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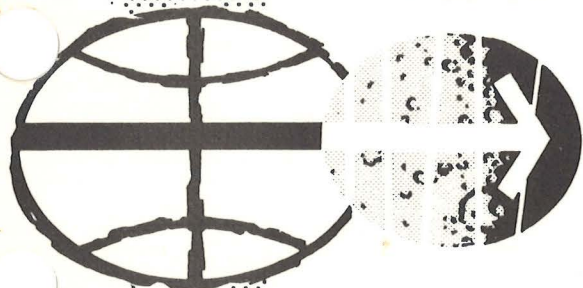
MSC INTERNAL NOTE NO. 70-FM-64

March 31, 1970

SPACECRAFT OPERATIONAL TRAJECTORY
FOR APOLLO 13 (MISSION H-2)
LAUNCHED APRIL 11, 1970
VOLUME II - TRAJECTORY PARAMETERS
REVISION 1

Lunar Mission Analysis Branch,
Orbital Mission Analysis Branch,
and
Landing Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION



MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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BOX 079-42/43-A

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PROJECT APOLLO

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(MISSION H-2) LAUNCHED APRIL 11, 1970
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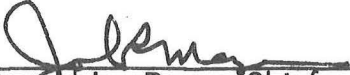
REVISION 1

By Lunar Mission Analysis Branch, Orbital Mission Analysis Branch,
and Landing Analysis Branch

March 31, 1970

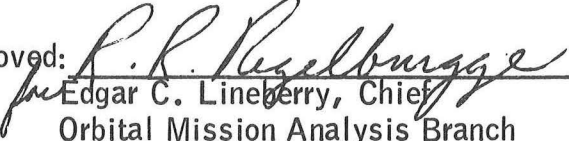
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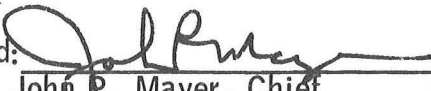
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FOREWORD

This document presents Revision 1 to Volume II of the Spacecraft Operational Trajectory for Apollo 13 (Mission H-2) launched April 11, 1970. Volume I will not be revised.

This volume presents an updated sequence of events table and the detailed trajectory parameters for the first launch opportunity, first injection opportunity on April 11, 1970. The revision was initiated because of the following changes.

1. The coordinates of the lunar landing site were changed from:

latitude	-3.617°
longitude	-17.55°
radius	937.6307 n. mi.

to

latitude	-3.6686°
longitude	-17.4842°
radius	937.735 n. mi.

2. A small change in the LM weight and the descent engine performance resulted in an update to the altitude and altitude-rate history for the descent and landing phase.

3. The coordinates of the photographic site, Davy crater chain, were changed from:

latitude	-10.866°
longitude	-6.0°

to

latitude	-10.95°
longitude	-6.10°

4. An ephemeris error appeared in the rendezvous phase for the previous Volume II of the operational trajectory document. This error affected the inertial state vectors and the G.m.t.'s.

5. Two earth entry guidance constants, LADPAD and LODPAD, have been changed to .30 and .18, respectively. The effect of these changes on the shape of the entry trajectory are slight.

TABLES

Table		Page
I	SEQUENCE OF MAJOR EVENTS	5
II	LAUNCH WINDOW SUMMARY	15
III	LUNAR LANDING AND PHOTOGRAPHY SITE POSITIONS	19
IV	SPACECRAFT WEIGHT SUMMARY	23
V	ENGINE PERFORMANCE SUMMARY	
	(a) Service module propulsion performance summary	27
	(b) Lunar module performance tabular inputs	28
VI	ASSUMED MISSION-INDEPENDENT EXPENDABLES	31
VII	MISSION RADAR TIMELINE	
	(a) MSFN station characteristics	35
	(b) Definitions of radar table headings	36
	(c) CSM acquisition and termination - 0° minimum elevation	37
	(d) CSM acquisition and termination - 5° minimum elevation	98
	(e) LM acquisition and termination - 0° minimum elevation	134
	(f) LM acquisition and termination - 5° minimum elevation	140
VIII	MISSION SHADOW TIMELINE	
	(a) CSM	149
	(b) LM	168
IX	SYMBOL DEFINITIONS AND COORDINATE SYSTEM DESCRIPTIONS	171
X	EARTH PARKING ORBIT	201

