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

B71 02038

SUBJECT: SPS Optimized Missions to Copernicus and Descartes during the J2 (3,4,5/72) and J3 (12/72, 1,2/73) Mission Time Frames - Case 310

DATE: February 22, 1971

FROM: R. J. Stern

ABSTRACT

The end-of-mission ΔV reserves for lunar missions to Copernicus and Descartes during the J2, J3 time frames (Apollo 16, 17) are optimized with respect to LM approach azimuth and sun elevation angle at landing. Results are presented for a short and a one-day-longer mission duration for both one and two days of post LM ascent orbital science. Reasonable values of approach azimuth common to all launch opportunities within a given three-month time frame are determined. These values are: -97° (Copernicus, J2), -95° (Copernicus, J3), -91° (Descartes, J2) and -84° (Descartes, J3).

It is found that day longer missions are feasible in all cases for both one and two days orbital science. Low end-of-mission ΔV reserves are encountered for some short missions, in particular Copernicus (J2). The launch opportunities within each time frame can be chosen so that the launch vehicle sigma capability is greater than two for all missions with optimum sun elevation angles.

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MEMORANDUM FOR FILE

Introduction

Current mission planning requires at least one launch opportunity for the nominal launch month and at least three launch opportunities during the two succeeding months. These launch opportunities are designated as nominal day (T_o), one day later launch (T+24) and one day earlier launch (T-24). In addition, a common LM approach azimuth must be selected for all launch opportunities during the given time frame. The current launch schedule fixes the J2 (Apollo 16) and J3 (Apollo 17) mission time frames at 3,4,5/1972 and 12/1972, 1,2/1973, respectively. The most probable sites for these missions are Descartes and Copernicus.

As a first step in the selection of mission parameters it is useful to optimize the end-of-mission ΔV reserve with respect to landing azimuth and sun elevation. An end-of-mission ΔV reserve of 500 ft/sec is considered desirable for a feasible mission whereas a minimum value of 250 ft/sec can be tolerated. With the determination of the optimum mission reserve ΔV, potential "difficult" or unfeasible missions can be determined and the tradeoffs that will have to be made in the selection of a common approach azimuth become evident. For the results presented here the end-of-mission ΔV was optimized with respect to approach azimuth and sun elevation subject to a DPS abort constraint and sun elevation limits of 5-25°. Twenty-five degrees is an estimate of the upper sun elevation limit based on the adoption of a steep LM descent profile. The mission designations and the more prominent ground rules are presented in Table I.

Results

The optimized results are presented in Tables II-V. In addition to the optimized value of approach azimuth, sun elevation angle and end-of-mission ΔV reserve, the launch vehicle sigma (σ) capability level corresponding to the optimized mission is presented. Launch vehicle capability is

defined using a 2σ baseline capability of 107,600 lbs for the J2 launch vehicle and 106,700 lbs for the J3 launch vehicle (derived from Reference 1). The contributions to payload capability from temperature and wind effects, FGR (230 lbs), mission specific energy and change in minimum launch azimuth from 72° to 80° (570 lbs, Reference 2) are added to the baseline figure. The result is then converted to a sigma capability corresponding to the injection of a control weight spacecraft by means of the factors 1.095 lbs payload per lb S-IVB propellant (Reference 3) and 1100* lbs S-IVB propellant per sigma level.

Based on the results in Tables II-V an estimate of the required landing azimuth for each time frame may be made. These values are presented in Table VI.

TABLE IV

ESTIMATE OF APPROACH AZIMUTH

Site	Approach Azimuth
Copernicus	
J2 time frame	-97°
J3 time frame	-95°
Descartes	
J2 time frame	-91°
J3 time frame	-84°

The above estimates of approach azimuth were made with the object of providing as much flexibility as possible with regard to science and mission duration. A general summary of the results in Tables II-V followed by comments on a mission specific basis is presented below.

Summary

- The day longer missions for both one and two days orbital science appear feasible in all cases.

*Based on AS-509 Flight Performance Reserve analysis.

