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CONDENSED SUMMARY REPORT STUDY OF UNMANNED SYSTEMS TO EVALUATE THE MARTIAN ENVIRONMENT

Contract NAS2-2477

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FOREWORD

This summary report was prepared by the Space and Information Systems Division of North American Aviation, Inc., for the National Aeronautics and Space Administration, Ames Research Center, in accordance with Article IV of the schedule accompanying Contract NAS2-2477. The contract directed a study of the requirements for unmanned systems to evaluate the Martian environment. This summary presents a concise description of the study approach, results of manned system environmental sensitivity analyses, and the resulting requirements for unmanned systems designed to acquire the environmental data necessary to support the planning and design of manned Mars missions.

A detailed description of the study results is presented in the Final Report, SID 65-1172.

TECHNICAL REPORT INDEX/ABSTRACT

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ABSTRACT

This condensed summary report presents a concise description of the study approach, results of manned system environmental sensitivity analyses, and the resulting requirements for unmanned systems designed to acquire the environmental data necessary to support the planning and design of manned Mars missions.

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INTRODUCTION

Previous studies of manned Mars missions have shown that uncertainties in the interplanetary and Martian environments can significantly affect the design and performance of the spacecraft and subsystems. The planning of these mission therefore requires further definition of a number of critical environmental parameters. Current and planned unmanned programs (e. g., Mariner and Voyager) will acquire some of the data required; however, inasmuch as the announced objective of these missions is the acquisition of fundamental scientific data, there may be some concern regarding adequate coverage of the engineering requirements. The Space and Information Systems Division (S&ID) of North American Aviation was awarded a contract by the NASA/Ames Research Center to systematically investigate the effects of environmental uncertainties on systems design for the conduct of manned missions, to identify the critical environmental parameters, and to examine the adequacy of planned unmanned missions to evaluate these environments. Both the interplanetary (transit phases) and Martian (areocentric, atmospheric, and surface) environments were considered in the study; basic manned mission design and subsystem concepts developed in previous S&ID studies were employed as a basepoint for the sensitivity analyses.

Major emphasis in this investigation was placed upon the manned systems sensitivity analyses and on the identification of the environmental data and measurement requirements for the support of manned missions. Another objective defined by NASA was to evaluate the capabilities of current unmanned programs (i.e., Voyager) to obtain the environmental data needed to support manned mission planning and design and to define any new unmanned system requirements where they were found lacking. Finally, throughout the conduct of the study, those problem areas wherein additional, or future research and development may be required to enhance mission success were noted and evaluated.

STUDY APPROACH AND ASSUMPTIONS

The study was initiated on 28 October 1964, one month prior to the launching of Mariner 4. Completion of all technical activities was scheduled for 30 July 1965, two weeks after planet encounter and prior to the transmission, review, and release of all the Mariner data. The reader therefore should be aware that the results presented in this report are predicated upon the pre-Mariner environmental models which either were available or were postulated in the course of the study.

Subsystem sensitivities due to critical environments were examined to define the data acquisition requirements for manned Mars missions. Instrumentation capabilities and availabilities were examined, and the requirements for data were compared with the estimated capabilities of Voyager. Based upon this comparison, those environmental parameters that could not be defined adequately by the currently planned unmanned missions were identified. Finally, the requirements were established for new unmanned systems designed specifically to acquire data necessary to support the planning and design of manned Mars missions.

Preliminary analyses of the various manned missions and vehicle subsystems identified those Martian environmental parameters which potentially could create significant design penalties if the uncertainties in the absolute value of these parameters cannot be reduced (Table 1). It was anticipated that uncertainties in the micrometeoroid environment, radiation, solar constant, and planet physical characteristics (i.e., mass, radius, and albedo) potentially posed significant design

Table 1. Environment/Subsystem Sensitivity Matrix

Environmental Parameter	Manned Mission Subsystem	Power	Structure	Propulsion	Environ. Control	Guid./Navigation	Life Support	Communications	Entry Heat Shield	Retardation	Flight Control	Landing Gear
Inter-Planetary	Meteoroids		X									
	Solar & Galactic Radiation	X	X	X								
	Solar Constant	X		X	X							
	Static Charge											
Areocentric	Ephemeris				X	X						
	Radius & Oblateness			X		X						
	Gravitational Constant			X		X	X					
	Magnetic Fields/Trapped Radiation		X									
	Albedo				X		X					
Atmospheric	Composition				X		X	X	X			
	Pressure			X	X		X	X				
	Temperature			X	X		X	X	X			
	Density			X	X	X	X	X	X	X		X
	Winds				X		X			X	X	X
Surface	Emissivity/Reflectivity				X		X					
	Topography				X		X					X
	Soil Mechanics (Bearing Strength)											X
	Sandstorms				X		X					
	Quakes											
	Radioactivity											
	Biolife											

penalties for the transit phases of the mission. The Martian atmospheric characteristics (e. g., density, scale height, composition, pressure, and temperature) were expected to be the most critical for landing on the planet. The known postulations of each pertinent parameter therefore were examined; and a summary of these data was prepared in the form of expected minimum, nominal, and maximum values.

