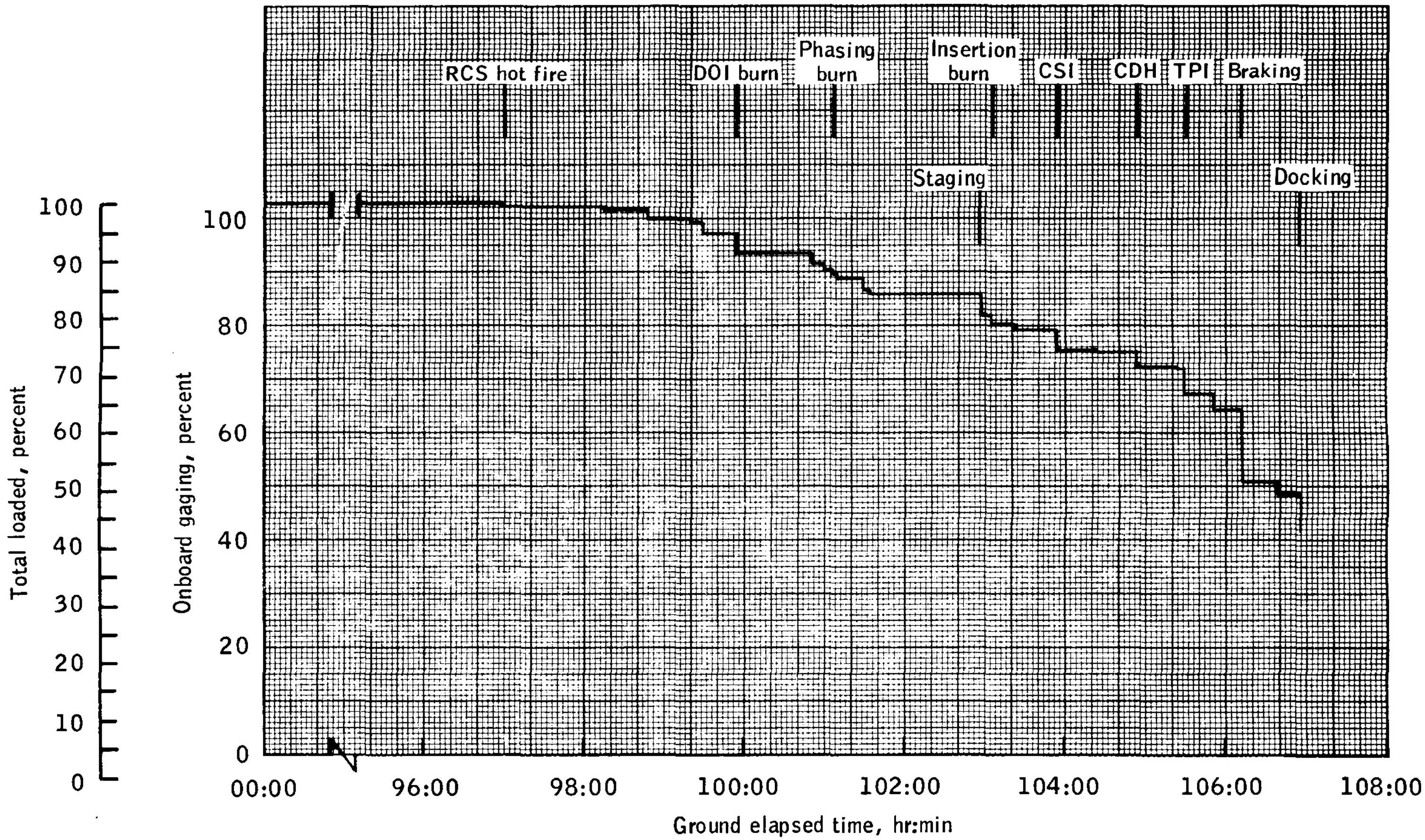


Figure 4-1- LM RCS propellant profile.

5.0 THE DPS ANALYSIS

The assumptions for the DPS analysis are presented in table 5-I, and the DPS propellant requirements are shown in table 5-II. The loading numbers are from amendment 41 of reference 3. Burn requirements reflect the following thrust profiles: DOI performed at 10 percent for 15 seconds and at 40 percent for 11.7 seconds, phasing performed at 10 percent for 26 seconds and F.T.P. at 10 percent for 15 seconds. A propellant margin of 16 767 pounds exists.

TABLE 5-I.- ASSUMPTIONS FOR THE DPS ANALYSIS

1. Mixture ratio = 1.6 ± 0.024.
2. Propellant cost for engine and valve operation is 8.6 lb per engine start.
3. Buildup and tailoff cost is 19.15 lb of propellant per burn.
4. Propellant flow rates for various throttle settings were taken from reference 2.

TABLE 5-II.- DPS PROPELLANT SUMMARY

Item	Propellant required, lb	Propellant remaining, lb
Loaded		18 229.5
Trapped outside tanks[a]	95.5	18 134.0
Tanked		18 134.0
Trapped inside tanks[a]	272.0	17 862.0
3σ outage	214.5	17 647.5
Available for ΔV		17 647.5
Required for ΔV[b]		
DOI, 72.8 fps, 26.7 sec[c]	255.7	17 391.8
Phasing, 193.5 fps, 41.0 sec[d]	625.0	16 766.8
Propellant margin		16 766.8

[a]Reference 3, amendment 41.

[b]Includes nonpropulsive usage and buildup/tailoff usage.

[c]15 seconds at 10% and 11.7 seconds at 40%.

[d]26 seconds at 10% and 15 seconds at F.T.P.

6.0 THE APS ANALYSIS

The assumptions for the APS analysis are presented in table 6-I. The APS propellant budget is presented in table 6-II. The data for usable propellant were taken from amendment 41 of reference 3 and assume a 50 percent APS propellant loading. The CSI was performed with RCS propellant for 10 seconds and with APS propellant through the RCS/APS interconnect for 22 seconds. Because of the APS burn to depletion, a zero APS propellant margin exists.

TABLE 6-I.- ASSUMPTIONS FOR THE APS ANALYSIS

1. I_{sp} = 306.3 ± 1.5 sec.
2. APS propellant tanks are 50% loaded.
3. Ascent stage at earth lift-off weighs 8012 lb (unmanned).
4. LM RCS and EECOM weight loss is 88.6 lb prior to insertion burn.
5. Mixture ratio = 1.6 ± 0.0183.
6. Engine and valve operation uses 3.6 lb of propellant per APS burn.