Table	Page	
XI	TRANSLUNAR COAST	
	(a) TLI cutoff to hybrid transfer midcourse maneuver	209
	(b) Hybrid transfer midcourse maneuver	236
	(c) Coast from hybrid transfer midcourse maneuver to LOI	242
XII	LUNAR ORBIT INSERTION	283
XIII	LUNAR ORBIT COAST IN 60- BY 170-NAUTICAL MILE ORBIT	297
XIV	DOI BURN	311
XV	LUNAR PARKING ORBIT TO UNDOCKING	319
XVI	CSM PARAMETERS - UNDOCKING AND SEPARATION TO LM LANDING	
	(a) Inertial selenocentric Cartesian coordinates (position and velocity)	357
	(b) Rotational selenographic polar coordinates (position and velocity vectors) and selenocentric osculating elements	364
XVII	LM PARAMETERS - UNDOCKING AND SEPARATION TO LM LANDING	
	(a) Inertial selenocentric Cartesian coordinates (position and velocity)	373
	(b) Inertial selenocentric ideal IMU coordinate system (PGNS navigated position and velocity)	380
	(c) Surface range, rotational selenographic polar coordinates (position and velocity vectors), and selenocentric osculating elements	387
	(d) Performance and weight	394
	(e) Descent propellant summary	398
	(f) Three-body relationships - LM referenced	402
	(g) Landing radar parameters	409
	(h) Powered landing guidance displays	413
	(i) Powered landing guidance coordinate system (time-to-go and position and velocity vectors) - LM	417
	(j) Horizon and FDAI angles	421

Table	Page
XVIII	LM/CSM PARAMETERS - UNDOCKING AND SEPARATION TO LM LANDING
	(a) Vehicle attitudes 431
	(b) Relative parameters 438
XIX	CSM LUNAR ORBIT COAST TO CSM PLANE CHANGE 1 447
XX	CSM LUNAR ORBIT PLANE CHANGE 1 MANEUVER 469
XXI	CSM LUNAR PARKING ORBIT COAST TO LM ASCENT
	(a) CSM coast to Censorinus 475
	(b) CSM coast to LM ascent 504
XXII	CSM PARAMETERS - ASCENT PHASE
	(a) Inertial selenocentric Cartesian (position and velocity) and polar coordinates 523
	(b) Rotational selenographic polar coordinates (position and velocity vectors) 526
	(c) Landing site coordinates 529
XXIII	LM PARAMETERS - ASCENT PHASE
	(a) Inertial selenocentric Cartesian (position and velocity) and polar coordinates 535
	(b) PGNS navigated position and velocity 538
	(c) Rotational selenographic polar coordinates (position and velocity vectors) 541
	(d) Rotational selenographic parameters - radial and tangential velocity component and altitude above landing site 544
	(e) Selenocentric osculating elements 547
	(f) Landing site coordinates 550
	(g) Performance and weight 553
	(h) Ascent propellant summary 556
	(i) Three-body relationships - LM referenced 559
	(j) PGNS ascent guidance parameters - local vertical coordinate system 562
	(k) Present position and V_{go} vector 565
	(l) Horizon and FDAI angles 568
	(m) Vehicle attitude and rates 571

