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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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
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PROJECT APOLLO

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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.

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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 Launch complex	~72 39A
EPO insertion	00:11:39.6	13:24:39.6	Geodetic latitude, deg Longitude, deg Geodetic altitude, n. mi. Velocity, fps	32.7 -53.3 103.3 25 567.7
Translunar injection Burn initiation	02:35:23.5	15:48:23.5	Geodetic latitude, deg Longitude, deg Velocity, fps Apogee altitude, n. mi. Geodetic altitude, n. mi.	-22.2 143.2 25 593.6 106.4 98.9
Burn termination	02:40:49.0	15:53:49.0	Geodetic latitude, deg Longitude, deg Burn duration, sec Plane change, deg Apogee altitude, n. mi. Geodetic altitude, n. mi.	-9.7 166.1 325.4 .7 308 693. 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 MCC-1	TLI plus 9 hr	April 12, 1970 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. ΔV, fps Burn duration, sec SM RCS propellant used, lb Plane change, deg	121 437. 14.7 127.4 164.4 .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

[a]Mission 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 Selenographic latitude, deg Selenographic longitude, deg Altitude above LLS, n. mi. Perilune altitude above LLS, n. mi. Apolune altitude above LLS, n. mi. Velocity, fps Revolution number	36 286.3 -5.0 -48.1 56.2 55.7 61.7 5360.6 19
Burn termination	113:46:12.6	06:59:12.6	Mass, lb ΔV, fps Burn duration, sec Selenographic latitude, deg Selenographic longitude, deg Altitude above LLS, n. mi. Perilune altitude above LLS, n. mi. Apolune altitude above LLS, n. mi. Plane change, deg Selenographic inclination, deg Velocity, fps Revolution number	35 639.1 181.4 10.0 -5.0 -48.6 56.2 55.7 61.7 1.9 5.0 5360.1 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 Selenographic latitude, deg Selenographic longitude, deg Revolution number	10 774.9 -3.7 -17.5 31
LM insertion	137:22:32.4	06:35:32.4	Mass, lb ΔV, fps Burn duration, sec Latitude, deg Longitude, deg Altitude above LLS, ft Perilune altitude above LLS, ft Apolune altitude above LLS, ft	5843.1 6042.8 430 -4.2 -27.5 59 957.0 52 944.4 266 267.9

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
			SPS propellant used, lb	8794.8
			Velocity, fps	8270.6
Transearth 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	Transearth 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
Transearth 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

[a]All 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

[a]Two-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
Transearth MCC (0fps), lb	0
SPS propellant allowances	
Unbalance meter, lb	100
Mean outage, lb	59
Dispersions, lb	426