- Since available LM rescue ΔV and end-of-mission ΔV are approximately equal it can be seen from the ΔV data pertaining to longer missions that the LM rescue requirement of 600 ft per sec can generally be satisfied for longer transearth flight times.

- The launch schedule can be chosen so that the sigma capability level is greater than two for all optimized cases. The effect of varying approach azimuth has negligible effect on launch vehicle capability. The reduction of the sun elevation from its optimum value would result in a higher translunar energy and a decrease in launch vehicle sigma capability.

- Short missions generally optimize at lower sun elevation angles (higher translunar energy) than longer missions. This is a result of the high TEI ΔV cost for short missions. Reducing the sun elevation at landing results in an earlier time of arrival at the moon and an earlier time of TEI for fixed science duration. Since earth landing times are determined primarily by the earth's rotation and are therefore relatively fixed, the net result is an increase in the transearth time of flight and a reduction in TEI ΔV cost.

Mission Specific Results

Descartes (J2)

- Short missions for both one and two day science appear feasible with some cases near the minimum required end-of-mission ΔV (250 ft/sec).

Descartes (J3)

- Three nominal launch opportunities are available for first launch month (12/7,8,9/72). Of these 12/8/72 appears to be the most advantageous as 12/7/72 is a borderline case for short missions.

- Short missions appear feasible for one and two day science.

- Four launch days are available in January 1972. This is indicated by the presence of two launch sequences, 1/5,6,7/73 and 1/6,7,8/73. It should be noted, however, that launch vehicle requirements for 1/8/73 are more stringent.

Copernicus (J2)

- Short missions for one and two days science are not feasible for the first month launches (3/20,21/72) and for the nominal launch day in the second month (4/18/72).

- Short missions for the launch opportunities 4/17/72, 4/19/72 have end-of-mission ΔV's above 250 ft/sec, however, these may fall below for a non-optimum approach azimuth. The remaining short mission opportunities (third month) appear feasible.

Copernicus (J3)

- Short missions for one and two days orbital science appear generally feasible with the possible exception of 2/8/73, 2/9/73.

R. J. Stern

2013-RJS-slr R. J. Stern

Attachments

REFERENCES

1. "J Mission Performance Status," R. E. Beaman, December 15, 1970.

2. Caldwell, S. F., and K. E. Martersteck, "Optimization of Launch Azimuth Range to Adjust Launch Window Duration and Improve Launch Vehicle Performance Margin," Bellcomm Memorandum for File B70 12065, Case 310, December 23, 1970.

3. "Saturn V Performance Study for AS 511-515," Memorandum S&E-AERO-MFT-76-70, Boeing Company, June 2, 1970.

TABLE I

MISSION DESIGNATIONS AND GROUND RULES

One Day Orbital Science

Short Mission	Duration between 11-12 days (T_o, T+24 launches) Duration between 12-13 days (T-24 launch)
One Day Longer Mission	Duration between 12-13 days (T_o, T+24 launches) Duration between 13-14 days (T-24 launch)

Two Days Orbital Science

Short Mission	Duration between 12-13 days (T_o, T+24 launches) Duration between 13-14 days (T-24 launch)
One Day Longer Mission	Duration between 13-14 days (T_o, T+24 launches) Duration between 14-15 days (T-24 launch)

Launch Azimuth = 80°

Pacific Injections

Time in LPO from LOI to PDI $\cong$ 24 Hrs. for T_o, T+24 Launch
$\cong$ 48 Hrs. for T-24 Launch

Approach Azimuth Optimized for each Mission

Sun Elevation Optimized Between 5°-25°

Stay Time 67-68 Hrs.

Transearth Flight Time Between 50 and 120 Hrs.