TABLE 6-II.- APS PROPELLANT SUMMARY

Item	Propellant required, lb	Propellant remaining, lb
Loaded		2631.7
Trapped outside tanks[a]	12.7	2631.7
Tanked[a]		2619.0
Trapped in tanks[a]	40.4	2578.6
Available for ΔV		2578.6
Required for ΔV		
Insertion, 213.3 fps, 14.5 sec	182.1	2396.5
CSI, 50.3 fps, 22 sec through interconnect	32.3	2364.2
Burn to depletion	2364.2	0
Propellant margin		0

[a]Reference 3, amendment 41.

7.0 ASSUMPTIONS AND RESULTS OF THE EPS ANALYSIS

The power levels of each component were obtained from reference 1; the cryogenic loading data were obtained from reference 3. However, because the component data for F mission were not available, the D mission component values were used. Cislunar heater cyclic rates were used for TLC and TEC.

The EPS profile presented in figure 7-1 indicates that no serious problems exist. There are ample cryogenics (figs. 7-2 and 7-3) for the May 17 launch date even with a one-tank failure at TEI. However, a May 18 launch date will require powering the vehicle down during TEC with a tank failure. The cryogenics become marginal because the mission duration is increased by 24 hours. Figure 7-4 presents the total DC energy that accumulates during the mission.

The metabolic O_2 requirements were altered to 0.197 lb/hr, rather than 0.23 lb/hr, based on postflight analyses of Apollo 7 and 8. This alteration corresponds to approximately 400 Btu/hr as compared with 467 Btu/hr.

The 45 A-h rating mentioned in assumption 3 also was based on postflight testing of the entry and postlanding batteries.

TABLE 7-I.- ASSUMPTIONS FOR THE CSM EPS ANALYSIS

1. The system was assumed to operate with three fuel cells and two inverters.

2. The fuel cells were purged every 900 A-h.

3. Three entry and postlanding batteries were considered available to supply the total spacecraft power required for entry, parachute descent and postlanding time. Each battery was assumed to have a 40 A-h capacity until splashdown, at which time the capacity was uprated to 45 A-h.

4. Two batteries were considered to be in parallel with the fuel cells during ascent and for each SPS maneuver.

5. No cryogenic venting was assumed.

6. The EPS hydrogen consumption rate (lb/hr) = $0.00257 \times I_{fc}$.

7. The EPS oxygen consumption rate (lb/hr) = $7.936 \times \dot{H}_2$.

8. Two SPS midcourse corrections were assumed.

9. Six battery charges were assumed: three on battery A and three on battery B.

10. Five percent uncertainty in the EPS profile is included in the cryogenic requirements.

TABLE 7-II.- CRYOGENICS SUMMARY

Item	H_2, lb	O_2, lb
Loaded (two tanks)	58.60	660.2
Less residual	2.32	13.0
Less 2.65% instrumentation error	1.53	17.5
Total usable	54.75	629.7
Prelaunch requirements		
t minus 28.5 hr to t minus 6 hr at 40A	2.38	18.4
6-hr built-in hold at 40A	.63	4.9
t minus 6 hr to t minus 2 hr at 40A	.42	3.3
ECS requirements (3 hr)	--	.7
t minus 2 hr to t (hr) at 75A	.39	3.1
Total	3.82	30.4
Mission requirements		
EPS	35.21	268.5
ECS	--	91.5
Total	35.21	360.0
Uncertainties		
4.5-hr launch window at 75A	.87	7.8
5% uncertainty	1.76	13.4
Total	2.63	21.2
Total required	41.66	411.6
Margin	12.09	218.1

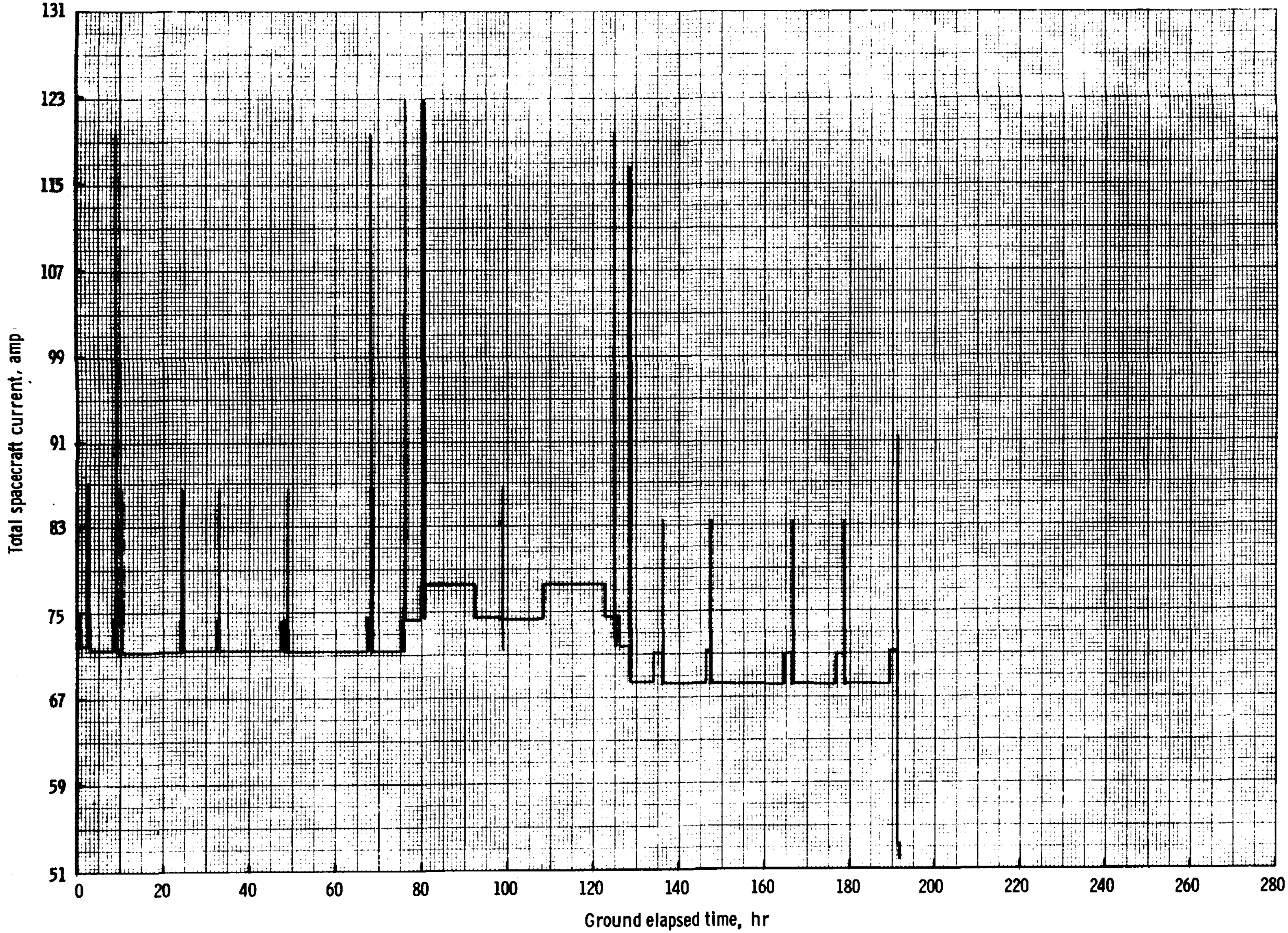


Figure 7-1. - Total spacecraft current versus time.

