NASA TECHNICAL MEMORANDUM

NASA TM X-53651

August 31, 1968

111.4

NASA TM X-53651

MANNED PLANETARY FLYBY MISSIONS (BASED ON SATURN/APOLLO SYSTEMS) EXECUTIVE SUMMARY REPORT

By B. G. Noblitt

NASA

George C. Marshall Space Flight Center Huntsville, Alabama

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ABSTRACT

This report summarizes a study (by North American Aviation, Space Division) of Manned Interplanetary Flyby Missions to Venus and Mars during the period from 1975 to 1982. [The study was a broad but penetrating technical investigation of using a manned flight system for planetary exploration.] The results, along with previously known aspects of manned Mars and Venus flyby missions, vehicles, and systems, were integrated into total mission-system capable of performing a realistic and meaningful planetary exploration program.

Manned Planetary Missions are feasible. Attractive multiplanet flyby missions can be performed by Saturn/Apollo systems. However, injected payload and mission requirements developed within the guidelines and assumptions of this study cannot be met with modified S-II or S-IVB stages when used with the standard Saturn V Earth-launch vehicle.

When using an Earth orbit assembly mode and an uprated Saturn Earth-launch vehicle for application to manned planetary flyby missions, the launch vehicle should have a payload capability (2-stage to low Earth orbit) of 400,000 pounds or more for use with M(S)-IVB planetary injection stages.

Manned planetary flyby missions provide a means of combining the favorable aspects of both manned and unmanned missions into a unique and highly effective planetary exploration mission-system capable of providing

major significant inputs to the scientific and engineering questions concerning the interplanetary medium, our Sun, and our neighboring planets Venus and Mars.

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RESEARCH AND DEVELOPMENT OPERATIONS

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MANNED PLANETARY FLYBY MISSIONS (BASED ON SATURN/APOLLO SYSTEMS), EXECUTIVE SUMMARY REPORT

SUMMARY

Manned planetary missions can be performed by Saturn/Apollo systems. Injected payload and mission requirements developed within the guidelines and assumptions of this study, however, cannot be met with modified S-II or S-IVB stages when used with the standard Saturn V Earth-launch vehicle. An Earth orbit assembly mode of an uprated Saturn Earth-launch vehicle for application to manned planetary flyby missions should have payload capability (2-stage to low Earth orbit) of 400 000 pounds or more for use with M(S)-IVC planetary injection stages.

Manned planetary flyby missions provide a means of combining the favorable aspects of both manned and unmanned missions into a unique and highly effective planetary exploration mission-system capable of providing major significant inputs to the scientific and engineering questions concerning the interplanetary medium, our sun, and our neighboring planets Venus and Mars.

INTRODUCTION

Manned flyby missions to Mars and Venus have been studied for a number of years by NASA both under contract and in-house. The early studies were concerned with establishing gross mission requirements and vehicle capabilities. Initially, flyby missions were considered incidental to more ambitious missions.

As additional studies of manned planetary missions were performed it became evident that the technology, systems, and hardware developments necessary to conduct ambitious missions such as a manned Mars landing would require significant extensions beyond the Apollo capability. Attention was then focused upon manned planetary flyby missions, and studies were conducted to define mission requirements and develop preliminary system concepts. Objectives for planetary exploration were established by the in-house study, Planetary Joint Action Group, which was begun in 1966. The following paragraphs illustrate the chronology of the major studies oriented toward manned planetary flyby missions.

In early 1962, contracts were awarded through MSFC to Lockheed Aircraft Company, Ford Aeronutronic, and General Dynamics/Convair to perform a study entitled "Early Manned Planetary-Interplanetary Roundtrip Expedition" (EMPIRE). These studies were primarily concerned with total vehicle and systems requirements for orbiting and flyby missions, and therefore considered a broad range of vehicle-systems capabilities.

A 9-month follow-on effort, beginning in June 1963, was awarded to Lockheed Missiles and Space Company by MSFC to continue their investigation of manned Mars and Venus flyby missions in the early 1970's. This study, Early Manned Planetary Flyby Mission Study (contract NAS8-5024), concentrated on the use of available Saturn/Apollo hardware. This beneficial study was somewhat hampered by some narrow assumptions, i. e., that missions would not be later than 1975, and that launches would be limited to two Saturn V's.

In 1964, MSFC conducted an in-house study "Manned Planetary Reconnaissance Mission-Venus/Mars Flyby." The "how to" of accomplishing a Mars and Venus flyby mission in terms of vehicles and systems was the focal point of this study. The last half of 1970 was considered a more feasible time for the mission.

In mid-1964 MSC awarded a contract to North American Aviation for "Manned Mars and/or Venus Flyby Vehicle Systems Study" (contract NAS9-3499). Here again, the "how to" of performing flyby missions was primary.

An OMSF-sponsored intercenter study of manned planetary missions was begun in the spring of 1966. The study, known as the Planetary Joint Action Group (JAG), was conducted by personnel from the OMSF centers (KSC, MSC, MSFC) and OMSF Headquarters. The group interfaced with OSSA to plan for an integrated planetary exploration program. The study was heavily oriented towards flyby missions but capture missions were also considered.

Using contributions from the various centers, vehicles and systems capable of performing Mars and Venus flyby missions were studied and integrated into a total manned interplanetary spaceflight system, and efforts were also begun to establish mission objectives. This study considered only a few of the many alternatives associated with the various aspects of manned planetary flyby missions, but it served as a valuable aid in guiding later study efforts. The results of this study were documented in August 1966.