TABLE	Page
XXIV	LM/CSM RELATIVE PARAMETERS - ASCENT PHASE 577
XXV	LM--ACTIVE RENDEZVOUS
	(a) Coast to rendezvous radar tracking prior to CSI 583
	(b) Rendezvous radar tracking prior to CSI 587
	(c) Coast to CSI 592
	(d) CSI burn 594
	(e) Coast to rendezvous radar tracking prior to TPI 596
	(f) Rendezvous radar tracking prior to TPI 598
	(g) Coast to TPI 610
	(h) TPI burn 615
	(i) Coast to first braking gate 617
	(j) Coast to second braking gate 625
	(k) First braking maneuver 627
	(l) Coast to third braking gate 630
	(m) Second braking maneuver 632
	(n) Coast to fourth braking gate 635
	(o) Third braking gate 637
	(p) Coast to fifth braking gate 640
	(q) Fourth braking maneuver 642
	(r) Stationkeeping to docking 645
XXVI	CSM/LM COAST TO LM JETTISON 649
XXVII	CSM SEPARATION AFTER LM JETTISON 659
XXVIII	LM ASCENT STAGE DEORBIT
	(a) LM coast to deorbit 665
	(b) LM deorbit burn 671
	(c) LM coast to impact 673
XXIX	CSM LUNAR ORBIT COAST TO CSM PLANE CHANGE 2 677
XXX	CSM LUNAR ORBIT PLANE CHANGE 2 MANEUVER 697
XXXI	LUNAR ORBIT COAST
	(a) CSM coast to Descartes 705
	(b) CSM coast to Davy Rille 714
	(c) CSM coast to TEI 715

Table	Page
XXXII	TEI BURN 735
XXXIII	TRANSEARTH COAST TO ENTRY 747
XXXIV	ENTRY
	(a) Position vector 821
	(b) Velocity vector 825
	(c) Position and velocity vector - earth centered inertial coordinate system 829
	(d) IMU gimbal angles 833
	(e) Aerodynamic altitudes and load factors 837
	(f) Direction cosines 841
	(g) Heating parameters 845
	(h) Aerodynamic and guidance parameters 849
A-I	FREE-RETURN CIRCUMLUNAR COAST
	(a) Translunar coast (no midcourse correction) . . . 857
	(b) Transearth coast (no midcourse correction) . . . 879
A-II	NON-FREE-RETURN TRANSEARTH COAST TO PERIGEE 917

SEQUENCE OF MAJOR EVENTS

LAUNCH WINDOW SUMMARY

LUNAR LANDING AND PHOTOGRAPHY
SITE POSITIONS

SPACECRAFT WEIGHT SUMMARY

ENGINE PERFORMANCE SUMMARY

ASSUMED MISSION-INDEPENDENT
EXPENDABLES

MISSION RADAR TIMELINE

MISSION SHADOW TIMELINE

SYMBOL DEFINITIONS AND
COORDINATE SYSTEM DESCRIPTIONS

EARTH PARKING ORBIT

TRANSLUNAR COAST

LUNAR ORBIT INSERTION

LUNAR ORBIT COAST IN 60- BY
170-NAUTICAL MILE ORBIT

DOI BURN

LUNAR PARKING ORBIT TO
UNDOCKING

SEQUENCE OF MAJOR EVENTS

TABLE I.- SEQUENCE OF MAJOR EVENTS

Event	Time, hr:min:sec, g.e.t.	Time, hr:min:sec, c.s.t.	Data summary
Launch	00:00:00	April 11, 1970 13:13:00	Azimuth, deg ~72 Launch complex 39A
EPO insertion	00:11:39.6	13:24:39.6	Geodetic latitude, deg 32.7 Longitude, deg -53.3 Geodetic altitude, n. mi. 103.3 Velocity, fps 25 567.7
Translunar injection Burn initiation	02:35:23.5	15:48:23.5	Geodetic latitude, deg -22.2 Longitude, deg 143.2 Velocity, fps 25 593.6 Apogee altitude, n. mi. 106.4 Geodetic altitude, n. mi. 98.9
Burn termination	02:40:49.0	15:53:49.0	Geodetic latitude, deg -9.7 Longitude, deg 166.1 Burn duration, sec 325.4 Plane change, deg .7 Apogee altitude, n. mi. 308 693. Geodetic altitude, n. mi. 164.0
Post-TLI events			
CSM/S-IVB separation	03:05:49.0	16:18:49.0	
Docking	03:15:49.0	16:28:49.0	
CSM/LM ejection	04:00:49.0	17:13:49.0	
Evasive maneuver (performed by S-IVB)	04:13:49.0	17:26:49.0	ΔV , fps 9.4
Translunar coast, midcourse correction maneuvers		April 12, 1970	
MCC-1	TLI plus 9 hr	00:53:49	Geodetic altitude, n. mi. ~57 000
MCC-2 (hybrid transfer) ^a	30:40:49.0	19:53:49	Geodetic altitude, n. mi. 121 437. ΔV , fps 14.7 Burn duration, sec 127.4 SM RCS propellant used, lb 164.4 Plane change, deg .1
MCC-3	LOI minus 22 hr	April 13, 1970 20:39:05.3	Geodetic altitude, n. mi. ~176 400
MCC-4	LOI minus 5 hr	April 14, 1970 13:39:05.3	Altitude above mean lunar radius, n. mi. ~12 400