Maximum Return Inclination = 70°

End-of-Mission ΔV Reserve Based on Control Weight Spacecraft

TABLE II

OPTIMIZED MISSION PARAMETERS (Descartes, One Day Orbital Science)

Descartes	Landing Azimuth (deg)	Sun Elevation Angle (deg)	End-Of-Mission ΔV Reserve (ft/sec)	Mission Duration (days)	Launch Vehicle Sigma Capability*	Landing Azimuth (deg)	Sun Elevation Angle (deg)	End-Of-Mission ΔV Reserve (ft/sec)	Mission Duration (days)	Launch Vehicle Sigma Capability*
	Short Mission					One Day Longer				
J2 Mission										
3/17/72 T_o	-88.8	5.0	512	11.3	2.95	-90.9	9.9	1103	12.3	3.21
3/18/72 T+24	-90.5	17.4	423	11.3	2.83	-91.8	22.3	1058	12.3	3.16
4/15/72 T-24	-92.9	10.2	376	12.3	2.99	-92.9	14.2	993	13.3	3.24
4/16/72 T_o	-89.4	10.4	444	11.3	2.89	-92.0	15.8	1095	12.3	3.24
4/17/72 T+24	-89.0	23.0	465	11.3	2.84	-89.0	25.0	1126	12.3	3.00
5/14/72 T-24	-92.1	5.1	429	12.3	3.22	-93.2	8.8	1062	13.3	3.42
5/15/72 T_o	-88.5	5.0	536	11.3	3.10	-89.7	9.0	1219	12.3	3.37
5/16/72 T+24	-87.1	17.0	611	11.3	2.99	-88.2	21.7	1308	12.3	3.32
J3 Mission										
12/7/72 T_o	-82.9	5.0	250	11.3	2.52	-82.9	6.9	980	12.3	2.59
12/8/72 T+24	-83.4	12.8	473	11.3	2.32	-83.6	19.3	990	12.3	2.62
12/9/72 T+48	-85.3	25.0	519	11.3	2.36	-85.2	25.0	859	12.3	2.36
1/5/73 T-24	-86.8	5.0	626	12.3	2.30	-86.6	11.3	1127	13.3	2.57
1/6/73 T_o	-86.7	5.1	557	11.3	2.30	-86.5	11.9	1098	12.3	2.60
1/7/73 T+24	-87.0	17.5	616	11.3	2.34	-87.0	24.1	1170	12.3	2.63
2/4/73 T-24	-87.0	9.2	636	12.3	2.32	-87.0	15.1	1185	13.3	2.59
2/5/73 T_o	-87.1	9.4	633	11.3	2.32	-87.0	15.1	1199	12.3	2.59
2/6/73 T+24	-87.2	21.3	593	11.3	2.30	-87.1	25.0	1129	12.3	2.50
**1/6/73 T-24	-87.0	17.1	659	12.3	2.31	-87.0	23.6	1179	13.3	2.60
1/7/73 T_o	-87.9	17.5	616	11.3	2.34	-87.0	24.1	1170	12.3	2.63
1/8/73 T+24	-87.0	25.0	443	11.3	1.97	-87.0	25.0	651	12.3	1.97

*Defined for Control Weight Spacecraft (Injected Weight = 107,350 lbs). Includes payload contributions from temperature and wind, FGR, energy, and minimum launch azimuth of 80°. Payload weight is converted to sigma capability using a factor of 1205 lbs/σ

**Alternate sequence.

TABLE III

OPTIMIZED MISSION PARAMETERS (Descartes, Two Days Orbital Science)

