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MANNED MARS FLYBY MISSION AND CONFIGURATION CONCEPT

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ABSTRACT

A concept is presented for a flyby mission of the planet. The mission was sized for the 2001 time period, has a crew of three, uses all propulsive maneuvers, and requires 442 days. Such a flyby mission results in significantly smaller vehicles than would a landing mission, but of course loses the value of the landing and the associated knowledge and prestige. Stay time in the planet vicinity is limited to the swingby trajectory but considerable time still exists for enroute science and research experiments. All propulsive braking was used in the concept due to unacceptable g-levels associated with aerobraking on this trajectory. LEO departure weight for the concept is approximately 594,000 pounds.

MISSION DESCRIPTION

The Mars round-trip trajectories are the Martian Counterpart of lunar free-return flight paths, with the exception that when the mission time is optimized a powered maneuver is required during Mars passage in order to achieve the desired return trajectory to Earth. A round-trip flyby may be attractive as a possible early manned mission to Mars. The basic objective for such a mission would be to reconnoiter the planet at close range, to monitor scientific probes during this atmospheric entry and landing, and to perform scientific experiments enroute to and return from Mars. The gravitation encounter with Mars plus a required powered maneuver must necessarily cause a significant alteration of the interplanetary vehicle's heliocentric trajectory. Within the activity sphere of Mars, planets sphere of influence, the trajectory is approximated by a planetocentric hyperbolic that serves as a transition segment between the outbound and inbound heliocentric trajectories. Therefore, the characteristic of the Martian encounter trajectory, i.e., passage altitudes, passage speed, orientation relative to the sunline and planet equator, powered maneuver, etc. are unique functions of the Earth departure, Mars encounter and Earth return dates.

The three requisite characteristics of the two heliocentric transfer trajectories which make up a round-trip Mars flyby mission are as follows: (1) the outbound arrival and inbound departure dates must be the same; (2) the hyperbolic excess speed at Mars, V_∞, on the inbound and outbound trajectories must be within some tolerance range with respect to each other, and (3) the angle between the V_∞'s of approach and departure must be less than a certain critical value in order to keep the required power maneuver and passage distance to the planet within an acceptable range.

The propulsive energy required to achieve the Mars flyby mission is highly dependent on time of mission opportunity because of Mars' elliptical orbit about the Sun; where Mars' distance from the Sun varies from 1.38 to 1.66 a.u. The year 2001 opportunity requires less propulsive energy than any other opportunity within a plus or minus 15 year span about the year 2001 because Mars is at its closest position from the Sun during the mission's Mars passage date. The optimum launch date for the 2001 Mars flyby opportunity is March 9, 2001, with a flight time to Mars of 172 days and a total mission time of 442 days. The Mars flyby date is August 20, 2001, and the Earth return date is May 25, 2002. The Earth departure trajectory has a C_3 value of 10.1 km^2/sec^2. A propulsive maneuver, requiring a ΔV of 1.281 km/sec, is made during Mars' flyby to achieve the necessary turn angle at Mars to connect to the Earth return trajectory. The Earth return trajectory C_3 at Earth is 117 km^2/sec^2. The Earth return braking maneuver must be achieved propulsively in order to stay with in g-level constraints required for a manned mission; braking the Earth return spacecraft aerodynamically would result in g-level greater than 4 g's.[1] An Earth return module, which is separated from the interplanetary vehicle just before Earth braking maneuver, of 7,500 lbs is decelerated propulsively into a 24 hour capture ellipse at Earth. Figure 1 gives the mission profile for the 2001 opportunity.

A weight of 594,000 lbs is required to be assembled in low Earth orbit to achieve the 2001 flyby opportunity. The 594,000 lbs assembled weight can be accomplished with 4 Shuttle-Derived Vehicle (SDV) flights and 3 Shuttle flights.[2]