A follow-on Planetary JAG exercise was conducted in early 1967 to provide additional study of many problem areas identified earlier. The follow-on exercise served as a valuable guide in conducting the concurrent contracted study effort.

The studies produced very useful and meaningful results, but additional indepth study was required to establish the desirability and feasibility of manned planetary flyby missions. Specifically, NASA desired that the following major areas should be emphasized:

1. Thoroughly assess the missions and systems requirements in terms of modification to Saturn/Apollo hardware and systems;

2. Determine the utility and capability of a manned spaceflight system to acquire the necessary data to meet the scientific and engineering objectives of planetary exploration;

3. Examine the many mission-vehicle-systems alternatives applicable to a manned planetary flyby mission program;

4. Integrate all known aspects of Mars and Venus flyby missions into a total systems-mission program, including estimated cost and schedules.

To provide analyses of the above mentioned areas, the following three contract studies were issued through MSFC during August and September of 1966.

1. A 7-month $100K study entitled "Feasibility of Modifying the S-II Stage as an Injection Stage for Manned Planetary Flyby Missions" (Contract NAS8-18031), North American Aviation;

2. A 7-month $100K study entitiled "Feasibility of Modifying the S-IVB Stage as an Injection Stage for Manned Planetary Flyby Missions" (Contract NAS8-18032), Douglas Aircraft Company;

3. The study "Manned Planetary Flyby Missions Based on Saturn/Apollo Systems" (Contract NAS8-18025), which was a 12-month $400K, open bid contracted study awarded to North American Aviation, Space Division, on August 3, 1966, is summarized in this report. Details of this study are documented in the following final report: "Study of Manned Planetary Flyby Missions Based on Saturn/Apollo Systems" (U), North American Aviation, Space Division, Report No. SID 67-549, Vol 1-9, August 1967.

SCOPE AND OBJECTIVES

This study covered the definition of Mars and Venus flyby mission objectives and requirements and the assessment of these requirements in terms of the Saturn/Apollo systems capabilities. This included vehicles, systems, operations, utility, experiments, possible development schedules, and estimated costs.

The objectives of this study were as follows:

1. Integrate known aspects of the manned Mars and Venus flyby missions into a total mission systems analysis that defined, insofar as possible, the vehicles, systems, operations, development schedules, and estimated costs to perform the missions with modified Saturn/Apollo hardware;

2. Examine and compare the many mission-system-vehicle alternatives and combinations applicable to manned planetary flyby missions which could evolve into a planetary flyby program;

3. Determine the capability and utility of manned flyby missions to significantly enhance man's knowledge of our solar system;

4. Define all aspects of the scientific and engineering data gathering program that could be carried out by a manned flyby system;

5. Provide data for guidance and direction to such efforts as the Apollo Application Program through the definition of experiment requirements, the Advanced Research and Technology Program through the specification of areas requiring attention, and the total program of manned space flight and planetary exploration.

ASSUMPTIONS

The nature and scope of this study required that guidelines be provided to establish bounds for missions, vehicles, systems and operations. Although most of these guidelines could be provided at the initiation of the study, additional assumptions and guidelines were made during the course of the study in regard to certain operational questions as their requirements became more clearly defined. Initial guidelines were established as follows:

1. Missions. Mars and Venus flyby missions to be during the 1975 - 1982 time period;

2. Earth Launch Vehicles. Saturn V and uprated Saturn V to be studied. Determine most desirable Earth orbital payload capability for uprated Saturn V for assembly of flyby spacecraft;

3. Orbit Launch Stage. Consider modified S-II and S-IVB stages as defined by concurrent studies [1, 2]. Compare orbit launch vehicles (such as nuclear and advanced propulsion). Use previous study results of orbital tanker studies;

4. Systems.

   a. Spacecraft. Require maximum use of Saturn/Apollo hardware and previous study results. Where new development is required assume a 1970 state-of-the-art;

   b. Propulsion. Consider only chemical propulsion for spacecraft;

   c. Crew. Use previous study results and current study objectives to determine crew size requirements.

5. Operations.

   a. Earth Orbital. Assume no orbital launch facility, but identify possible advantages to be gained by such a facility;

   b. Gravity Environment. Consider spacecraft configurations for both simulated and zero gravity;

c. Earth Entry. Consider full aerodynamic braking and retro-braking to 40 000 ft/sec;

d. Environmental Models. Conform to specifications by NASA;

e. Probability of Mission Success. Assume adequate weight and performance margins and operational choices to give high probability to mission success.

METHOD OF APPROACH

The nature of this study necessitated that certain basic data such as mission requirements, performance capabilities, operation requirements, etc., be established before the assessment of vehicle and systems capabilities. This was especially true with regard to the two concurrent studies [1, 2]. Therefore, a phased study approach was taken. A study plan was developed which was divided into four 3-month phases as follows:

1. Phase I. Mission and system requirements were developed, subsystems performance was defined, and major design influencing factors were identified. Mission and system operational requirements were provided for the concurrent orbit launch vehicle studies;

2. Phase II. Concepts of experiment systems, spacecraft, subsystems, launch scheduling, and facility utilization were developed.

3. Phase III. Alternative experiments, probes, spacecraft, and Earth and orbital launch vehicles were integrated into total systems concepts. Performance, schedules, and estimated costs were developed for each alternative.

4. Phase IV. By comparing the alternatives developed in Phase III (on the basis of performance, schedules, and cost) a total flight system was selected, and a mission plan, funding, and technology requirements were developed.