The few existing meteoroid data were extrapolated to higher masses and lower fluxes to postulate a nominal micrometeoroid environment. A three-order-of-magnitude increase above the nominal was assumed for the maximum cometary environment, and a one-order-of-magnitude decrease was assumed for the minimum model (Figure 1). The maximum model was obtained by considering uncertainties in the mass of zero magnitude meteors, iron abundance of meteors in situ, and asteroid belt collision products. The cometary flux was assumed to decrease with solar distance, and the flux of larger (asteroidal) particles was assumed to vary inversely with distance from the asteroid belt. Mariner 4 gathered some data (i. e., on particles in the 10^{-8} to 10^{-10} gram mass range) which fall between the minimum and nominal models used in this study; the design of the experimental apparatus precluded the detection of larger particles.

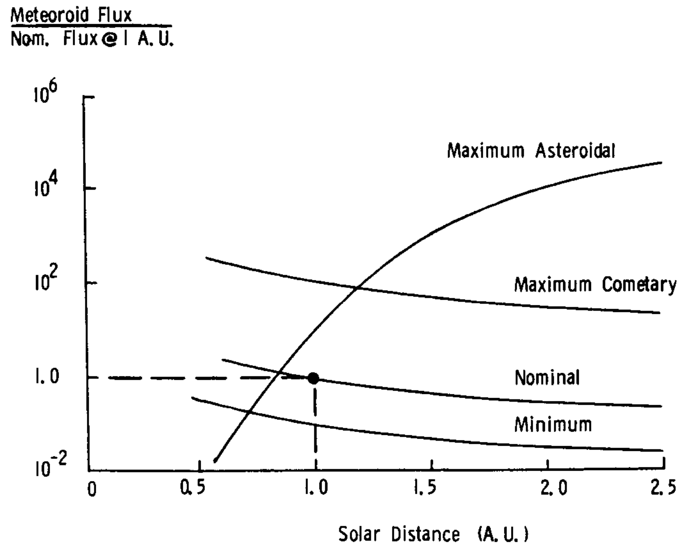

Figure 1. Meteoroid Flux Models

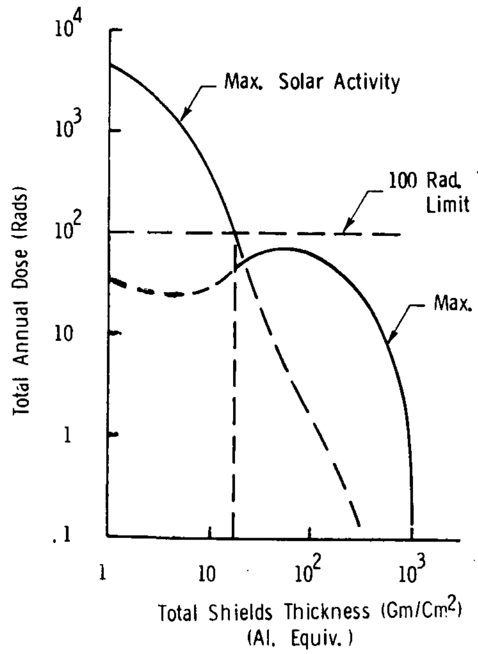

Figure 2. Radiation Environment

The NASA/MSC model for the radiation environment was used; amendments were suggested for those portions where it is not sufficiently detailed to perform a realistic design analysis. The maximum estimates of solar activity (Figure 2) require heavy shielding unless the "storm cellar" concept is applied to limit the crew's radiation dosage to tolerable levels. Estimates of Martian trapped radiation flux generated in the study indicated it to be at least an order of magnitude lower than that of Earth; Mariner 4 data disclosed that the Mars magnetic field was insignificant and that the trapped radiation was some six orders of magnitude below that of the Van Allen belt. The Martian atmospheric and physical uncertainties are summarized in Table 2. Preliminary assessment of the Mariner 4 data indicated a surface pressure of 8 to 12 mb and a scale height of 7 to 8 km (i.e., within the limits of the assumed models).

The basepoint manned missions considered in the sensitivity analyses are summarized in Table 3. A Mars orbiting rendezvous (MOR) aerobraking mode, which utilizes chemical propulsion, was selected as the nominal mission. Retrobraking MOR, direct entry, and flyby missions also were considered. The effects of employing nuclear stages for Earth orbit escape and Mars retrobraking on the basepoint systems were assessed. Earth orbital weights were determined for the various modes based upon a 1982 launch. In addition, the nominal mission launch year sensitivities over the 1980-to-1995 time period and a 1975 flyby mission were examined.