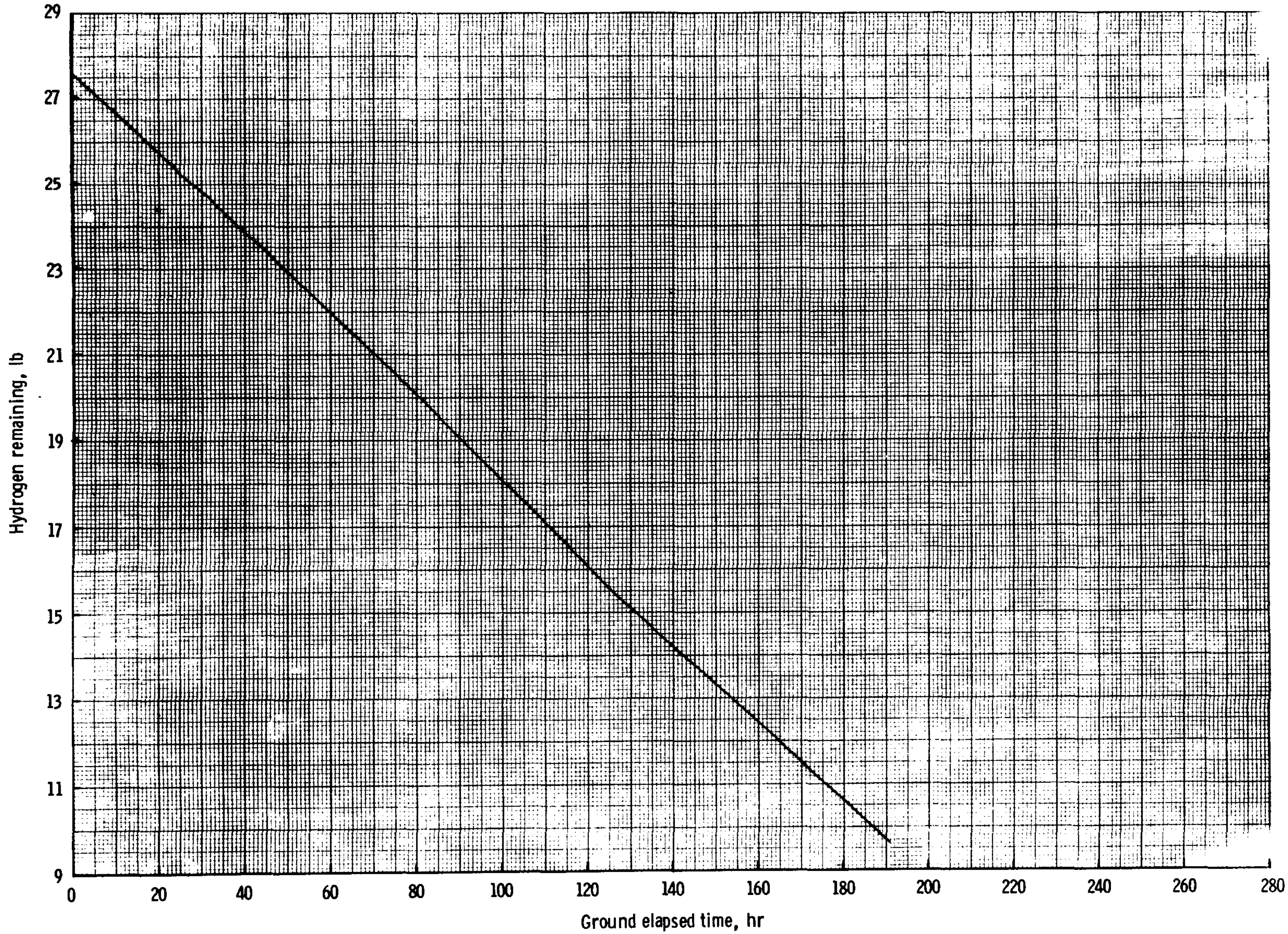


Figure 7-2. - Hydrogen remaining for mission for one tank versus time.