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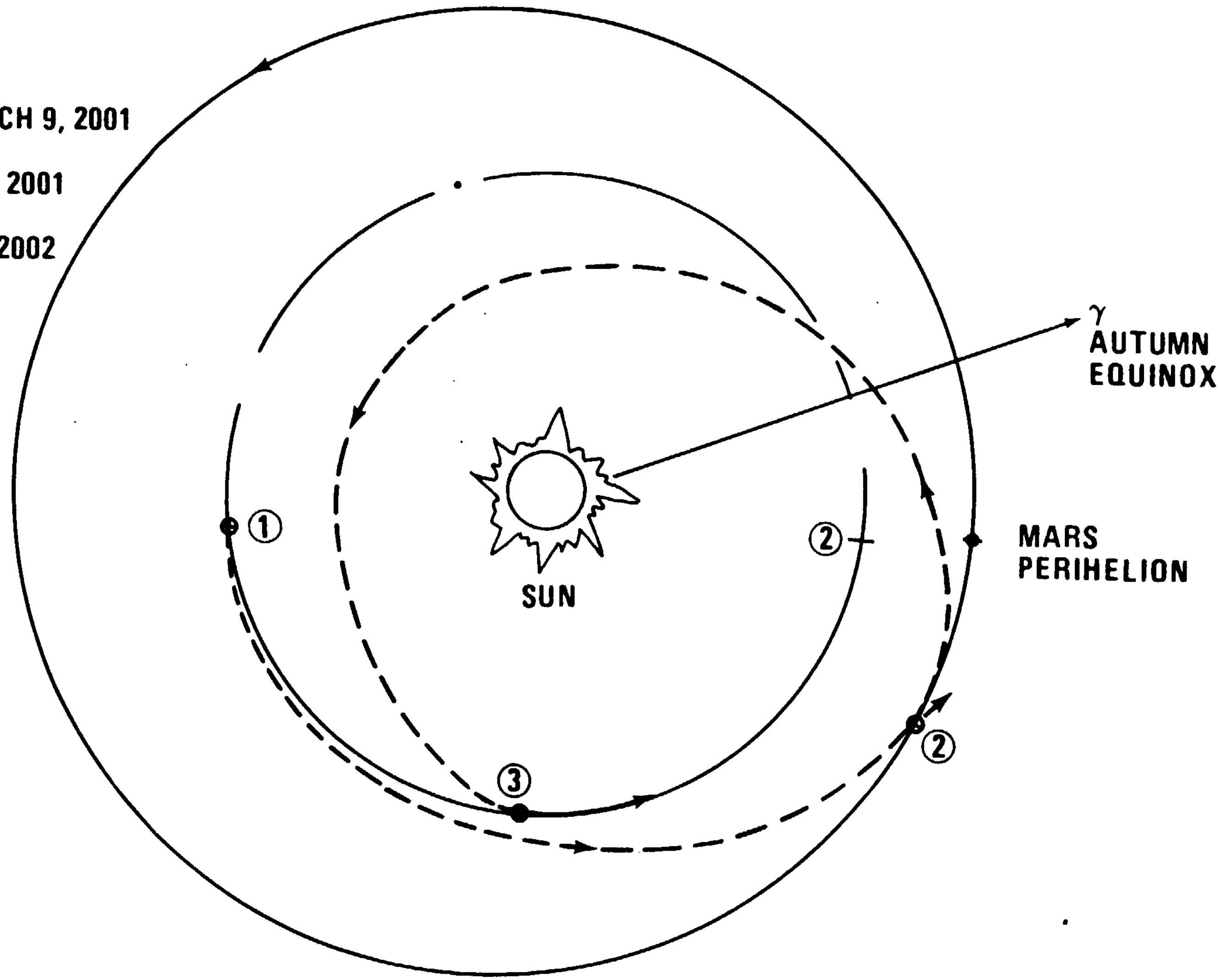
FIGURE 1 MANNED MARS FLYBY 2001 OPPORTUNITY

① EARTH DEPARTURE, MARCH 9, 2001

② MARS FLYBY, AUGUST 28, 2001

③ EARTH RETURN, MAY 25, 2002



A C_3 level less than 117 km^2/sec^2 for Earth return can be obtained by performing optimum midcourse maneuvers on the outbound and inbound legs.[3] A C_3 level of less than 25 km^2/sec^2 can be realized; however, the outbound and inbound midcourse correction maneuver would have to be performed with the heavier interplanetary vehicle, thereby requiring a larger initial mass in low Earth orbit than the 594,000 lbs asssociated with Earth return C_3 of 117 km^2/sec^2. AC_3 value of less than 25 km^2/sec^2 would allow aerobraking for capture into the Earth return orbit.

CONFIGURATION

Figure 2 shows a concept for the all propulsive maneuver mission. The configuration consists of two LO_2/LH_2 propulsion stages, a spacecraft, and experiments (probes, etc.). The configuration is assembled and prepared for the mission in LEO and is sized for the swingby mission of the planet and return to LEO (24 hour elliptical orbit) using propulsive energy for departure from LEO, maneuver at the Mars vicinity, and braking for Earth orbit capture.