^aMission rules state that if the first maneuver is less than 3 sec it will be performed by RCS; however, a decision has been made to perform this maneuver using SPS.

TABLE I.- SEQUENCE OF MAJOR EVENTS - Continued

Event	Time, hr:min:sec, g.e.t.	Time, hr:min:sec, c.s.t.	Data summary
Lunar orbit insertion (LOI) Burn initiation	77:26:05.3	18:39:05.3	Mass, lb 95 530.4 Altitude above LLS, n. mi. 69.2 Selenographic latitude, deg 2.4 Selenographic longitude, deg -169.9 Perilune altitude above LLS, n. mi. 58.0 Selenographic inclination, deg 5.9 Velocity, fps 8251.6
Burn termination	77:32:02.4	18:45:02.4	Altitude above LLS, n. mi. 60.1 Selenographic latitude, deg 4.2 Selenographic longitude, deg 166.6 Selenographic inclination, deg 5.4 Burn duration, sec 357.1 Inertial burn arc, deg 23.4 Plane change, deg .5 ΔV , fps 2821.3 SPS propellant used, lb 23 321.8 Velocity, fps 5480.4 Orbital period, hr:min:sec 02:08:41 Perilune altitude above LLS, n. mi. 58.9 Apolune altitude above LLS, n. mi. 170.1
S-IVB predicted lunar impact	77:48:32.0	19:01:32.0	Selenographic latitude, deg -3.0 Selenographic longitude, deg -30.0
Descent orbit insertion (DOI) Burn initiation	81:45:49.9	22:58:49.9	Mass, lb 72 154.0 Altitude above LLS, n. mi. 58.9 Selenographic latitude, deg 3.6 Selenographic longitude, deg 174.9 Perilune altitude above LLS, n. mi. 58.9 Apolune altitude above LLS, n. mi. 170.2 Velocity, fps 5486.5
Burn termination	81:46:12.7	22:59:12.7	Altitude above LLS, n. mi. 58.8 Selenographic latitude, deg 3.7 Selenographic longitude, deg 173.7 Selenographic inclination, deg 5.4 Burn duration, sec 22.8 Inertial burn arc, deg 1.2 Plane change, deg 0.0 ΔV , fps 210.5 Velocity, fps 5278.5 SPS propellant used, lb 1490.9 Orbital period, hr:min:sec 01:54:12.5 Perilune altitude above LLS, n. mi. 8.9 Apolune altitude above LLS, n. mi. 59.2
First pass over Censorinus	84:24:55.0	April 15, 1970 01:37:55.0	

TABLE I.- SEQUENCE OF MAJOR EVENTS - Continued

Event	Time, hr:min:sec, g.e.t.	Time, hr:min:sec, c.s.t.	Data summary
Descent CSM/LM undock and SEP	99:18:28.7	16:31:28.7	Revolution number 12
Circularization (CSM) Burn initiation	100:37:22.0	17:50:22.0	Mass, lb 36 592.1 Selenographic latitude, deg 1.2 Selenographic longitude, deg -166.2 Selenographic inclination, deg 5.4 Altitude above LLS, n. mi. 58.3 Perilune altitude above LLS, n. mi. 9.0 Velocity, fps 5297.9 Revolution number 12
Burn termination	100:37:25.9	17:50:25.9	ΔV , fps 70.3 Burn duration, sec 3.9 Altitude above LLS, n. mi. 58.3 Perilune altitude above LLS, n. mi. 54.3 Apolune altitude above LLS, n. mi. 63.6 Velocity, fps 5366.5 SPS propellant consumed, lb 254.8 Burn arc, deg 0.2 Period, hr:min:sec 01:58:37
PDI (DPS ignition time)	103:33:11.4	20:46:11.4	Altitude above LLS, ft 51 488 Velocity, fps 5573.8 Revolution number 14
High gate (P63 to P64)	103:41:43.4	20:54:43.4	Altitude above LLS, ft 7181 Velocity, fps 475.9
Low gate (500 ft)	103:43:21.4	20:56:21.4	Altitude above LLS, ft 592 Velocity, fps 72.3
Vertical descent (P64 to P65)	103:44:03.4	20:57:03.4	Altitude above LLS, ft 140 Velocity, fps 9.3
LM landing	103:44:36.2	20:57:36.2	ΔV , fps 6621.4 Burn duration, min:sec 11:24.8 DPS propellant consumed, lb 16 738.3 Revolution number 14
CSM first pass over LLS	103:45:13.6	20:58:13.6	Revolution number 14