STUDY RESULTS

MANNED SUBSYSTEMS SENSITIVITIES

Meteoroid Protection. The meteoroid shield weights required for the maximum, minimum, and nominal environments were assessed for 0.90 to 0.99 "probability of no penetration" during the mission. The results, shown in Figure 3, indicate that for an "optimized" meteoroid shielding structure the weight penalty would be 100% for the aerobraking MOR and direct missions; this penalty could increase to 120% if the Mars entry heat shield is also protected. The penalty for the retrobraking MOR structure may approach 150% inasmuch as the basic structure is lighter than that of the aerobraking vehicles; the Earth orbit weight increases 14 to 20 percent because

Table 2. Martian Atmospheric Properties and Physical Characteristics

PARAMETER	MIN.	NOMINAL	MAX.
Surface			
Temperature (°K)	200	250	300
Pressure (mb)	10	25	133
Density ($gm/cm^3 \times 10^{-5}$)	1.7	3.56	14.9
Composition-CO_2 (% by Vol.)	0.7	16	100
N_2	0	84	98.7
A	0	0	35.2
Molecular Wt.	28	29.7	44
Winds (m/sec.)	0	8	40
Density Scale Height (km.) (At 30 km Altitude)	6.3	13.7	20.4

PARAMETER	MIN.	NOMINAL	MAX.
Radius (km) Polar	3291		3359
Equatorial	3323	3380	3438
Ellipticity Dynamical		.0052	
Optical		.0130	
Acceleration Due to Gravity (cm/sec^2)	360	375	390
Solar Constant ($cal/cm^2/sec$)*	0.7	0.8[illegible]	1.1
Albedo	.08	.15	.26
Mass ($gm \times 10^{-24}$)	639	643	645.5
Surface Topography	RELATIVELY SMOOTH		
Surface Feature Elevations (m)		< 762	
Surface Composition (Grain Dia., μ)	50	100	1000

*Based on Variation in Distance of Mars from Sun; Uncertainty in Basic Solar Constant ± 7%.

Table 3. Base-Point Manned Missions

Mission Mode	Propulsion Type	Launch Year	Crew	Stay Time (Days)	Mission Duration (Days)	Wt. in Earth Orbit (10^6 lb.)	Remarks
Flyby	Chem	1982	3	-	685	0.46	Flyby vs. MOR
Flyby	Chem	1975	3	-	667	0.51	Early Flyby
MOR-A/B	(1) Nuc + Chem	1982	7	7	407	0.84	Effect of Nuc. Propul
MOR-A/B	Chem	1980-95	7	7	407-450	1.3 - 2.72	Effect of Launch Year
MOR-A/B	Chem	1982	7	7	407	1.62	Nominal Mission
MOR-R/B	(2) Nuc + Chem	1982	7	7	450	1.90	Effect of Nuc. Propul
MOR-R/B	(1) Nuc + Chem	1982	7	7	450	2.70	Effect of Nuc. Propul
Direct-A/B	Chem	1982	4	7	407	4.65	Reduced Crew/Direct vs. MOR
MOR-R/B	Chem	1982	7	7	450	4.81	A/B vs. R/B Comparison
Direct-A/B	Chem	1982	7	7	407	5.72	MOR vs. Direct Comparison

(1) Nuc. Trans-Mars Inj. Stage
(2) Nuc. Trans-Mars Inj. and Mars-Retro Stages

of structural penalties. The flyby mode experiences the most severe penalty because of the contribution of the asteroidal component in the maximum environment, inasmuch as the trajectory most closely approaches the asteroid belt (i.e., aphelion = 2.2 A.U.), and the exposure time is longest.

Radiation Effects. The radiation hazard experienced by the crew of a manned Mars mission will arise primarily from exposure of the blood-forming organs to galactic corpuscular particles; exposure of the blood-forming organs and skin to solar corpuscular radiation; proton, electron, and bremsstrahlung doses encountered in the trapped radiation zones about Earth and Mars; and, possibly, exposure to nuclear propulsion and/or power supplies. Investigation showed that utilization of the ERM and the surrounding equipments as a storm cellar to shield the crew will afford adequate solar-flare protection and maintain the total mission dose within acceptable limits (i.e., < 100 rads to blood forming organs).

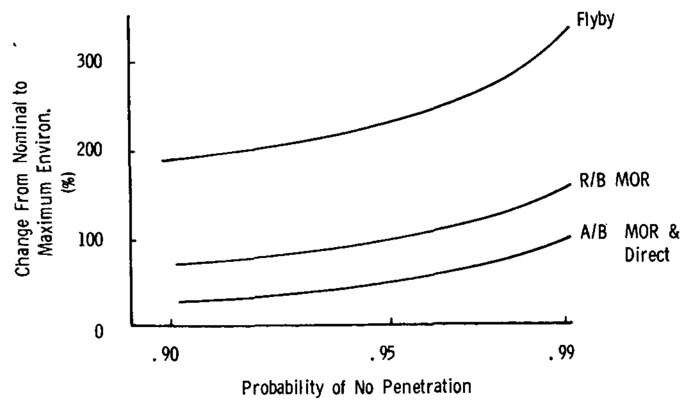

Figure 3. Effect of Meteoroid Environment on External Structural Weight

Mars surface radioactivity dosages were estimated, assuming solar and galactic radiations to be the activating source, and were found to be negligible. Ultraviolet solar radiation reaching the astronauts on the surface may exceed Earth intensities; however, no sunburn or eye damage hazards are expected that cannot be prevented by thin clothing and eye protection.