Descartes	Landing Azimuth (deg)	Sun Elevation Angle (deg)	End-Of-Mission ΔV Reserve (ft/sec)	Mission Duration (days)	Launch Vehicle Sigma Capability*	Landing Azimuth (deg)	Sun Elevation Angle (deg)	End-Of-Mission ΔV Reserve (ft/sec)	Mission Duration (days)	Launch Vehicle Sigma Capability*
	Short Mission					One Day Longer				
J2 Mission										
3/17/72 T_o	-88.9	5.0	566	12.3	2.95	-90.0	9.4	1139	13.1	3.21
3/18/72 T+24	-89.7	17.3	494	12.3	2.86	-90.1	21.4	1089	13.1	3.12
4/15/72 T-24	-92.9	10.5	447	13.3	3.01	-92.5	14.3	1018	14.1	3.30
4/16/72 T_o	-89.4	10.6	530	12.3	2.91	-89.5	14.6	1133	13.1	3.19
4/17/72 T+24	-87.1	23.4	565	12.3	2.87	-89.0	25.0	1164	13.2	3.00
5/14/72 T-24	-93.2	5.1	494	13.3	3.22	-92.5	8.7	1091	14.2	3.44
5/15/72 T_o	-88.0	5.0	651	12.3	3.10	-88.5	8.6	1263	13.2	3.34
5/16/72 T+24	-87.1	17.3	728	12.3	3.03	-87.1	21.4	1356	13.2	3.30
J3 Mission										
12/7/72 T_o	-82.9	5.0	336	12.3	2.52	-82.9	7.2	986	13.3	2.59
12/8/72 T+24	-83.6	13.1	507	12.3	2.34	-84.5	19.7	998	13.3	2.60
12/9/72 T+48	-85.2	25.0	541	12.3	2.36	-85.1	25.0	857	13.3	2.36
1/5/73 T-24	-86.7	5.0	658	13.3	2.30	-87.0	11.5	1142	14.3	2.58
1/6/73 T_o	-86.6	5.4	589	12.3	2.32	-86.4	11.9	1111	13.3	2.60
1/7/73 T+24	-87.0	17.8	647	12.3	2.36	-87.0	24.4	1187	13.3	2.64
2/4/73 T-24	-87.0	9.4	677	13.3	2.34	-87.0	15.2	1214	14.3	2.61
2/5/73 T_o	-87.0	9.7	675	12.3	2.34	-87.0	15.3	1227	13.2	2.59
2/6/73 T+24	-87.1	21.5	639	12.3	2.31	-87.3	25.0	1159	13.2	2.50
**1/6/73 T-24	-87.0	17.4	688	13.3	2.33	-87.0	23.8	1195	14.3	2.62
1/7/73 T_o	-87.0	17.8	647	12.3	2.36	-87.0	24.4	1187	13.3	2.64
1/8/73 T+24	-87.0	25.0	461	12.3	1.97	-87.0	25.0	659	13.3	1.97

*Defined for Control Weight Spacecraft (Injected Weight = 107,350 lbs). Includes payload contributions from temperature and wind, FGR, energy, and minimum launch azimuth of 80°. Payload weight is converted to sigma capability using a factor of 1205 lbs/σ.

**Alternate sequence.

TABLE IV

OPTIMIZED MISSION PARAMETERS (Copernicus, One Day Orbital Science)

Copernicus	Landing Azimuth (deg)	Sun Elevation Angle (deg)	End-Of-Mission ΔV Reserve (ft/sec)	Mission Duration (days)	Launch Vehicle Sigma Capability*	Landing Azimuth (deg)	Sun Elevation Angle (deg)	End-Of-Mission ΔV Reserve (ft/sec)	Mission Duration (days)	Launch Vehicle Sigma Capability*
	Short Mission					One Day Longer				
J2 Mission										
3/20/72 T_o	-100.5	10.6	9	11.1	2.91	-100.5	15.0	860	12.1	3.15
3/21/72 T+24	-101.2	22.8	57	11.1	2.86	-101.2	25.0	810	12.1	2.99
4/17/72 T-24	-97.5	5.0	333	12.1	3.13	-97.5	8.2	1145	13.2	3.28
4/18/72 T_o	-98.3	5.0	142	11.1	3.05	-98.3	9.3	1016	12.2	3.26
4/19/72 T+24	-97.4	16.0	266	11.1	2.91	-97.5	23.0	1123	12.2	3.26
5/17/72 T-24	-93.4	9.4	651	12.2	3.11	-93.4	15.8	1421	13.2	3.44
5/18/72 T_o	-93.4	9.6	551	11.2	3.05	-93.4	16.9	1355	12.2	3.44
5/19/72 T+24	-93.3	22.1	673	11.2	3.05	-93.3	25.0	1373	12.3	3.24
J3 Mission										
12/10/72 T_o	-93.2	5.0	485	11.2	2.55	-93.2	5.0	826	12.2	2.55
12/11/72 T+24	-93.2	15.0	598	11.2	2.47	-93.2	18.7	885	12.2	2.66
1/8/73 T-24	-93.2	6.9	581	12.2	2.35	-93.2	10.5	840	13.2	2.55
1/9/73 T_o	-93.2	8.9	610	11.2	2.48	-93.2	13.2	1074	12.2	2.66
1/10/73 T+24	-93.3	21.6	513	11.1	2.53	-93.3	24.5	1025	12.1	2.65
2/7/73 T-24	-93.9	13.4	569	12.2	2.42	-94.0	17.0	1120	13.1	2.59
2/8/73 T_o	-97.5	13.8	359	11.1	2.42	-97.5	16.8	959	12.1	2.57
2/9/73 T+24	-98.8	25.0	277	11.1	2.35	-98.8	25.0	702	12.1	2.35