The propulsive stages are sized for a 6:1 propellant mixture ratio, with both stages using OTV engines as shown in the figure. The first stage is separated after the burn for LEO departure. The remaining energy requirements for a maneuver at Mars and subsequent braking at Earth required most of the energy at Earth. Therefore, one stage was chosen to perform both of these burns rather than two stages or a drop tank option. This stage may have potential commonality with Orbital Transfer Vehicles developed for other programs. The sizing of the second stage also was based on returning only a portion of the spacecraft to LEO in order to reduce total propellant requirements. The recoverable portion is returned to a 24 hour elliptical orbit and would require support from an auxiliary stage (such as the planned Orbital Maneuvering Vehicle) for recovery.

The spacecraft is sized using Space Station diameter modules (approximately 14 feet). A criteria used in the design was provision of two separately pressurizable modules for safety consideration in the event one module were to become uninhabitable during the mission. Since one of these modules was to then be jettisoned on Earth return, they were sized unequally in order to return the minimum mass. This then led to

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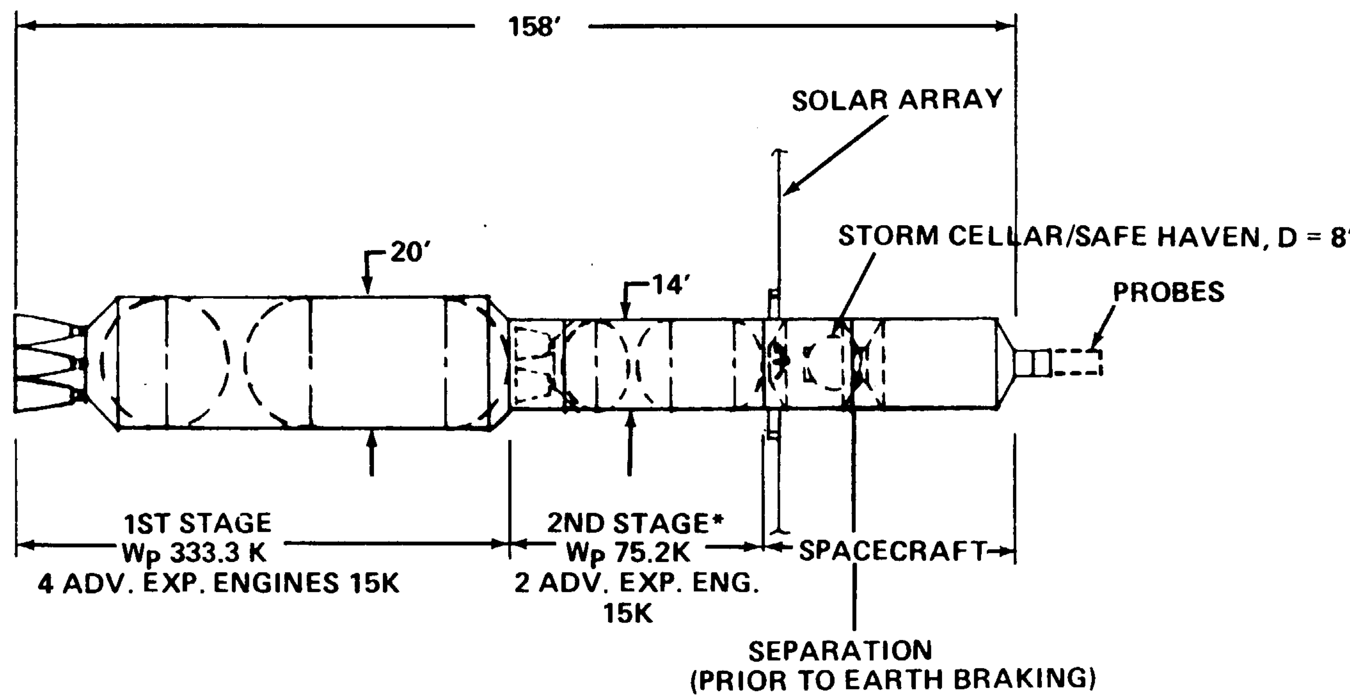
FIGURE 2 MARS MANNED FLYBY CONCEPT ALL PROPULSIVE, 2001 OPPORTUNITY, 442 DAY MISSION



* SECOND STAGE PERFORMS PROPULSIVE MANEUVER AT MARS & BRAKING AT EARTH RETURN.

inclusion of a separate pressurized compartment within the Earth return module to serve in the event that Earth return module was the one that had become uninhabitable. This provides redundancy within the Earth return portion and is also used as a storm cellar during the mission (packaging of equipment, etc. around the compartment provides shielding). Internal layouts of these modules were not evaluated and size was estimated. A solar array system is shown for the power system during the mission. The vehicle is oriented to minimize solar array pointing requirements and to minimize heating of the propellant tanks.