Many areas that were covered in this study had either not been studied or were not studied to the desired technical depth for integration into the current study. Airesearch was awarded a subcontract by North American Aviation to perform a study of environmental control and life support systems during the current study effort. To assist in the study of the scientific and engineering data gathering aspects of manned flyby missions (probe configurations, physical, functional and operational interfaces) the Space Systems Division of AVCO was awarded a subcontract by North American Aviation. In addition, the AVCO subcontract also provided support in defining requirements and qualification of the heat shield for the Earth entry module at hyperbolic velocities. A consultant panel consisting of six scientists was retained by North American Aviation to assist their staff scientists in reviewing and establishing objectives, investigations, and experiments to meet the goals of planetary exploration. Although many types of data can be shown in parametric form, cost and schedule data must be tied to specific configurations. Therefore, cost and schedule data for Uprated Saturn V launch vehicles were obtained from Reference 3. Launch facilities data for the Improved Saturn Vehicles were obtained from Reference 4.

A major integration effort was required to incorporate the results of previous and concurrent studies into this study effort. Several iterations and data exchanges were required between this study and the concurrent studies as more refined mission, systems, and operational requirements were defined and subsequently assessed against vehicle and system capabilities.

BASIC DATA GENERATED

1. A complete mission description was generated for Mars Twilight, Venus Lightside, and Multiplant Flyby Missions. This description included impulsive injection velocity requirements from Earth orbit for mission windows and injection windows of specified widths and impulsive velocity requirements for post transplanetary injection abort. Encounter conditions at each planet were defined in terms of passage dates, distances, velocities, and passage plane orientations. Interplanetary maneuvering requirements for midcourse corrections and major powered maneuvers (required for some multiplanet missions) were also defined. Table I contains a summary of the mission characteristics. Additional details are contained in report SID 67-549-3.

2. A computer program was developed to calculate the impulsive velocity requirements (orbit launch window) caused by the effects of Earth oblateness as a function of time, initial Earth orbit plane orientation, and outgoing hyperbolic excess velocity conditions.

3. Transplanetary injection performance data for the various Earth launch vehicle-orbit launch vehicle combinations were calculated for all missions and these capabilities assessed against the mission requirements. Tables II

TABLE I. MISSION CHARACTERISTICS SUMMARY

		Earth Departure			Venus Encounter		Mars Encounter		Earth Return	
Mission	Duration (days)	Launch Date	Injection ΔV (km/sec)	Abort ΔV (km/sec)	V_∞ (km/sec)	ΔV (km/sec)	V_∞ (km/sec)	ΔV (km/sec)	Entry Veloc (km/sec)	Retro** ΔV (km/sec)
Venus Lightside										
1975	375	May 23 Jun 22	4.33	0.94	5.56				13.40	1.55
1977	376	Dec 28 Jan 27	4.55	0.88	5.13				13.50	1.71
1978	377	Jul 31 Aug 30	4.52	0.85	5.83				13.18	1.23
1980	378	Mar 15 Apr 14	4.69	1.03	5.91				13.71	1.98
1981	372	Oct 28 Nov 27	4.69	1.01	5.35				13.55	1.74
Perihelion Accel 1974	400	Nov 19 Dec 9	5.24*	2.54			6.26		16.06	4.88
Mars Twilight										
1975	690	Sep 6 Oct 6	4.97	2.43			8.47		14.65	3.14
1977	695	Oct 10 Nov 9	4.87	2.24			9.19		14.30	2.67
1979	700	Nov 13 Dec 13	4.93	2.13			10.50		14.30	2.67
1982	690	Dec 18 Jan 21	5.24	2.16			12.01		14.20	2.55
Dual-Planet (Pwr)										
1976	727	Oct 22 Nov 4	5.22	2.82	7.11		4.66	0.183	16.66	5.67
1978	481	Nov 11 Dec 11	5.03	1.83	10.70		7.28	1.30	17.88	7.30
1982	577	Dec 2 Jan 11	4.70	1.06	12.82		8.24	1.31	14.51	2.94
Dual-Planet										
1978	654	Nov 28 Dec 28	5.15	2.03	11.05		6.03		15.50	4.19
Triple-Planet (Pwr)										
1977	679	Feb 11 Mar 3	5.22	2.79	6.75 (8.42)	0.183	5.53		13.78	1.98

Pwr - Power maneuver required at one of the target planets to effect a flyby encounter.

* A maximum propulsive maneuver of 2.52 kmps is performed at or near perihelion of the Earth-to-Mars transfer trajectory.
Earth departure injection ΔV included 3% performance reserve and guarantees a 6-day induction window.

** ΔV required to reduce the maximum entry velocity to 12.19 km/sec with end of burn occurring 15 minutes from entry interface (400 000 - foot altitude)

TABLE II. INJECTED PAYLOAD WEIGHT - S-IIB INJECTION MODE

	Saturn V[1] (1000 lb)				Product Improved Saturn V[2] (1000 lb)			Saturn V-4 (S) B[3] (1000 lb)		Saturn V-25 (S)[4] (1000 lb)	
Mission	1 TK**	2 TK	3 TK	4 TK	1TK	2 TK	3 TK	1TK	2 TK	1 TK	2 TK
Mars Twilight											
1975		135	235	264	98	206	333	145	279	230	411
1977		146	247	278	104	216	346	151	290	240	424
1979		139	240	268	100	210	337	146	282	233	415
1982		107	201	225	80	181	296	124	252	202	375
Venus Lightside											
1975	90	204	320		143	274		200		310	
1977	76	180	290		126	243		179		280	
1978	77	183	294		129	293		181		285	
1980	65	164	270		115	233		165		260	
1981	65	164	270		115	233		165		260	
Perihelion Acceleration											
1974		107	201	225	80	181	296	124	252	202	375
Dual-Planet, Powered											
1976		110	204	229	81	184	300	125	255	205	378
1978		130	229	255	94	200	325	140	273	233	402
Dual-Planet, Unpowered											
1978		117	213	237	85	190	309	131	261	211	387
(1978)		(92)	(183)	(202)	(70)	(170)	(275)	(113)	(240)	(190)	(355)
Triple-Planet Flyby											
1977		110	204	229	81	184	300	125	255	205	378