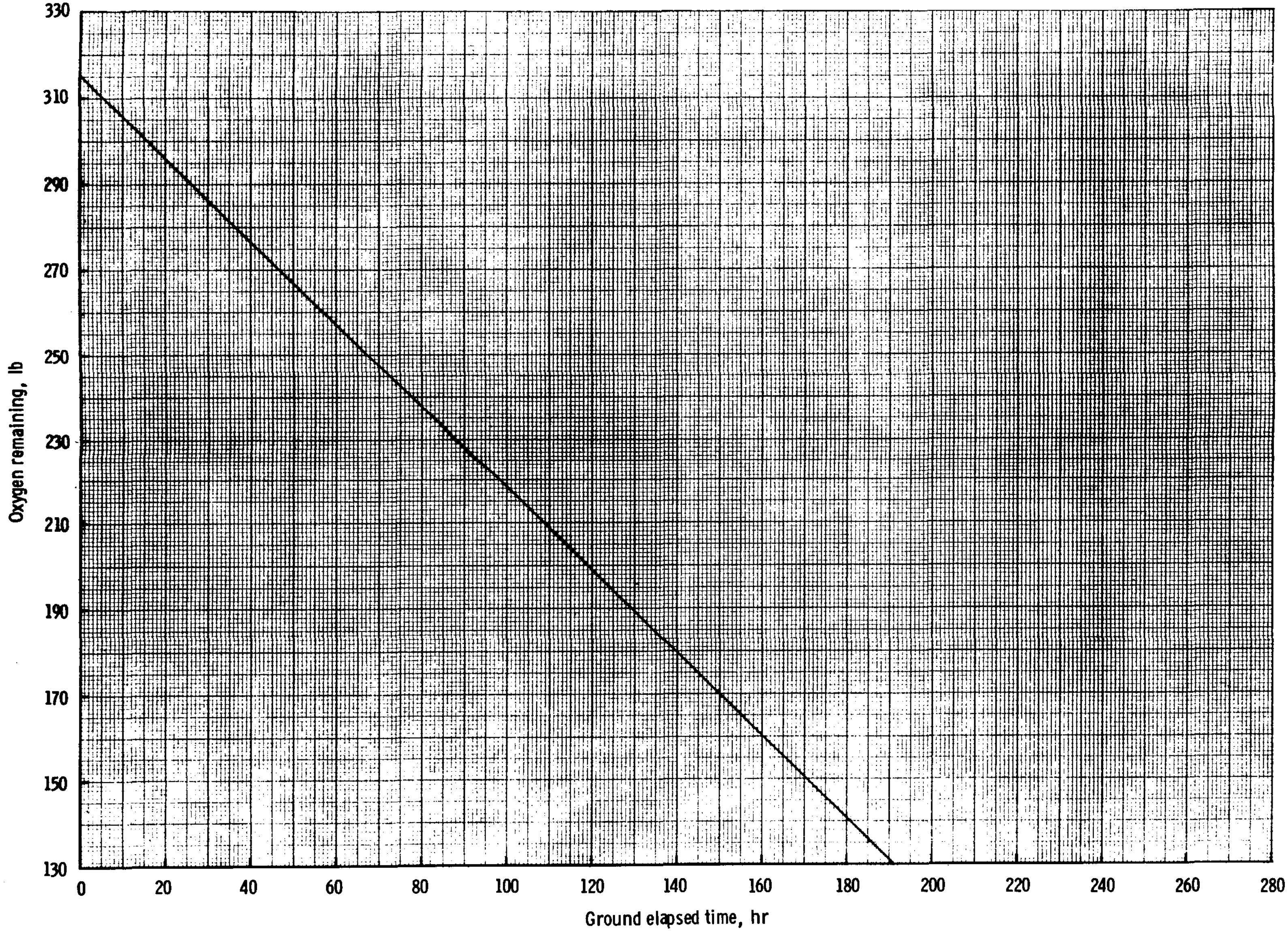


Figure 7-3. - Oxygen remaining for mission for one tank versus time.

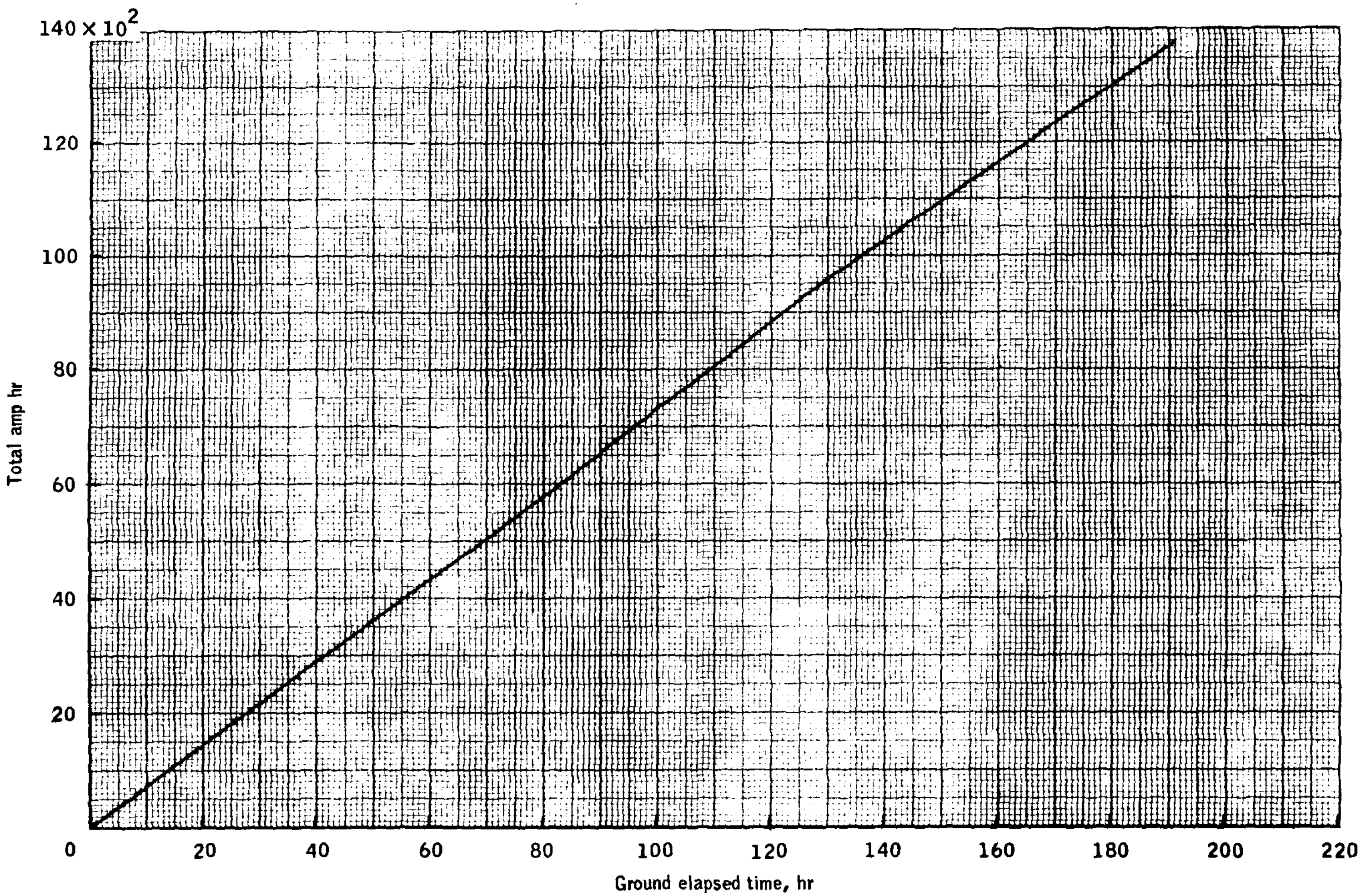


Figure 7-4.- Total DC energy profile versus time.

8.0 THE CSM ECS ANALYSIS

The CSM ECS analysis will be supplied when the detailed operational trajectory time line is available.

9.0 THE LM EPS ANALYSIS

The LM descent and ascent stage battery energy used for the nominal mission is 550 A-h and 432 A-h, respectively. Unusables defined in assumptions 2, 3, and 4 of table 9-I indicate that the descent stage and ascent stage have 62 and 21 percent energy remaining, respectively.

This particular analysis was performed by an individual block type approach rather than by the integration of crew procedures switch settings through the mission. As Apollo 10 becomes more defined, more detailed data will be published, including total spacecraft current profiles.