External experiments were not evaluated but a weight allowance was included for them. These would include probes attached to the modules.

WEIGHT SUMMARY

Weight summary for the all-propulsive cryogenic manned Mars flyby vehicle for 2001 opportunity is presented in Table 1. The interstages and payload adapter weights are included with the structures. The number of engines (OTV type) in the propulsion system is shown in parentheses for each stage. The thermal control system includes the heavy vapor cooled shield which allows less than 500 pounds boiloff in the 2nd stage, and none in the 1st stage after departure from LEO. The avionics system for the propulsive stages are minimal since the main avionics system is in the spacecraft. A 15% contingency is added to all the dry weights, since most of the hardware is new and considered to be current technology equipment. The usable propellants (consumables) for the propulsive stages were determined by performance analysis as shown in Table 1. The stage launch weight at LEO as the vehicle departs is shown for each propulsive stage.

The weights for the Earth Entry Module and spacecraft are shown together in the third column. The weights for the avionics, ECLSS, crew systems, consumables, and mission equipment were estimated using data from[4]. The configuration is shown in Figure 2 with the propulsive stages attached. The pressurized modules including the safe haven are included in the structures. One airlock is also included with the structures in addition to the micrometeoroid shield and outer insulation weights. The main avionics and power for the vehicle are shown in the spacecraft. The consumables for the spacecraft include food, water, oxygen, nitrogen, clothes, power system reactants, and other crew systems

TABLE 1

WEIGHT SUMMARY (POUNDS)

ALL-PROPULSIVE CRYOGENIC VEHICLE FOR 2001 OPPORTUNITY MANNED MARS FLYBY

		Earth Departure 1st Stage		Mars Maneuvers & Earth Braking 2nd Stage	Earth Entry Module & Spacecraft
Structures		12,592		4,017	21,275
Thermal & Insulation		5,543		1,992	2,354
Propulsion System	(4 Eng)	4,358	(2 Eng)	2,253	-
Avionics		500		300	8,373
ECLSS		-		-	10,986
Crew Systems		-		-	8,419
Contingency (15%)		3,449		1,258	7,711
Residuals		2,560		1,011	295
Consumables		332,340		76,060 (w/boiloff)	17,749
Mission/Science Equipment		-		-	6,645
Science/Mars Probes		-		-	20,000
Crew (3)		-		-	1,140
Stage Launch Weight (LEO)		361,342		86,891	104,947
Total Vehicle Weight (LEO)				553,180	

expendables (closed-loop ECLSS). The mission/science equipment and science/Mars probes are only representative and would change as requirements are established. The crew weights include three men with flight suits. The total vehicle weights are for a 442-day mission at launch from LEO.

SUMMARY

A manned Mars flyby mission can be achieved early with inplace resources and facilities and would utilize high heritage from other space programs; i.e., Shuttle, Space Station, Shuttle Derived Vehicle (SDV), and the Orbit Transfer Vehicle. The launch opportunity of March, 2001, will be the least demanding launch opportunity through launch opportunities up to year 2016. The objectives of an early Mars flyby mission would be to conduct scientific experiments enroute to and return from Mars, observe scientific probes sent through the Martian atmosphere and probes which accomplish surface landings and mapping of the planet at close range (180 n.mi.)

The 594,000 lbs weight required in low Earth orbit (LEO) to achieve this mission can be assembled with 4 SDV flights and 3 Shuttle flights. The 594,000 lbs required in LEO for the 2001 Mars flyby mission compares to 1,602,000 lbs required in LEO for the 2001 Mars landing mission with a 60-day stay time at Mars[5]. A Venus inbound swingby is used to reduce the propulsion requirement for the 2001 Mars landing mission. Other alternatives to the Mars direct flyby mission would be to (1) flyby Venus on the inbound leg, however, this mission profile would require an increase in mission time of about 200 days over the 442 days direct mission profile;[6]; or (2) make midcourse maneuvers both on the outbound trajectory and inbound trajectory in order to be aerodynamically captured at Earth return. However, this option would increase the initial weight required in LEO above the 594,000 lbs.

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