[1] 275 000 lb in 185-km orbit [2] 327 000 lb in 185-km orbit [3] 380 000 lb in 185-km orbit [4] 494 000 lb in 185-km orbit
** Number of tankers used to refuel S-IIB stage in parking orbit.
Six-day injection window (488-km departure orbit)

and III contain payload injection capabilities of the S-IIB and S-IVC orbit launch vehicles with the candidate Earth launch vehicles. Report number SID-67-549-4 contains additional details.

4. Detailed spacecraft system weight statements reflecting the design and weight influencing mission,and operational factors were established for all missions. A spacecraft system weight statement for representative missions is contained in Table IV. More detailed weight data for all missions are contained in Report SID 67-549-5-3.

5. Spacecraft design concepts were studied with the capability of artificial gravity simulation but which would not create major weight penalties should artificial gravity not be required.

6. Earth launch scheduling and orbital operations timelines were established for each Earth/orbit launch vehicle combination and for each mission under consideration. The timelines established the launch sequence and Earth orbit staytime of each component of the flyby spacecraft system. A realistic rendezvous and assembly mode providing a high degree of operational flexibility was developed and used for the assembly of the multilaunch payloads.

7. Crew timeline analyses were performed for the planetary encounter phase of the missions to establish crew size requirements. The timelines defined the crew functions for probe launchings, probe operations, tracking, navigation experiments, telecommunications and data management. The crew functions were then superimposed on the normal housekeeping timelines to establish the time requirements for each individual crew member and subsequently the crew size requirements. Table V is a schedule of crew functions during a 24-hour period before planetary encounter.

8. Investigations to support scientific and engineering objectives, which were then defined in terms of experiments, sensors, support equipment and operations, were determined for Venus and Mars as well as the interplanetary medium. A list of equipment and instrumentation for all experiments carried on each probe was generated. Probe complements were defined for each mission. Table VI contains a listing of scientific objectives of planetary exploration.

9. Using the modular approach for each major spacecraft hardware element, and considering the desirability of making maximum use of Saturn/Apollo hardware, preliminary design concepts were conceived for a mission module, propulsion module, Earth entry module, and probe compartment.

TABLE III. INJECTED PAYLOAD WEIGHT - S-IVC* INJECTION MODE NO TRANSTAGE, 30-DAY CONFIGURATION

	Saturn V[1] (1000 lb)			Product Improved Saturn V[2] (1000 lb)			Saturn V-4(S)B[3] (1000 lb)			Saturn V-25(S)[4] (1000 lb)	
Mission	2** Stages	3** Stages	4** Stages	2 Stages	3 Stages	4 Stages	2 Stages	3 Stages	4 Stages	2 Stages	3 Stages
Mars Twilight											
1975	111	158	190	159	235	303	201	300	385	272	398
1977	116	166	200	166	244	314	210	312	397	277	414
1979	113	161	193	161	239	306	204	304	389	275	404
1982	96	138	162	140	211	275	178	266	350	244	354
Venus Lightside											
1975	146	208	256	208	298		261			344	
1977	135	191	234	191	277		240			319	
1978	136	194	237	192	280		242			322	
1980	126	180	218	179	261		225			302	
1981	126	180	218	179	261		225			302	
Perihelion Acceleration											
1974	96	138	162	140	211	275	178	266	350	244	354
Dual-Planet, Powered											
1976	97	139	164	140	213	278	180	270	354	242	359
1978	117	154	185	155	230	297	196	293	377	266	390
Dual-Planet, Unpowered											
1978	101	145	171	146	220	284	186	278	361	253	369
(1978)	(88)	(126)	(146)	(120)	(196)	(259)	(165)	(247)	(330)	(227)	(330)
Triple-Planet, Flyby											
1977	97	138	164	140	213	278	180	270	354	242	359

[1]275 000 lb in 185-km orbit [2]325 000 lb in 185-km orbit [3]380 000 lb in 185-km orbit [4]494 000 lb in 185-km orbit

* OLV designation S-IVB/C when used with Saturn V launch vehicle.

Six-day injection windows (488-km departure orbit)

** Number of S-IVC stages in tandem to perform earth escape maneuver from parking orbit. S-IVC stages are rendezvoused and assemblied in parking orbit.