TABLE I.- SEQUENCE OF MAJOR EVENTS - Continued

Event	Time, hr:min:sec, g.e.t.	Time, hr:min:sec, c.s.t.	Data summary
CSM plane change (LOPC-1)			
Burn initiation	113:46:02.7	April 16, 1970 06:59:02.7	Mass, lb 36 286.3 Selenographic latitude, deg -5.0 Selenographic longitude, deg -48.1 Altitude above LLS, n. mi. 56.2 Perilune altitude above LLS, n. mi. 55.7 Apolune altitude above LLS, n. mi. 61.7 Velocity, fps 5360.6 Revolution number 19
Burn termination	113:46:12.6	06:59:12.6	Mass, lb 35 639.1 ΔV , fps 181.4 Burn duration, sec 10.0 Selenographic latitude, deg -5.0 Selenographic longitude, deg -48.6 Altitude above LLS, n. mi. 56.2 Perilune altitude above LLS, n. mi. 55.7 Apolune altitude above LLS, n. mi. 61.7 Plane change, deg 1.9 Selenographic inclination, deg 5.0 Velocity, fps 5360.1 Revolution number 19
Second pass over Censorinus	129:04:59.6	22:17:59.6	Revolution number 27
CSM second pass over LLS	137:14:05.1	April 17, 1970 06:27:05.1	Revolution number 31
Ascent			
LM lift-off	137:15:22.5	06:28:22.5	Mass, lb 10 774.9 Selenographic latitude, deg -3.7 Selenographic longitude, deg -17.5 Revolution number 31
LM insertion	137:22:32.4	06:35:32.4	Mass, lb 5843.1 ΔV , fps 6042.8 Burn duration, sec 430 Latitude, deg -4.2 Longitude, deg -27.5 Altitude above LLS, ft 59 957.0 Perilune altitude above LLS, ft 52 944.4 Apolune altitude above LLS, ft 266 267.9

TABLE I.- SEQUENCE OF MAJOR EVENTS - Continued

Event	Time, hr:min:sec, g.e.t.	Time, hr:min:sec, c.s.t.	Data summary
Rendezvous			
CSI	138:12:10.1	07:25:10.1	Revolution number 32 Burn duration, sec 44.7 ΔV , fps 49.5 Propellant used, lb 31.9 Resultant h_a/h_p , n. mi. 44.9/43.2 Range at cutoff, n. mi. 149.0 Range rate at cutoff, fps -121.4 Propulsion system LM RCS
CDH	139:10:28.9	08:23:28.9	Burn duration, sec 0.0 ΔV , fps 0.0
TPI	139:51:44.6	09:04:44.6	Burn duration, sec 22.4 ΔV , fps 25.0 Propellant used, lb 16.0 Resultant h_a/h_p , n. mi. 60.7/43.6 Range at cutoff, n. mi. 32.0 Range rate at cutoff, fps -132.6 Propulsion system LM RCS Revolution number 32
Braking	140:33:05.0	09:46:05.0	Burn duration, sec 27.9 ΔV , fps 31.1 Propellant used, lb 19.9 Range at final braking, n. mi. 0.01 Range rate at final braking, fps -0.2 h_a/h_p at final braking, n. mi. 59.4/58.0 Propulsion system LM RCS Revolution number 33
Docking	140:50:00.0	10:03:00.0	
LM jettison	143:10:59.8	12:23:59.8	Selenographic latitude, deg -3.9 Selenographic longitude, deg -24.8
CSM/LM separation			
Burn initiation	143:15:58.4	12:28:58.4	
Burn termination	143:16:04.5	12:29:04.5	Mass, lb 35 766.8 ΔV , fps 1.0 Burn duration, sec 6.1 Selenographic latitude, deg -4.6 Selenographic longitude, deg -40.3 Altitude above LLS, n. mi. 59.4 Perilune altitude above LLS, n. mi. 57.2 Apolune altitude above LLS, n. mi. 59.5 Plane change, deg 0.0 Selenographic inclination, deg 5.0 Velocity, fps 5342.7 Revolution number 34