*Defined for Control Weight Spacecraft (Injected Weight = 107,350 lbs). Includes payload contributions from temperature and wind, FGR, energy, and minimum launch azimuth of 80°. Payload weight is converted to sigma capability using a factor of 1205 lbs/σ.

TABLE V

OPTIMIZED MISSION PARAMETERS (Copernicus, Two Days Orbital Science)

Copernicus	Landing Azimuth (deg)	Sun Elevation Angle (deg)	End-Of-Mission ΔV Reserve (ft/sec)	Mission Duration (days)	Launch Vehicle Sigma Capability*	Landing Azimuth (deg)	Sun Elevation Angle (deg)	End-Of-Mission ΔV Reserve (ft/sec)	Mission Duration (days)	Launch Vehicle Sigma Capability*
	Short Mission					One Day Longer				
J2 Mission										
3/20/72 T_o	-100.4	10.9	40	12.1	2.93	-100.5	15.0	868	13.1	3.15
3/21/72 T+24	-101.2	23.2	104	12.1	2.88	-100.5	25.0	825	13.2	2.99
4/17/72 T-24	-97.5	5.0	385	13.2	3.13	-97.7	8.2	1161	14.2	3.28
4/18/72 T_o	-98.3	5.0	198	12.2	3.04	-98.3	9.3	1035	13.2	3.26
4/19/72 T+24	-97.5	16.5	322	12.2	2.94	-97.6	22.5	1150	13.2	3.26
5/17/72 T-24	-93.4	9.8	710	13.3	3.14	-93.4	15.8	1477	14.3	3.44
5/18/72 T_o	-93.4	10.1	612	12.3	3.09	-93.4	16.9	1388	13.3	3.44
5/19/72 T+24	-93.3	22.5	742	12.3	3.09	-93.3	25.0	1393	13.3	3.24
J3 Mission										
12/10/72 T_o	-93.2	5.0	430	12.3	2.55	-93.2	5.1	710	13.3	2.55
12/11/72 T+24	-93.2	15.2	508	12.2	2.48	-93.2	18.7	776	13.3	2.66
1/8/73 T-24	-93.2	7.1	464	13.3	2.36	-93.2	10.4	763	14.3	2.55
1/9/73 T_o	-93.2	9.2	520	12.2	2.49	-93.2	13.2	977	13.2	2.66
1/10/73 T+24	-93.4	21.6	440	12.2	2.52	-93.4	24.5	945	13.2	2.66
2/7/73 T-24	-93.9	13.5	512	13.2	2.43	-93.2	16.9	1066	14.2	2.58
2/8/73 T_o	-97.6	13.9	326	12.1	2.43	-97.6	16.9	928	13.1	2.57
2/9/73 T+24	-98.8	25.0	257	12.1	2.35	-98.8	25.0	685	13.1	2.35

*Defined for Control Weight Spacecraft (Injected Weight = 107,350 lbs). Includes payload contributions from temperature and wind, FGR, energy, and minimum launch azimuth of 80°. Payload weight is converted to sigma capability using a factor of 1205 lbs/σ.

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