TABLE IV. SPACECRAFT SYSTEM WEIGHT

	MISSION			
	1976 Dual	1977 Triple	1978 Dual	1977 Venus
LAUNCH ESCAPE SYSTEM	11 060	9390	10 250	9310
EARTH ENTRY MODULE AT LAUNCH	19 110	15 250	17 250	15 070
-Abort	18 110	14 250	16 250	14 077
Structure & Heat Shield	(12 260)	(8400)	(10 400)	(8220)
Systems	(5170)	(5170)	(5170)	(6170)
Protective Cover	(1000)	(1000)	(1000)	(1000)
Crew	(680)	(680)	(680)	(680)
PROPULSION MODULE AT LAUNCH	78 190	71 750	57 710	32 180
Structure	(6500)	(6500)	(6500)	(5840)
Systems	(8500)	(8500)	(8500)	(7960)
Propellant, Total	(63 190)	(56 750)	(42 710)	(18 380)
MISSION MODULE	93 040	93 840	93 040	74 030
Structure	(24 410)	(24 410)	(24 410)	(24 030)
Guidance & Navigation	(110)	(110)	(110)	(110)
Communications & Data	(2330)	(2330)	(2330)	(2330)
Stabilization & Control	(1200)	(1200)	(1200)	(1200)
Electrical Power	(13 490)	(13 490)	(13 490)	(12 980)
Personnel Accommodations	(2900)	(2900)	(2900)	(2900)
Environmental Control & Life Support	(13 950)	(14 350)	(13 950)	(11 560)
Atmosphere Supply System	(29 080)	(29 480)	(29 080)	(16 320)
Scientific Payload	(5570)	(5570)	(5570)	(4600)
PROBE COMPARTMENT	65 040	63 580	93 500	25 640
Structure	(19 660)	(18 310)	(27 600)	(6450)
Systems	(2350)	(2350)	(2350)	(1200)
Probes	(43 030)	(42 920)	(63 550)	(17 990)
GROSS EARTH LAUNCH WEIGHT	265 440	253 810	271 750	156 230
RENDEZVOUS WEIGHT	254 380	244 500	261 500	146 920
INJECTED WEIGHT	242 380	232 890	249 170	139 990

TABLE V. SCHEDULING (PER MAN PER 24 HOURS)

Function	Duration	Schedule	Remarks
Sleep	6 hours and 1.5 hours	8 hours ±2 hours between 6 and 1.5 hour period	Should sacrifice 1.5 hour nap only as last resort
Eat	Hot meal - 30 minutes Cold snack or light hot meal - 30 minutes	Cold snack or light hot meals - after 6 hours sleep period. Two hot meals per day as convenient, not less than 4 hours apart.	
Personal hygiene and defecation	30 minutes	After sleep periods	Can be reduced by 10 minutes to meet exigencies.
Exercise			Contained in physiological and performance check (PPC) function
PPC	Total: 1.5 hours	15 minutes before 6 hours sleep; 15 minutes after 6 hours sleep	Recording and blood and urine samples before and/or after sleep
		45 minutes before 1.5 hours sleep	30 minutes exercise, 15 minutes recording
		15 minutes as convenient	Checklist & behavioral type tasks
Urination	5 minutes each	As required	
Drinking	2 minutes each	As required	
Navigation sighting	40 minutes with IMU coarse and fine alignment 30 minutes with IMU fine alignment only. 20 minutes without IMU fine alighment. 10 minutes without navigation station set up.	One sighting every 5 to 6 hours for -10 to -5 days. One sighting per hour for -4 to -3 days. Three sightings per hour for -2 days to -32 hours. Four sightings per hour for -32 hours to -6 hours.	Assumed that navigation station will have spacecraft altitude control, controls and displays
IMU alignment	10-minute station setup 10-minute coarse alignment 10-minute fine alignment	One coarse and fine IMU alignment every 12 hours and before MCC	
Midcourse correction (MCC) ΔV	60 minutes	-20 hours	
Post ΔV align SCS	30 minutes	-19 hours	
Probe launch Soft landers (2)	48 minutes (2) (30 minute concurrent warmup and 8-minute checkout and launch per probe)	-120 hours	
Orbiter (1)	38 minutes (30-minute warmup and 8-minute checkout and launch)	-19 hours	
MSSR (1)	38 minutes (30-minute warmup and 8-minute checkout and launch)	-118 hours	
Atmospheric probes 1, 2, 3	54 minutes (30-minute concurrent warmup and 8-minute checkout and launch per probe)	-18.8 hours	
Probe tracking (all probes except hard landers)	1 minute in each 10 minutes until MCC	Continuous	Atmospheric probes require tracking, MCC, or inflight systems check
Probe telephoto (all probes except hard landers)	90 minutes first time; 30 minutes thereafter	One each 12 hours and one at -5 hours.	Includes measuring angles from photos and inserting angles into computer. All probes in one photo.
Inflight probe systems check (all probes except hard landers)	10 minutes every 6 hours per probe until -7 hours	Concurrent with probe tracking	
Probe MCC (all probes except hard landers) Softlanders Orbiter MSSR		 -7, -8 hours -7 hours -6 hours	MM computer computes MCC parameters from range and rate and angle data and instructs probe to make MCC. Special monitoring of MSSR and orbiter MCC is desirable.
Probe data handling (all probes)	Continuous	-4 hours to + 10 days	Time sharing with spacecraft systems monitoring after +5 days
Spacecraft sybsystems monitoring and management	Flexible	Varies	Approximate scheduling, can be adapted to exigencies
MSSR (retriever) launch and docking Launch Rendezvous and dock	 - 2 minutes	 -16 minutes +20 minutes	
Telescope Photography (others to be resolved)	20 minutes	Every 3 hours from -42 hours to -3 hours	