Environmental Control and Life Support. The spacecraft temperature control system must be designed to accommodate the extremes in solar heating that are due to variations in the basic trajectory and, therefore, can accommodate the small perturbations introduced by uncertainties in the solar constant. The Mars albedo uncertainty is estimated to change the heat load of an orbiter by less than one percent. This again would fall well within the design tolerances, and, therefore, this effect also is considered negligible.

The MEM environmental control and life support systems were found to be affected by the surface atmospheric pressure, composition, and temperature uncertainties; however, these effects all were small. If the temperature control system radiator surface were pitted by sandstorms, the area would need to be increased by 240 percent.

Electrical Power. The sensitivity of solar dynamic and isotrope primary electrical power sources to environmental uncertainties were compared. The system weight penalties that result from projected changes in cycle efficiencies because of the effect of uncertainties in the solar constant on the space heat sink temperature are well within those introduced by the variations in the mission profile (i.e., orbiting in Mars' shadow, varying solar distances, etc.). If solar panels are employed for primary power, variations in the space radiation environment require an increase in the glass shielding for the cells and/or an increase in the panel area of 10 to 14 percent to offset the degradation in performance for the maximum radiation flux postulated (as compared to the nominal radiation environment).

Guidance, Navigation, and Control. The effects of uncertainties in Mars' mass, radius, and atmospheric altitude-density profile on navigation errors, ΔV requirements, and entry corridor depths were analyzed. The uncertainty in the planet mass was found to be negligible on Mars-approach and initial trans-Earth midcourse correction ΔV's. The most important single effect of the density profile uncertainty is to narrow the entry corridor for the Mars aerobraking mode (Figure 4). The available entry corridor for the nominal mission in the minimum atmosphere is 32 km; if the range of postulated atmospheres (minimum to maximum) is considered, the corridor depth is reduced to 26 km. Mariner 4 data indicate that the minimum atmosphere corridor is probably most realistic. The planet approach navigation accuracy would be degraded by the postulated planet radius uncertainty; however, Mariner 4 apparently has reduced this uncertainty to 0.1 percent, which combined with the other navigation errors would produce a 0.9995 probability of hitting the entry corridor.

Entry Heating. Although local heating rates may vary, the gross weight of the entry heat protection system was found to be relatively insensitive to the uncertainties in

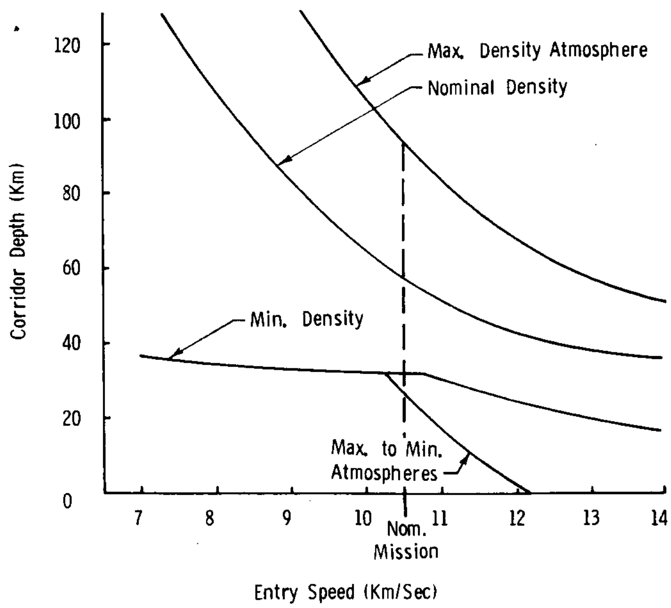

Figure 4. Effect of Martian Atmosphere Density Uncertainty on Entry Corridor Depth

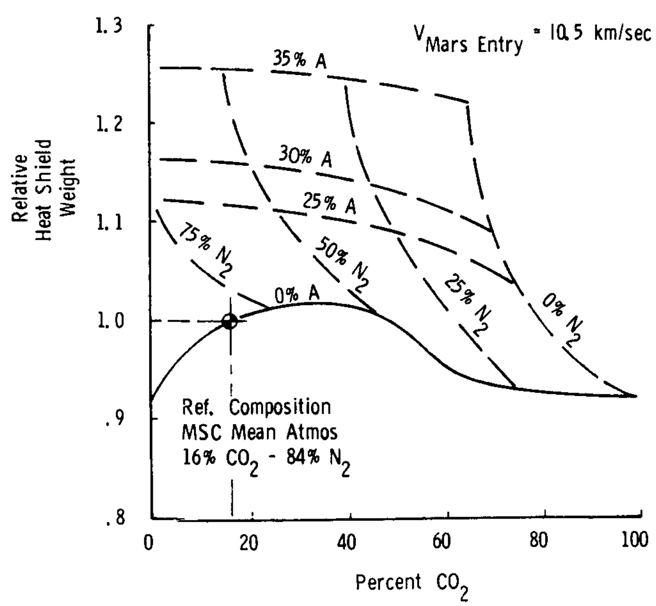

Figure 5. Effect of Martian Atmospheric Composition on Aerobraking Vehicle Ablative Heat Shield