TABLE 9-I.- ASSUMPTIONS FOR THE LM EPS ANALYSIS

1. Energy available for the descent stage batteries is 1600 A-h and for the ascent stage batteries is 592 A-h.

2. Energy unusable for the descent stage batteries and the ascent stage batteries because of lack of MSFN coverage is 21 A-h and 7 A-h, respectively.

3. Energy unusable for the descent stage batteries and the ascent stage batteries because of telemetry inaccuracy is 8 A-h for both vehicles.

4. Energy unusable for the descent stage batteries and the ascent stage batteries because of equipment power dispersions is 28 A-h and 22 A-h, respectively.

5. The descent stage batteries would go on the line at lift-off minus 30 minutes with no recycle on the pad. They would go off the line again at transposition and docking.

6. All RCS quad heaters were considered to be on continuously for 1 hour prior to the first RCS hot fire test.

7. All S-band equipment was considered to be on continuously from initial activation until the completion of the mission.

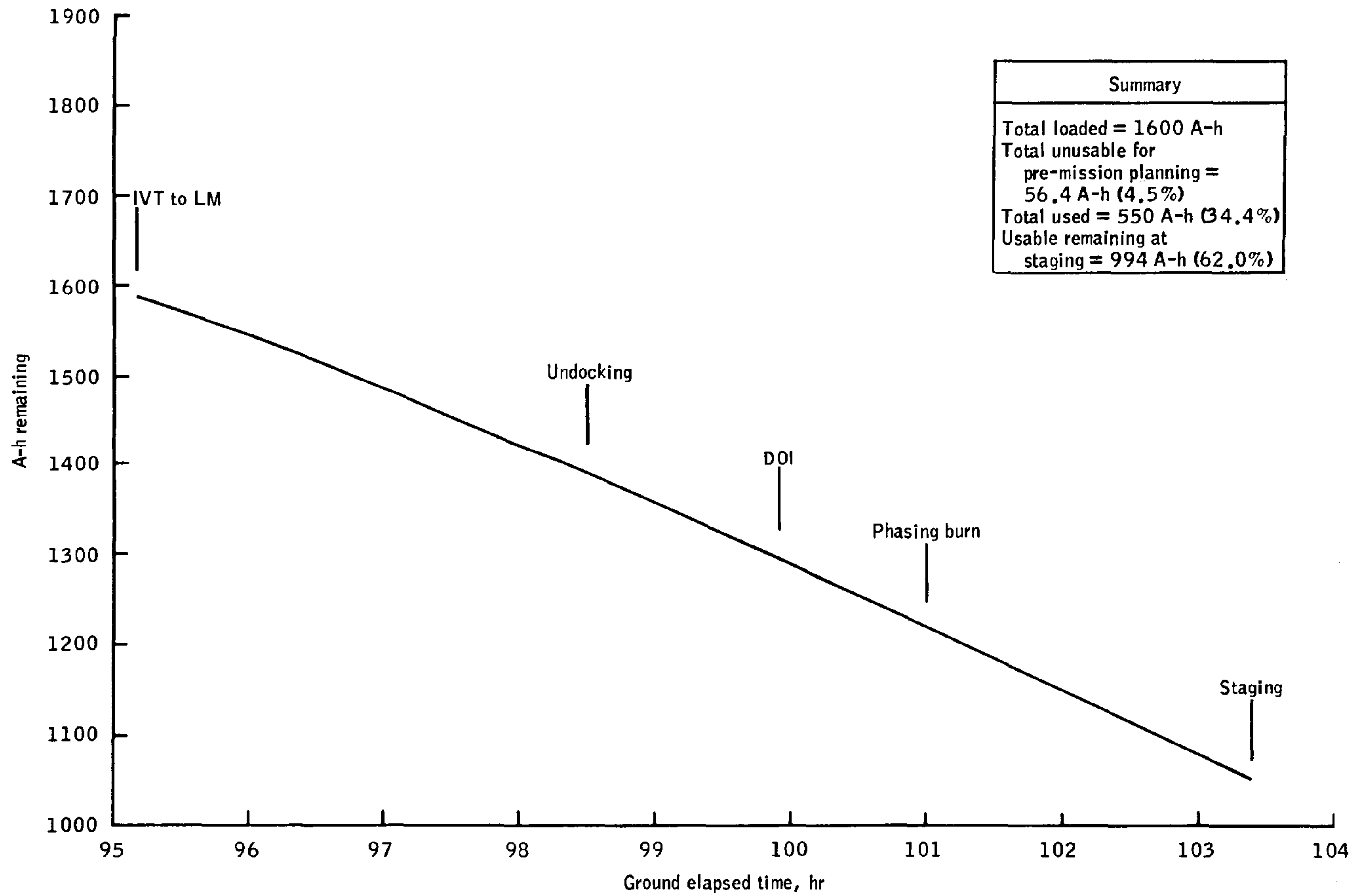


Figure 9-1.- Descent electrical power profile for an F mission flight plan.