TABLE VI. PLANETARY EXPLORATION SCIENTIFIC OBJECTIVES

1.	Is there life on the planets (other than Earth)? What is the chemistry of this life? What has been the evolutionary sequence of life forms? What is past environment from which life evolved?
2.	Has life existed on the planets in the past?
3.	Do proto-organic materials exist?
4.	Are environmental conditions favorable to support indigenous life or the evolution of life in the foreseeable future?
5.	What are the characteristics of planetary atmospheres?
6.	What are the chemistry and geology of surface water?
7.	Is the internal structure of the planet radially symmetric; if so, is it differentiated as the Earth is? Specifically, does it have a crust?
8.	What is the geometric shape of the planet? How does the shape depart from fluid equilibrium?
9.	What is the present internal energy regime of the planet? Specifically, what is the present heat flow at the planetary surface and what are the sources of this heat? Is the planet seismically active, and is there active volcanism? Does the planet have an internally produced magnetic field?
10.	What is the average composition of the rocks at the surface of the planet, and how does the composition vary from place to place? Are volcanic rocks present on the surface of the planet?
11.	What are the principal processes responsible for the present relief of the planet surface?
12.	What is the present distribution of tectonic activity on the planet?
13.	What are the dominant processes of erosion, transport, and deposition of material on the planet surface?
14.	What volatile substances are present on or near the surface of the planet or in the atmosphere?
15.	What are the age and processes of formation of the planet? What is the range of age of the stratigraphic units on the planet surface, and what is the age of the oldest material? Is a primordial surface exposed?
16.	What is the thermal history of the planet? What has been the distribution of tectonic and possible volcanic activity in time?
17.	What has been the past flux of solid objects striking the planet surface, and how has it varied with time?
18.	What has been the flux of cosmic radiation and high-energy solar radiation over the history of the planet?
19.	What past magnetic fields may be recorded in the rocks on or near the surface of the planet?
20.	What was the origin of the Martian satellites?
21.	How are plasma, magnetic fields and energetic particles propagated from the sun through interplanetary space?
22.	What are the structures, histories, and origins of active phenomena in the solar atmosphere?
23.	What are the relationships among meteoroids, asteroids, and comets? How is meteoric material distributed in space in the solar system?

10. Major systems and subsystems were selected on the basis of providing a primary, a backup, and an emergency system. An example of this, as applied to electrical power systems, is contained in Table VII.

TABLE VII. RECOMMENDED ELECTRICAL POWER SYSTEMS

SYSTEM	MISSION		
	Mars Twilight	Venus Lightside	Multi-planet
RADIOISOTOPE (PU-238)	13 040 lb	12100	12410
Primary-Rankine, Downtherm A	(10895)	(10895)	(10895)
Backup-Cascaded T. E.	(655)	(655)	(655)
Emerg. -Solar Photovoltaic	(1490)	(550)	(860)
SOLAR PHOTOVOLTAIC	9655 lb	6325 lb	8540
Primary-Solar Arrays	(6360)[(1)]	(4605)[(2)]	(6070)[(3)]
Backup/E. O/Emerg. - Solar Arrays	(3295)	(1720)	(2470)