density and scale height of the atmosphere; radiative heating rates, however, may be seriously affected by atmospheric composition, i.e., CO_2 and A content. For CO_2/N_2 mixtures, the effect is most pronounced for velocities in the range of 6.5 to 10 km/sec; at higher velocities, the radiative heating intensities may approach those of air. At a given velocity, the maximum heat flux is observed at a concentration of approximately 40% CO_2 and results in a 9% increase in heat shield weight (compared to either 100% CO_2 or N_2) for the nominal mission. Argon significantly increases the radiant flux at entry velocities above 8.25 km/sec; at 10.5 km/sec the heat shield weight may increase 25% in 35% argon mixtures (Figure 5). Convective heating rates were found to be relatively insensitive to gas composition.

Communications. Communications-system sensitivity to atmospheric attenuation, ionospheric cut-off frequency, solar disturbances, and surface environmental effects were found to be negligible. High frequency breakdown could occur in the 10-mb atmosphere at S-band with a high-gain (30-db) directional antenna for transmitter power inputs over 30 kw. No strong experimental evidence was found to support the thesis that argon in the Martian atmosphere would place any additional constraints on transmitter power; however, insufficient data are available to completely rule out this possibility. The composition uncertainties of the atmosphere on shock/boundary-layer electron densities and collision frequencies as they might affect communications during the entry phase of the candidate missions also were investigated. During initial entry (e.g., aerobraking or direct entry), blackout could occur at altitudes equivalent to densities on the order of 10^{-9} slugs/ft^3. A communications blackout during entry from orbit of the MEM lander may be dependent upon the atmospheric composition (as well as upon the transmission frequency selected and a number of other variables); the point at which communications can be reestablished (e.g., altitude density 10^{-5} to 10^{-6} slugs/ft^3) also will be composition sensitive.

Retardation and Landing. MEM retardation and landing-system sensitivities to uncertainties in the atmospheric density-altitude profile and wind shears were examined.

The retardation system weight penalties imposed by designing for the lowest density, or maximum winds are 73 to 81%, respectively; the combined effects result in a 111% system-weight penalty. A "universal" retardation system that could satisfy the entire range of density and winds considered (i.e., a three-stage parachute system) would increase the weight by 162%.

The stability of a typical lander configuration was investigated for surface slopes up to 15° and friction coefficients from 0.1 to 1.0. An Apollo command-module-type lander with a low center of gravity and a wide spread, 3-legged landing gear was found to be stable under all conditions, including a 60 m/sec (200 fps) surface wind superimposed on the most critical condition (i.e., 15° slope, 1.0 friction coefficient, 5° pitch attitude). The effect of wide variations in surface bearing strength was found to be negligible in terms of the weight penalty for oversized gear pads, assuming a bearing strength of 10 psi (e.g., loose sand).

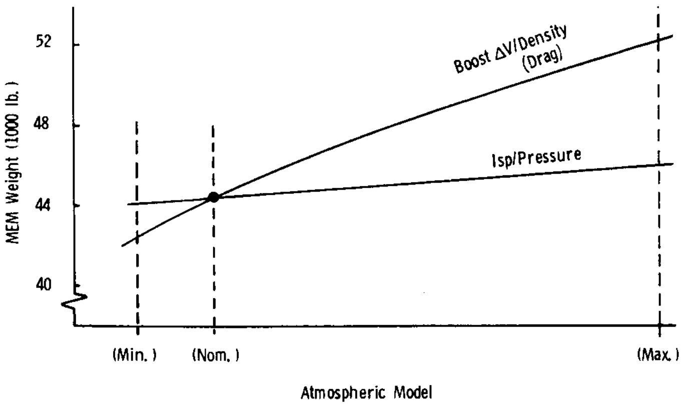

Figure 6. MEM Sensitivity to Atmospheric Density and Pressure Uncertainties

Propulsion. The effects of atmospheric density and pressure uncertainties on MEM propulsion are shown in Figure 6. The density uncertainty produces a 480 m/sec penalty in boost ΔV, resulting in an 18-percent increase in MEM gross weight. Variations in the MEM engine specific impulse to uncertainties in the pressure profile can be limited to 4% if a sufficiently high chamber pressure (1000 psia) and expansion ratio (c.a., 50) are employed. The effects of interplanetary radiation on cryogenic and storable liquid propellants were found to be insignificant. Variations in solar constant could affect the super-insulation requirements for cryogenic propellants by approximately 2.7%. The uncertainties in the Martian surface temperature increase the thickness of propellant tank insulation by 45% and could affect the storage pressure for cryogenic propellants.