TABLE I.- SEQUENCE OF MAJOR EVENTS - Continued

Event	Time, hr:min:sec, g.e.t.	Time, hr:min:sec, c.s.t.	Data summary
LM deorbit	144:39:12.6	13:52:12.6	Mass, lb 5329.1 ΔV, fps 185.5 Burn duration, sec 78.5 Selenographic latitude, deg 3.2 Selenographic longitude, deg 66.3
LM impact	144:55:31.1	14:08:31.1	Mass, lb 5220.8 Selenographic latitude, deg -3.0 Selenographic longitude, deg -19.7 Velocity, fps 5503.9 CSM latitude, deg -0.7 CSM longitude, deg 17.8 CSM revolution number 35
LOPC-2			
Burn initiation	154:21:19.6	23:34:19.6	
Burn termination	154:22:02.8	23:35:02.8	Mass, lb 32 892.9 ΔV, fps 827.6 Burn duration, sec 43.2 Selenographic latitude, deg 4.4 Selenographic longitude, deg 89.7 Altitude above LLS, n. mi. 55.5 Perilune altitude above LLS, n. mi. 55.4 Apolune altitude above LLS, n. mi. 60.8 Plane change, deg 8.8 Selenographic inclination, deg 11.6 Velocity, fps 5363.2 Revolution number 40
Pass over Descartes	158:42:43.9	April 18, 1970 03:55:43.9	Revolution number 42
Pass over Davy crater chain	158:49:46.0	04:02:46.0	Revolution number 42
Transearth injection			
Burn initiation	167:38:39.1	12:51:39.1	Mass, lb 32 824.2 Altitude above LLS, n. mi. 57.8 Selenographic latitude, deg 9.9 Selenographic longitude, deg -177.7 Perilune altitude above LLS, n. mi. 54.4 Selenographic inclination, deg 11.5 Velocity, fps 5351.2 Revolution number 46

TABLE I.- SEQUENCE OF EVENTS - Concluded

Event	Time, hr:min:sec, g.e.t.	Time, hr:min:sec, c.s.t.	Data summary
Burn termination	167:40:53.8	12:53:53.8	Altitude above LLS, n. mi. 63.2 Selenographic latitude, deg 11.4 Selenographic longitude, deg 173.8 Perilune altitude above LLS, n. mi. 56.3 Selenographic inclination, deg 17.8 Burn duration, sec 134.7 Inertial burn arc, deg 8.5 Plane change, deg 9.3 ΔV , fps 3143.9 SFS propellant used, lb 8794.8 Velocity, fps 8270.6
Transearch coast, midcourse correction maneuvers			
MCC-5	TEI plus 15 hr	April 19, 1970 03:53:53.8	Geodetic altitude, n. mi. ~186 600
MCC-6	EI minus 22 hr	April 20, 1970 16:02:49.6	Geodetic altitude, n. mi. ~104 000
MCC-7	EI minus 3 hr	April 21, 1970 11:02:49.6	Geodetic altitude, n. mi. ~2560
Entry interface	240:49:49.6	14:02:49.6	Transearch coast time, hr 73.1 Inertial velocity, fps 36 129.4 Geodetic altitude, n. mi. (ft) 65.8(400 249) Inertial flight-path angle, deg -6.5 Geodetic latitude, deg -15.1 Longitude, deg -173.5 Equatorial inclination (ascending), deg 40.
CM landing	241:03:40.8	14:16:40.8	Geodetic latitude, deg -1.575 Longitude, deg -157.497