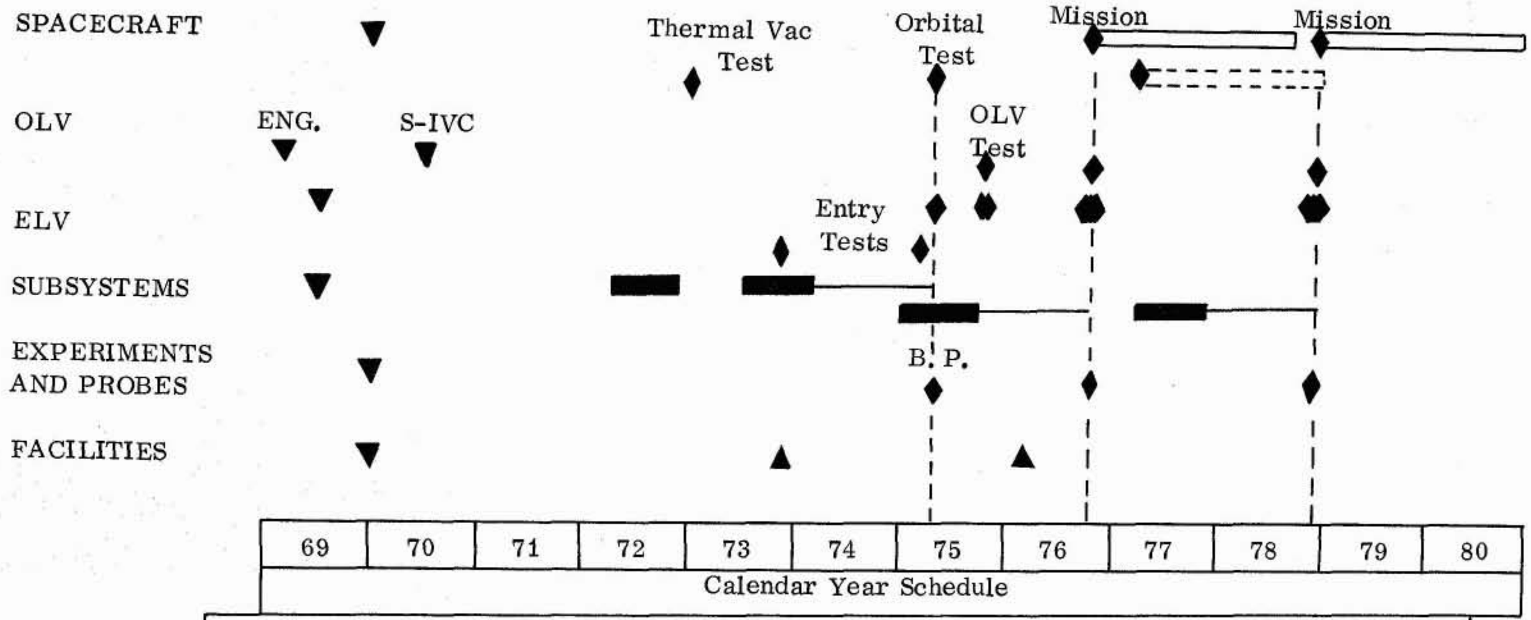
(1) 2720 ft^2 Array

(2) 1080 ft^2 Array

(3) 2450 ft^2 Array

11. Mission plans for a planetary exploration program (using a manned flyby system) were developed. The necessary hardware and systems development schedules with cost estimates are shown in Table VIII. Factors which could add to the cost of this program include additional missions, larger crew size, introduction of a nuclear stage for later missions, back-up launches, and an expanded probe complement. Factors which could subtract from the program cost include such things as a reduction of probe complements, fewer missions, and the elimination of the artificial gravity requirement.

TABLE VIII. DEVELOPMENT AND RESOURCES FOR RECOMMENDED MISSION-SYSTEM PROGRAM



	GFY Funding (Millions of Dollars)												
	69	70	71	72	73	74	75	76	77	78	79	80	Total
Development	50.0	337.4	1337.9	2736.8	3632.0	3428.7	2601.2	1510.5	376.3	175.0			16085.8
Operational													
1976 Dual						132.4	264.8	529.5	264.8	132.4			1323.9
1978 Dual								132.4	264.8	529.5	264.8	132.4	1323.9
Total	50.0	337.4	1337.9	2736.8	3632.0	3561.1	2866.0	2171.4	905.9	836.9	264.8	132.4	18733.6

SIGNIFICANT CONCLUSIONS

1. Mars twilight flyby missions in the 1975-1982 time period have favorable characteristics for Earth departure and return. The trajectories for these missions, however, extend through the asteriod belt and for the later mission years, the encounter velocity at Mars becomes increasingly higher.

2. Of the manned interplanetary missions, the Venus lightside flyby mission is the easiest to accomplish and can be done with an off-loaded Mars mission system.

3. Attractive multiplanet flyby missions exist in the 1975-1982 time period that alleviate the unfavorable characteristics of the twilight flyby missions. Based upon data return, encounter operation, and development schedule requirements,the most favorable multiplanet mission opportunities occur with a 1976 dual-planet mission which allows the 1977 triple-planet mission to be used as a backup mission, and the 1978 dual-planet mission to be used as the second mission in a 2-mission program.

4. The standard Saturn V Earth launch vehicle in conjunction with an orbit launch vehicle (consisting of tandem S-IVC stages) cannot meet the injected payload and mission requirements for the missions developed within the guidelines and assumptions of this study.

5. The standard Saturn V Earth launch vehicle, in conjunction with a modified S-II stage as the orbit launch vehicle, can meet the mission requirements only if the injected payload requirements are compromised by reducing the recommended probe complements or otherwise reducing the total injected spacecraft weight.

6. The standard Saturn V would not permit flight qualification of an operational-weight Earth-entry module (for full aerobraking entry) for the 1976 dual-planet mission. Therefore, partial retrobraking or reliance on scale testing will be required for this mission.

7. An uprated Saturn V Earth launch vehicle with a payload capability (2-stage to low earth orbit) of 400 000 lbs or more should be developed to be used in conjunction with a compatible MS-IVC orbit launch vehicle. This

Earth-launch orbit-launch vehicle combination would provide for significant payload margins. It is cost competitive with other vehicle combinations and reduces operational complexity by decreasing the number of launches required to assemble the flyby spacecraft. In addition, it would be compatible with the Post Apollo lunar program as well as the more ambitious planetary program payload requirements.

8. A manned flyby system can return to Earth high density information from the samples taken from the Mars atmosphere and surface; color and multispectral film of planets and sun; and original data records with the crew contributing significantly to real-time experiment control, targeting and landing of probes, sample recovery, and initial analyses.

9. A crew size of four is adequate to perform the operations necessary to satisfy the objectives of manned planetary flyby missions.

10. The Apollo command module can be modified for entry speeds of up to 55 000 ft/sec.

11. A modified Apollo service module can provide all propulsion maneuvers for flyby spacecraft after inteplanetary injection.

12. When providing post-injection abort capability, artificial gravity can be provided in the spacecraft design (with a small weight penalty resulting).

13. To meet a 1975 mission launch data a high-risk all-success hardware development program would be required.

14. Development schedules for a nuclear stage do not indicate the availability of an operational stage for missions before 1978. Such a stage could be introduced into the flyby program at that time. If the first mission to be undertaken is in 1978, the nuclear stage should be studied further as the primary orbit launch stage.

15. The systems design philosophy adopted by the contractor; i.e., design for mission and program success by providing design margins through the inclusion of primary, back-up, and emergency systems for such items as

the electrical power systems and life support systems has some attractive features. However, although the added weight penalty might be shown to be small, this approach could possible lead to a more costly program. A more logical approach might be to carry the two most promising candidate systems through the development stage, but not plan to carry different primary and back-up systems on the mission. Analyses should be conducted to provide means of ensuring a highly reliable primary system by determining repair capability, redundancy, etc. Plans should include provisions for an emergency system consistent with mission requirements and constraints. The resolution of the gravity conditions required for man during long-term space missions will have a strong influence on the choice of electrical power systems.