EARTH ORBITAL WEIGHT AND MISSION MODES SENSITIVITIES

The individual effects of uncertainties in the various environmental parameters on the affected subsystems have been summarized in Table 4 in terms of percent change in Earth orbital weight. The total system Earth orbital weight sensitivity to uncertainties in each environmental parameter are presented in Table 5. The interplanetary environmental uncertainties produce an Earth-orbital weight sensitivity four times greater for the nominal mission than the combined atmospheric and physical property uncertainties of the planet—primarily because of the uncertainty in the meteoroid flux-mass environment. The planetary property uncertainty which results in the greatest Earth-orbital weight sensitivity is the atmospheric density and scale height. The combined atmospheric and surface characteristic uncertainties are three times as significant as the uncertainties in areocentric properties (mass and radius) for the nominal mission.

The total effects of uncertainties in the interplanetary and Martian environments on mission mode weight are shown in Figure 7.

Comparing the overall Earth-orbital weight sensitivity of the various mission modes reveals that the retrobraking MOR mission is 7% less sensitive to uncertainties in the Martian and interplanetary environments than the nominal aerobraking MOR mission; the direct mode is 50% more sensitive than the nominal mission. In terms of

Table 4. Summary of Manned Mission Sensitivities to Environmental Uncertainties (Nominal Mission)

ENVIRONMENTAL PARAMETER	SUBSYSTEM OR MISSION PARAMETER	SENSITIVITY (NOM. TO WORST CASE)	CHANGE IN EARTH ORB. WT. (%)
INTERPLANETARY CHARACTERISTICS			
Radiation	Crew Shielding	11 gm/cm^2 shielding adeq. for Max. solar event/ERM used as storm cellar	--
	Solar Panels	Increase area 10%	0.4
Meteoroids	Outer Structure Weight	Increased 115%	20.0
AREOCENTRIC CHARACTERISTICS			
Mass	Trans-Earth Inj. ΔV	Increased 1.6 m/sec.	--
	Lander Escape ΔV	Increased 6 m/sec.	--
Radius	Approach Navig. ΔV	Increased 27 m/sec	1.0
	Lander Escape ΔV	Increased 34 m/sec	0.2
Trapped Radiation	Orbital Altitude	Orbital altitude < 300 km	--
MARTIAN ATMOS.			
Density/Alt.	Entry Corridor Depth	Reduced 25-75%	--
	Lander Retardation Sys.	Wt. incr. 73%	0.2
	Lander Escape ΔV req't.	Lander wt. incr. 18%	2.0
Gas Composition	Entry Heat Protection	Ablative Heat Shield wt. incr. 22%	1.2
	Lander Communications	Entry Plasma Blackout < 2300 MCS	--
	Lander ECS Radiator	Area increased 20%	--
Pressure/Alt.	Lander Propulsion Isp	Isp decreased 3%	0.4
	Lander ECS Radiator	Area incr. 10%	--
	Lander Communications	Hi-Freq. breakdown > 22 kw (min. pressure atmos.)	--
Temperature	Lander Propellant Tank Insulation	Insul. thickness incr. 45%	--
	Lander ECS Radiator	Area increased 20%	--
Sandstorms	Lander ECS Radiator	Area increased 240%	--
Winds	Lander Retardation System	Weight increased 81%	0.3
MARTIAN SURFACE			
Topography, Slopes	Lander Alighting System	Negligible	--
Friction Coefficient			
Bearing Strength	Lander Alighting System	Pad area increased 400%	--

Table 5. Summary of Manned Mission Orbit Weight Sensitivities to Environmental Uncertainties

ENVIRONMENTAL PARAMETER		TOTAL SYSTEM SENSITIVITY (% OF EARTH ORBIT WEIGHT) 1982 LAUNCH 7-MAN CREW					
		Chemical Propulsion				NUCLEAR + CHEMICAL	
		MOR-A/B (Nominal Mission)	MOR-R/B	Direct Lander	Flyby (3-Men)	MOR-A/B	MOR-R/B
INTER-PLANETARY	Radiation	0.4	0.4	0.4	0.2	0.5	0.5
	Meteoroid Flux	20.0	19.2	13.6	38.4	20.0	19.2
	Total	20.4	19.6	14.0	38.6	20.5	19.7
AREOCENTRIC CHARACT.	Mass	----	0.1	0.5	----	0.1	----
	Radius	1.2	1.1	2.8	----	1.1	1.0
	Total	1.2	1.2	3.3	----	1.2	1.0
MARTIAN ATMOS. & SURFACE CHARACT.	Density	2.2	2.4	16.5	----	2.2	2.4
	Composition	1.2	----	3.6	----	1.2	----
	Pressure	0.4	0.4	1.6	----	0.5	0.4
	Temperature	----	0.1	0.3	----	0.1	----
	Winds	0.3	0.3	2.3	----	0.3	0.3
	Sandstorms Bearing Strength	0.1	0.1	0.4	----	0.1	0.1
	Total	4.2	3.3	24.7	----	4.4	3.2
TOTAL		25.8	24.1	42.0	38.6	26.1	23.9