LAUNCH WINDOW SUMMARY

TABLE II.- LAUNCH WINDOW SUMMARY

Launch date	April 11, 1970
Site	Fra Mauro
Launch azimuth, deg	72 to 96
Launch time, hr:min, c.s.t.	13:13 to 16:36
Free-return h_p , n. mi.	210 to 60
Hybrid transfer ΔV , fps	14.7
Translunar flight time, hr:min	74:45
Lunar orbit inclination, deg	5.3
Approach azimuth at landing, deg	-93.9
Sun elevation at landing, deg	9.9 to 11.4
Goldstone landing coverage, hr:min,	7:15
Goldstone plus Parks landing coverage, hr:min	10:10
Lunar surface staytime, hr	~34
Photo sites	Censorinus Davy crater chain Descartes
Total lunar orbit staytime	90 hr, 46 revs
Transearch flight time, hr	73 to 71
Total mission time, hr.	241 to 238

LUNAR LANDING AND PHOTOGRAPHY
SITE POSITIONS

TABLE III.- LUNAR LANDING AND PHOTOGRAPHY SITE POSITIONS

Launch date	Lunar site name	Latitude, deg	Longitude, deg	Altitude, ^a n. mi.
April 11	Fra Mauro	-3.6686	-17.4842	-0.76
Photography sites				
April 11	Censorinus	-.147	32.408	-1.24
April 11	Descartes	-8.85	15.567	2.11
April 11	Davy crater chain	-10.95	-6.10	-1.45

^aAll altitudes shown are referenced to mean lunar radius of 938.4935 n. mi.

SPACECRAFT WEIGHT SUMMARY

TABLE IV.- SPACECRAFT WEIGHT SUMMARY

Total CSM inert lb	23 105.6
CM inert, lb	12 473.2
SM inert, lb	10 534.4
SLA ring, lb	98.0
Total SPS propellant tanked, lb	40 593.7
SPS deliverable, lb	40 354.6
SPS trapped, lb	239.1
Total LM at earth launch, lb	33 493.0
LM descent stage, lb	4 661.0
LM DPS tanked, lb	18 339.2
LM ascent stage + RCS propellant, lb	5 263.6
LM APS tanked, lb	5 229.2
Spacecraft at earth launch (including LES), lb	110 097.0
Spacecraft before T & D	101 091.9

ENGINE PERFORMANCE SUMMARY

TABLE V.- ENGINE PERFORMANCE SUMMARY

(a) Service module propulsion performance summary

Propulsion system	I_{sp} , sec	Thrust, lb	Flow rate, lb/sec
SPS	313.3	20 460.	65.30
RCS ^a	263.58	181.87	0.69

^aTwo-quad.

TABLE V.- ENGINE PERFORMANCE SUMMARY - Concluded

(b) Lunar module performance tabular inputs

Descent				Ascent		
DPS		RCS		APS + RCS		
Thrust, lb	I _{sp} , sec	Thrust per engine, lb	I _{sp} , sec	Burn time, sec	Effective thrust, lb	Effective I _{sp} , sec
1328	294.6	89.6	281.0	0	3581.5	308.8
2835	295.5			40	3569.5	309.1
3391	296.6			80	3556.9	309.3
5905	301.9			120	3544.4	309.4
6302	303.1			160	3532.0	309.4
9858	304.0			200	3520.1	309.4
9917	301.8			240	3508.7	309.3
				280	3497.8	309.3
				320	3487.2	309.2
				360	3482.9	309.2
				400	3485.5	309.1
				429.9	3488.1	309.0

ASSUMED MISSION-INDEPENDENT
EXPENDABLES

TABLE VI.- ASSUMED MISSION-INDEPENDENT EXPENDABLES

Mission-independent SPS budget	
Translunar MCC (120 fps), lb	1130
Transearch MCC (Ofps), lb	0
SPS propellant allowances	
Unbalance meter, lb	100
Mean outage, lb	59
Dispersions, lb	426