16. Table IX indicates the development and operational costs for a flyby program consisting of two multiplanet missions. The experiments and probes that perform the scientific and engineering data gathering functions for the flyby program make up approximately 33 percent of the total spacecraft development program costs. The Mission Module is by far the most costly component of the spacecraft. If by appropriate initial design considerations, a mission module designed for Earth orbital application could also be used for planetary flyby missions, the spacecraft development program could be reduced by approximately $ 5 billion. An additional reduction of the development program by approximately $1 billion would be realized if the launch vehicles were developed under some other program.

The total program cost of $18.7336 billion represents a program that includes a design philosophy of providing primary and secondary systems, maximum probe complements, and the development of a launch vehicle which has significant payload margin for manned planetary flyby missions.

Resources requirements developed for the flyby program in this study are charged completely against this program. The funding schedule covers systems and hardware such as the uprated Saturn V, mission module, life support, and electrical power systems, probes, etc. , that would have applicability to other manned spaceflight programs.

It should also be pointed out that in a total mission planning study such as this effort there are certain "judgment type" decisions that must be made in areas where no data or operational experience exists. For example, in the area of performance and design margins, adequate and realistic provisions must be made for such items as length of mission window and probe complements.

TABLE IX. TOTAL FLYBY PROGRAM COST, 1976-1978 DUAL PLANET MISSION PLAN (Millions of Dollars)

			R&D	Flight Test	Total
	S	Earth Entry Module	1,007.2	33.2	1,040.4
D	P	Propulsion Module	436.9	15.4	452.3
	A	Mission Module	3,911.1	147.7	4,058.8
E	C	Probe Compartment	485	11.0	506.0
	E	Probe & Experiments	2,950.0	50	3,000.00
V	C	GSE	-	-	1,850.0
	R	SE&I	-	-	1,350.0
E	A	Program Support & Mgt	-	-	1,500.0
	F	Facilities	-	-	95.0
L	T	Launch OPNS	-	-	562.6
		Total			14,415.2
O	Launch Vehicle, 4(S)B		370.2	340(2)	710.2
P	OLV, MSIVC(4) and Advanced Engine		524.9	61.4(2)	586.3
M	IU		50	25.0(2)	75.0
E	Facilities				133.0
N	Launch Operations		396.4	332.4(2)	728.8
T	Total Program Development				16,085.8
			No. of Units	Cost/Unit	Total
O	Launch Vehicles & Operations		8	166.2	1,329.6
P	Orbit Launch Vehicles		6	31.2	187.2
E R	Spacecraft	Hardware	2	291.4	582.8
A T	and	Facilities & OPNS		45.4	90.0
I O	Probes	Sustaining Engineering		29.1	58.2
N A		Mission Support		200	400.2
L	Total Program Operation				2,647.8
	Total Program (Development & Operation)				18,733.6

These have a direct bearing on the injected spacecraft weight. These weights impact, among other things, the launch vehicle requirements. And, when certain payload domains are reached or exceeded, a negative or marginal payload capability may exist. In these instances (for planning purposes) the mission and payload requirements must be reduced. Or, as in the case of launch vehicles, a vehicle of higher payload capability must be recommended. Realistically, all areas involving a judgment type decision must be carefully considered and their cascading effect upon hardware, systems, and vehicles assessed. Having done this, a recommended program should provide for adequate performance and design margins not only in areas where judgment must be imposed, but also where indepth technical analyses have been conducted and operational experience is available.

RECOMMENDED FUTURE ACTIVITIES

Manned planetary flyby missions are feasible. They provide a means of combining the favorable aspects of both manned and unmanned missions into a unique and highly effective planetary exploration system capable of providing inputs of major significance. Based on the results of this study, further efforts can be identified which will provide additional insight into planetary exploration requirements to identify that which can be accomplished, what developments are needed, and to determine the lowest program funding. Additional effort should be directed toward the following:

1. Sequential development of Earth launch vehicles, orbit launch vehicles, and an instrument unit based on realistic mission requirements;

2. An integrated analysis of the total manned flyby spacecraft system including the spacecraft, crew functions, and the data gathering and management system (telescope, probes);

3. Evolutionary systems development and synthesis considering Earth orbital, lunar and planetary missions, and AAP experiment support;

4. Exploration systems development such as probes, telescopes,and data management for flyby missions giving consideration to commonality of major subsystem and applicability to other types of planetary missions;

5. Development of requirements and techniques for multiple launch and Earth orbital rendezvous operations;

6. Multiplanet trajectory sensitivity and guidance studies and contingencies for probe target selection, guidance, and operation;

7. Biomedical effects of prolonged zero gravity and artificial gravity; determine crew work cycle and habitability requirements;

8. Stability systems for rotating and non-rotating systems; analyze the integration of advanced components into data management and telecommunication functions;

9. Investigation of deployment of large structural assemblies such as solar arrays and antennas;

10. Study of meteoroid environment, penetration mechanics, the detection and repair of punctures, vacuum degradation of materials in the heat shield, and engine ablators;

11. Study and testing of the development of man-rated power systems for prolonged use in space environment;

12. Analysis of the effect of extended space exposure and propulsion systems and components;

13. Analysis of crew vs. automated checkout; fault isolation and definition of man's capability to perform maintenance, repair, and replacement on long duration missions.

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APPROVAL

MANNED PLANETARY FLYBY MISSIONS (BASED ON SATURN/APOLLO SYSTEMS), EXECUTIVE SUMMARY REPORT

By

B. G. Noblitt

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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