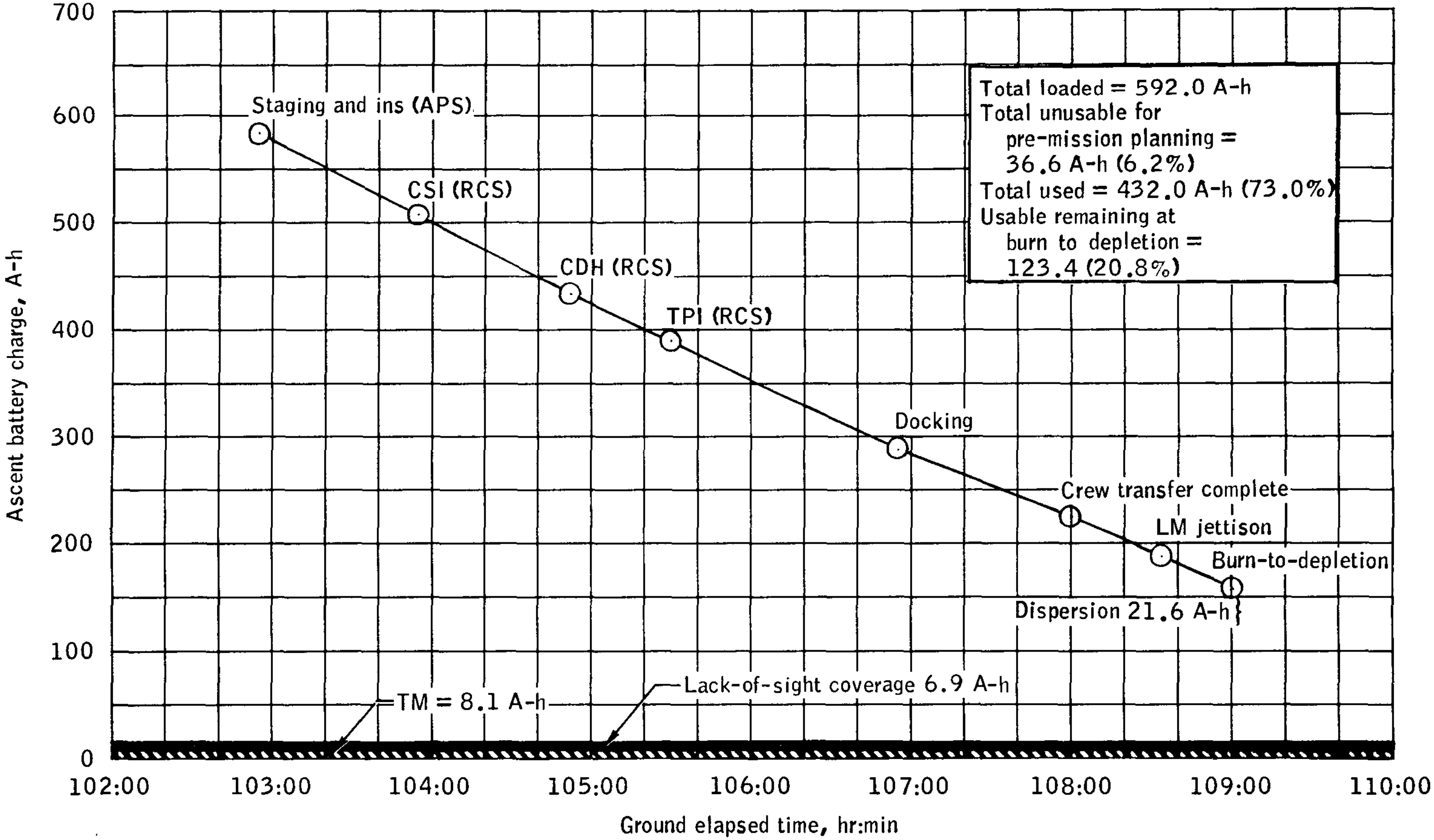


Figure 9-2.- Ascent electrical load analysis for an F mission flight plan.

10.0 THE LM ECS ANALYSIS

The LM ECS analysis will be supplied when the detailed operational trajectory time line is available.

TABLE 11-I.- TIME HISTORY OF CONSUMABLES WEIGHT LOSS

Mission time, hr	Event	EECOM weight loss, lb		RCS weight loss, lb		APS weight loss, lb	DPS weight loss, lb	SPS weight loss, lb
		CSM	LM	CSM	LM			
3:15	Lift-off to extraction	10		83.3	--	--	--	--
9:30	Extraction to MCC-1	2		58.3	--	--	--	1 128.4
26:30	MCC-1 to MCC-2	45		58.9	--	--	--	--
54:08	MCC-2 to MCC-3	57		88.4	--	--	--	--
71:08	MCC-3 to MCC-4	42	46	29.7	--	--	--	--
76:08	MCC-4 to LOI-1	2		35.8	--	--	--	22 932.5
80:32	LOI-1 to LOI-2	2		24.3	--	--	--	961.8
98:55	LOI-2 to CSM/LM SEP	42		47.8	--	--	--	--
99:54	SEP to DOI		7		38	--	255.7	--
100:58	DOI to LM phasing		7		29	--	625.0	--
102:53	LM phasing to staging		14	63.1	45	--	--	--
103:03	Staging to LM insertion		1		5	182.1	--	--
103:54	Insertion to CSI	12	6		22	--	--	--
104:52	CSI to CDH		7		36	32.3	--	--
105:29	CDH to TPI		4		17	--	--	--
106:55	TPI to Docking		10		168	--	--	--
108:34	Docking to LM jettison		11	8.8	--	--	--	--
109:03	APS burn to depletion		3	--	--	2364.2	--	--
129:51	LM jettison to TEI		--	58.1	--	--	--	11 711.6
144:51	TEI to MCC-5	41	--	27.2	--	--	--	--
176:18	MCC-5 to MCC-6	47	--	76.9	--	--	--	--
188:18	MCC-6 to MCC-7	5	--	13.9	--	--	--	--
193:00	MCC-7 to CM/SM SEP	2	--	15.7	--	--	--	--