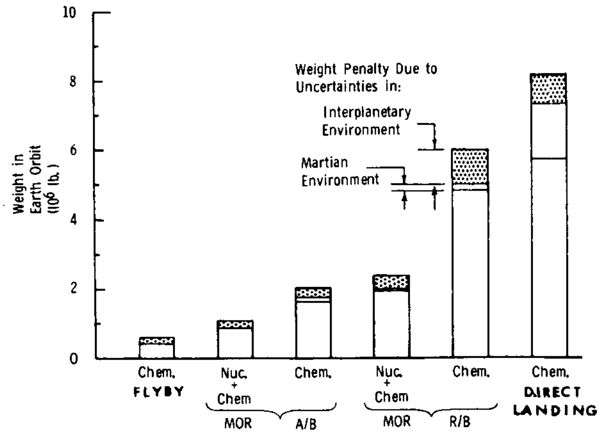

Figure 7. Comparison of Mission Mode Weight Sensitivities to Environmental Uncertainties

sensitivity to the atmospheric uncertainties, the direct mode is nearly six times as sensitive as the nominal mission. The only significant effects on the flyby mission are the meteoroid environment uncertainties; however, this mode is the most sensitive to this environment. The use of nuclear propulsion and variations in launch year were both found to result in negligible changes in sensitivity in terms of Earth-orbital weight.

DATA ACQUISITION REQUIREMENTS

The sensitivity study outputs were employed to establish the environmental data acquisition requirements shown in Table 6. For an arbitrarily selected Earth-orbital weight penalty of 0.1%, the accuracy to which each environment must be known to stay within this limit is shown and compared to the current accuracy or uncertainty. The current-accuracy/required-accuracy ratio was employed to obtain the relative data acquisition priorities for the critical environments shown in Table 6. The aerobraking and retrobraking MOR missions differ in priorities only insofar as the atmospheric composition does not affect retrobraking entry. The different order of the direct landing mission priorities reflects the more severe atmospheric and surface property effects on this mode. The flyby mission is sensitive only to the interplanetary environments as noted previously.

Table 6. Data Acquisition Priorities and Measurement Accuracies Required to Support Manned Mars Missions

ENVIRONMENTAL PARAMETER	CURRENT UNCERTAINTY (% OF NOMINAL VALUE)	REQUIRED ENVIRONMENT ACCURACY (in % of Nominal Value) FOR 0.1% PENALTY IN MANNED MISSION EARTH ORBIT WEIGHT				RELATIVE DATA ACQUISITION PRIORITY BASED ON Current Uncertainty / Required Accuracy			
		LANDER MISSIONS			FLYBY	LANDER MISSIONS			FLYBY
		Orbital Rendez.		Direct		Orbital Rendez.		Direct	
		Aerobrak. Entry	Retrobrak. Entry	Lndg		Aerobrak. Entry	Retrobrak. Entry	Lndg	
Meteoroids (Flyby)	2 x 10^5 (10^7)	40	40	290	230	1	1	1	1
Atmos. Density	40-300	16	16	2	---	2	2	2	---
Atmos. Composition	100-300	8-26	---	3-8	---	3	---	3	---
Planet Radius	1.7	0.16	0.19	0.09	---	4	3	5	---
Corpuscular Radiation	700	171	184	167	233	5	4	7	2
Surface Atmos. Pressure	400	105	100	28	---	6	5	6	---
Winds	200	62	61	9	---	7	6	4	---
Surface Atmos. Temp.	20	33	33	6	---	8	7	9	---
Planet Mass (Gravity)	4	7	8	2	[illegible]	9	8	10	---
Surface Bearing Strength	75	187	187	21	---	10	9	8	---

Environmental parameters such as meteoroids and the Martian atmosphere will be subject to temporal and spatial variations. In the case of meteoroids, data are required for design purposes on the occurrence of the low-flux/high-mass particles. If "conventional" panel detectors are employed, most data for the flux-mass distribution must be gathered on lower mass particles and extrapolated to the masses of interest if rational exposure times and detector areas are to be realized. One or more large interplanetary meteoroid probes will be required. A greater number of probes will be required for adequate sampling of the probable variations in the atmospheric and surface properties of Mars. If the atmospheric variations occur primarily at high altitudes, most of these probes could be hard landers. A comprehensive survey of instrument capabilities and availabilities is presented in the Final Report, SID 65-1172.

IMPLICATIONS TO CURRENT UNMANNED PROGRAMS

CURRENT PROGRAM CAPABILITIES

Previous JPL and S&ID studies were employed to project the data acquisition capabilities of Voyager. Although no experiments have been assigned as yet to the announced flights, candidate scientific payloads were considered, and probable data acquisition and transmission rates were estimated. Comparison of projected Voyager capabilities and the manned mission sensitivity analyses results indicated that the Voyager can adequately define all the environments with the possible exception of the meteoroids. The hard and soft lander probes required to "map" the Martian atmospheric and surface characteristics probably could be accommodated within the announced missions (which begin with the 1971 and 1973 orbiter/lander missions, followed by the 1975 and 1977 flyby missions, which incorporate larger soft landing capsules). Assuming likely scientific instrumentation and communications equipment developments, the higher projected data rate requirements probably can be realized within the confines of the presently envisioned configuration.