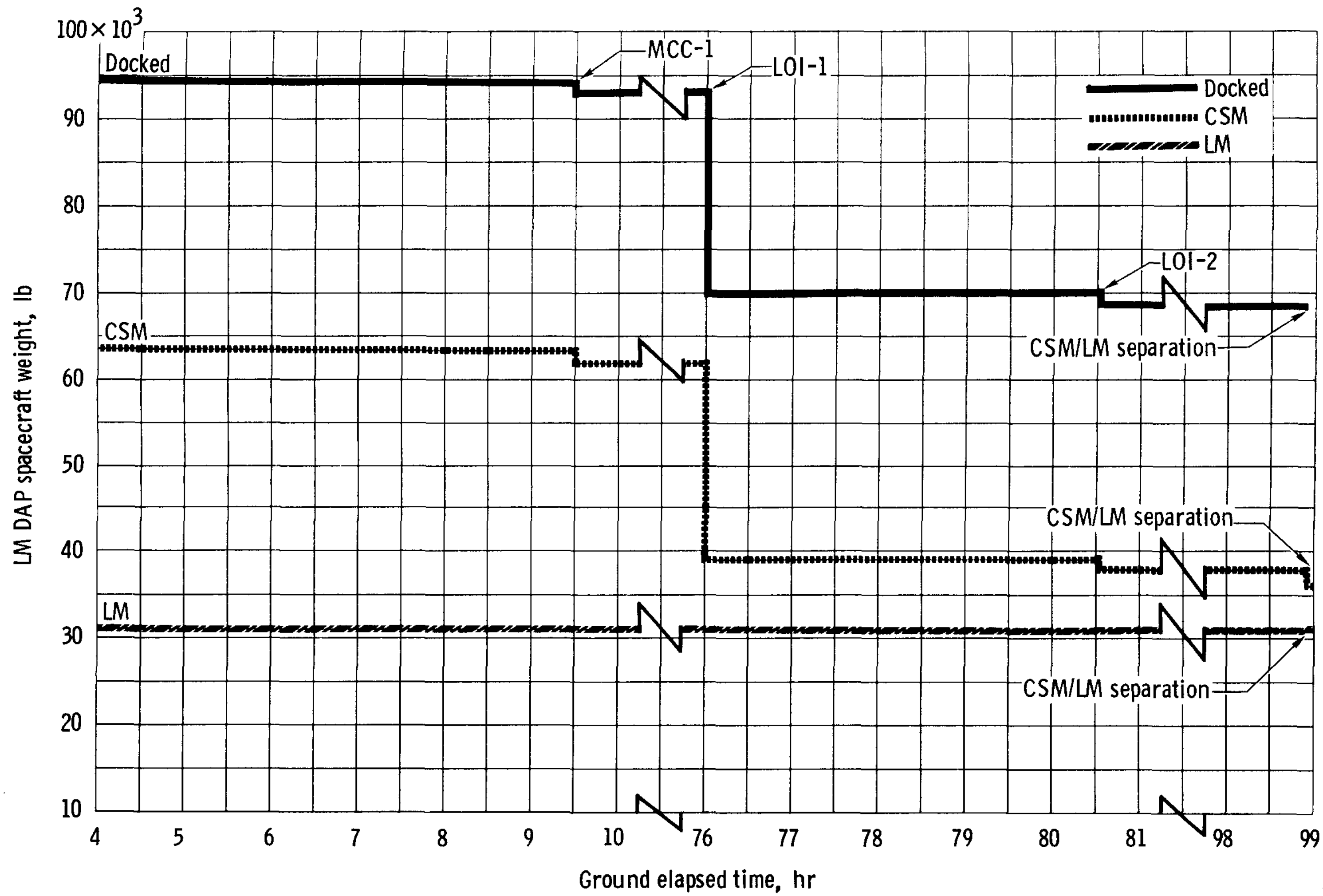


Figure 11-1. - Spacecraft weight versus ground elapsed time.

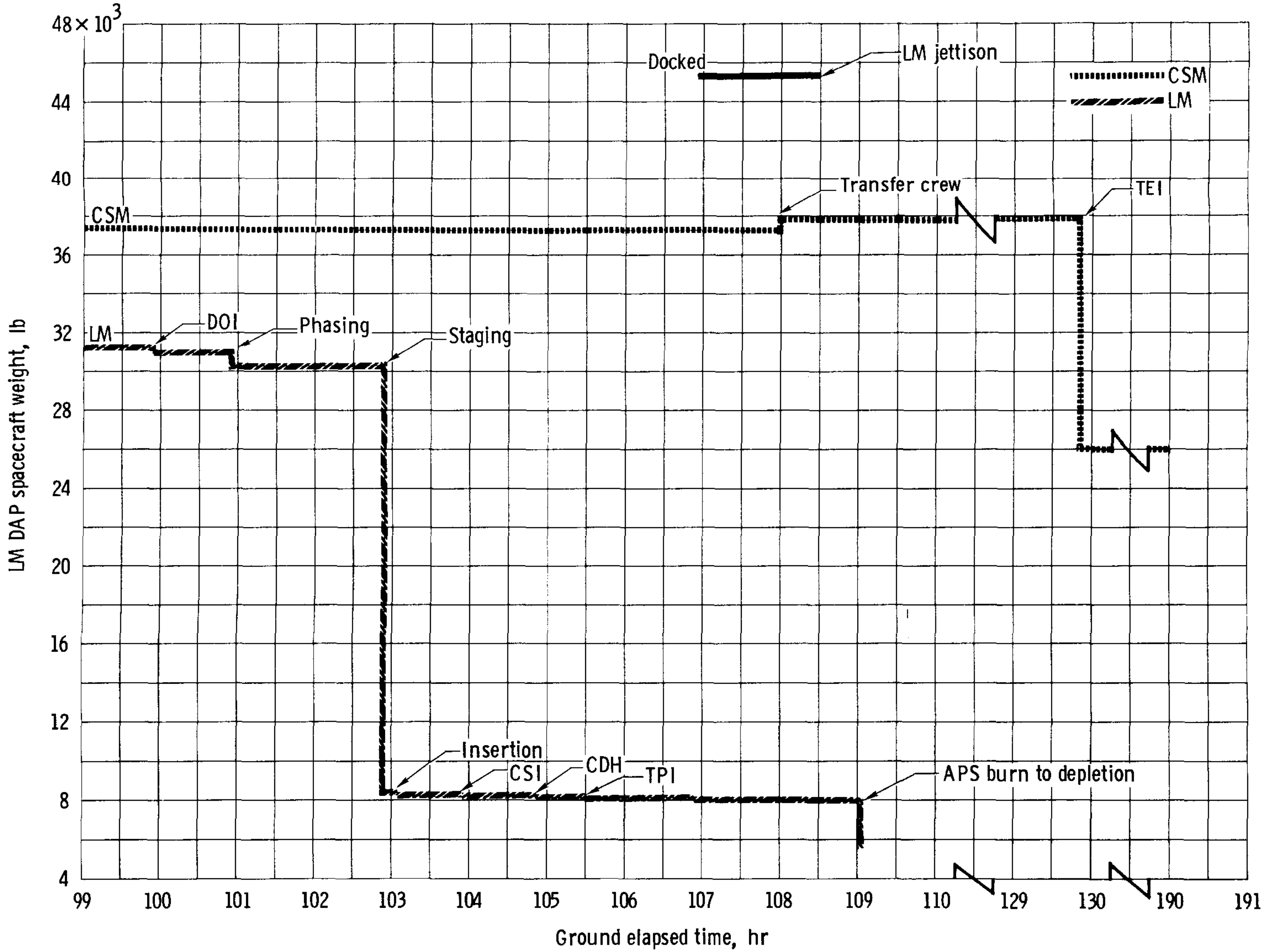


Figure 11-1.- Concluded.

12.0 REFERENCES

1. CSM/LM Spacecraft Operational Data Book, Volume I - CSM Data Book, Revision 1. MSC SNA-8-D-027, November 1968.

2. CSM/LM Spacecraft Operational Data Book, Volume II - LM Data Book. MSC SNA-8-D-027, June 1968.

3. CSM/LM Spacecraft Operational Data Book, Volume III - Mass Properties, Revision 1. MSC SNA-8-D-027, November 1968.

4. Anderson, W. M.: Preliminary Flight Plan Apollo 10 AS-505/CSM-106/LM-4. (Draft copy, February 14, 1969.)

5. Lunar Mission Design Section: Spacecraft Operational Trajectory for Apollo Mission F, Volume I - Operational Mission Profile Launched May 17, 1969. MSC IN 69-FM-65, March 26, 1969.

DISTRIBUTION D

AC Electronics
  Attn: S. Baron (1)
Bellcomm, Inc.
  Attn: V. Mummert (5)
Boeing Data Management HA-04 (1)
Boeing/Houston
  Attn: R. B. McMurdo (1)
Grumman Aircraft Eng. Corp.
  Attn: R. L. Pratt (12)
Grumman Aircraft Engineering Corp.
  Attn: J. Marino (4)
  Bethpage
Grumman Aircraft Engineering Corp.
  Attn: RASPO (1)
  Bethpage
General Electric/Houston
  Attn: W. M. Starr/743 (1)
IBM Houston/J. Bednarcyk (1)
IBM Houston/60E/J. H. Winters (1)
IBM-FSP
  Attn: G. K. Tomlin (1)
Link Group General Precision
  Attn: Director (2)
Massachusetts Institute of Technology
  Attn: N. Sears (1)
North American Rockwell Corp.
  Attn: RASPO (1)
North American Rockwell Corp.
  Attn: J. R. Potts/AB74 (10)
North American Rockwell Corp.
  Attn: G. Dimitruk/BB49 (1)
TRW/M. Barone (1)
TRW/Houston/B. J. Gordon (1)
TRW Houston/I. Zipper (1)
TRW Houston/M. M. Green (1)
TRW/J. Coffman (1)
TRW Houston/Library (4)
NASA/Goddard Spaceflight Center
  Attn: J. Shaughnessy/834 (1)
NASA/Goddard Spaceflight Center
  Attn: Dr. F. O. VonBun/550 (1)
John F. Kennedy Space Center - NASA
  Attn: Dr. A. H. Knothe, EX-SCI (1)
John F. Kennedy Space Center - NASA
  Attn: A. H. Moore/AP-SYS-1 (1)
John F. Kennedy Space Center - NASA
  Attn: R. D. McCafferty (4)
NASA/Marshall Space Flight Center
  Attn: A. McNair/1-MO-R (2)
NASA/Marshall Space Flight Center
  Attn: R. Barraza/I-V-F (1)

NASA/Marshall Space Flight Center
  Attn: T. J. McCullogh/I-VE (1)
NASA/Marshall Space Flight Center
  Attn: J. Cremin/R-AERO-DAP (1)
NASA/Marshall Space Flight Center
  Attn: C. Hagood/R-AERO-P (1)
NASA/Marshall Space Flight Center
  Attn: L. Stone/R-AERO-F (1)
NASA/Marshall Space Flight Center
  Attn: O. Hardage/R-AERO-M (1)
NASA/Marshall Space Flight Center
  Attn: J. McQueen/R-AERO-P (1)
NASA/Marshall Space Flight Center
  Attn: L. Thionnet/R-AERO-P (1)
NASA/Marshall Space Flight Center
  Attn: H. Hosenthien/R-ASTR-F (1)
NASA/Marshall Space Flight Center
  Attn: J. Kerr/R-ASTR-IR (1)
NASA/Marshall Space Flight Center
  Attn: F. Moore/R-ASTR-N (1)
NASA/Marshall Space Flight Center
  Attn: W. Chubb/R-ASTR-NG (1)
NASA/Marshall Space Flight Center
  Attn: S. Seltzer/R-ASTR-NG (3)
NASA/Marshall Space Flight Center
  Attn: J. Mack/R-ASTR-S (1)
NASA/Marshall Space Flight Center
  Attn: H. Ledford/R-SE-S (1)
NASA Headquarters
  Attn: Gen. Phillips (1)
NASA Headquarters
  Attn: Apollo Mission Director (1)
NASA Headquarters
  Attn: L. Abernathy (1)
NASA Headquarters
  Attn: J. T. McClanahan (1) (O.T. only)
NASA Headquarters
  Attn: Aller/MAO-4 (2)
NASA Headquarters
  Attn: Hickey/MAS-4 (1)
DDMS-TAG
  Patrick Air Force Base (1)
GNSO
  Patrick Air Force Base
  Attn: O. Thiele (1) (O. T. only)
AFETR/ETOOP-2
  Patrick Air Force Base (5)
AP/Public Info. Office (7) (O.T. only)
BM6/Technical Library (2)
BM86/Mission Data Package (15)
CA/D. K. Slayton (2)
CB/A. B. Shepard (5)
CF/W. J. North (1)
CF24/P. Kramer (1)
CF32/H. Kuehnell (1)
CF34/J. Oneill (1)

CF34/T. Holloway (1)
DA/H. R. Hair (1)
EB/P. H. Vavra (1)
ED3/M. T. Cunningham (1)
ED3/S. M. Keathly (1)
EE/G. Bills (1)
EE/R. W. Sawyer (1)
EG/Chief, G&CD (1)
EG21/M. Kayton (1)
EG23/C. F. Lively (1)
EG41/J. Hanaway (2)
EP/J. G. Thibodeau (1)
EP2/C. H. Lambert (1)
ES12/Project Support Office (1)
EW/C. C. Johnson (1)
EX2/B. Redd (1)
FA/C. C. Kraft, Jr. (1)
FA/R. G. Rose (1)
FC/E. F. Kranz (30)
FC4/Edlin (GAEC) (1)
FC6/C. B. Shelley (3)
FL/J. B. Hammack (1)
FL/H. Granger (2)
FM/J. P. Mayer (1)
FM/H. W. Tindall (1)
FM/C. R. Huss (1)
FM/D. H. Owen (1)
FM2/F. Bennett (1)
FM2/C. A. Graves (1)
FM2/J. Harpold (1)
FM3/C. Allen (4)
FM4/J. McPherson (1)
FM5/R. L. Berry (3)
FM6/E. Lineberry (1)
FM7/M. D. Cassetti (2)
FM8/J. Funk (1)
FM13/R. P. Parten (1)
FM13/G. Michos (1)
FM15/Editing (1)
FM13/M. A. Collins (2)
FM13/K. Henley (1)
FM15/Report Control Files (25)
FS/Dungan (5)
FS/L. Dunseith (10)
HA58/J. Pittman (TBC) (1)
HM23/D. W. Hackbert (1)
NA/W. M. Bland (1)
PD/R. J. Ward (1)
PD/A. Dennett (1)
PD/C. H. Perrine (1)
PD/L. Jenkins (1)
PD3/R. V. Battey (1)
PD7/M. Silver - NR (1)
PD7/R. Kohrs (1)
PD7/J. Mistrot (1)
PD9/J. W. Craig (1)

PT3/Test Division Document Library (3) (O.T. only)
PT4/J. Lobb (1)
SA/J. French (1)
TD4/Stephenson (1)
TE/Jackson (1)
TG/Dr. S. C. Freden (1)
ZR2/E. W. Ivy (2)