The panel areas and weights required, if a conventional approach to defining the meteoroid environment (i.e., impact detectors) is employed, are beyond the capability of the currently configured Voyager. Supplementary missions, flown with vehicles employing large panel areas designed specifically to sample the meteoroid environment, would be required for adequate definition of this parameter. Several concepts, which employ the use of magnetometers or other electromagnetic devices to sense the electromagnetic fields associated with meteoroid encounters, were considered. These would be compatible with the presently configured Voyager; however, extensive development is indicated to demonstrate their feasibility.

NEW UNMANNED SYSTEM REQUIREMENTS

New systems requirements derived from the Voyager capabilities analyses therefore indicate the need for interplanetary meteoroid probes. The magnetometer approach, if feasible, readily could be incorporated into the Voyager bus payload for minimal weight; a new meteoroid probe system is necessary if the brute-force approach to meteoroid detection is employed. A number of vehicles designed to maximize deployed panel area were configured employing the S-IB/Centaur launch vehicle. Various panel configurations were examined and sized to provide sufficient area so that statistically valid data could be obtained to enable extrapolation to the larger mass particles where the expected flux density is too low for direct measurement. Tradeoffs were performed between mission profiles requiring larger propellant loadings to attain longer exposure times in the 1.5 to 2.2 A.U. region and the utilization of larger panels, weights, and the proper distribution of panel area and thickness (penetrability), so that extrapolation of the flux-mass data (measured for small particles) to the larger particle masses would minimize the variance, or uncertainty, in establishing the flux of larger particles. In order to accomplish the latter tradeoff, it was necessary to return to the manned mission probability-of-penetration criterion and to compare the resulting structural weight penalty of the manned spacecraft as a function of the uncertainty in the environment. It was found that the number of probe missions, and the degree of uncertainty in the environment, could be related to the resulting structural weight penalty of a manned mission (Figure 8). Assuming that adequate additional precursor-type data on the low-mass/high-flux portion of environment became available (i.e., Mariner-type detectors), the meteoroid environment conceivably could be defined by a single probe exposing on the order of 10^2 to 10^3 m^2 of panel area for 250 days to the degree required for manned system design; it should be noted, however, that because of the probable temporal-spatial variations in this environment, additional probes might be desirable to enhance confidence in the results.

SIGNIFICANT PROBLEM AREAS AND RECOMMENDATIONS FOR FUTURE WORK

A number of areas for future research became apparent as a result of the study. Investigation of the manned system sensitivities disclosed shortcomings in the data needed to predict the effects of atmospheric composition (i.e., CO_2 and A) on radiative heating during entry and on possible communications breakdowns, as well as the effects of large mass meteoroid particles impacting multi-layered, heavy structural shields at high velocities. In both cases, further experimental work is recommended to verify the estimated sensitivities, and, more importantly, to provide a basis for design optimization of future manned interplanetary spacecraft, whatever the

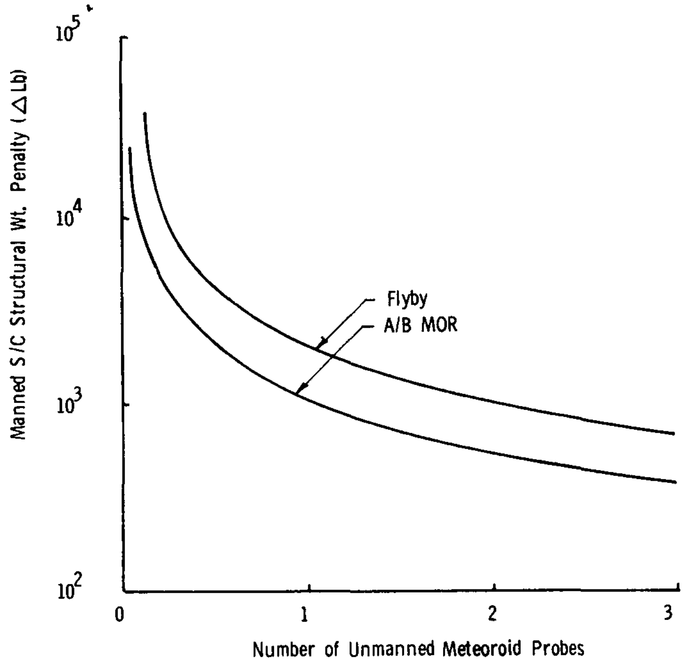

Figure 8. Effect of Unmanned Meteoroid Probes on Manned Spacecraft Structural Weight for Maximum Meteoroid Flux

environments may be. Additional development and testing is necessary to validate the high projected parachute glide ratio (i. e., three), and the high velocity deployment and flight characteristics, particularly in high winds, of the MEM retardation system.

Considerable controversy exists on the dangers of heavy particle radiation; more extensive analytical and experimental studies are required to define clearly the biological implications. Consideration of possible pathenogenic bio-life hazards of the planet which would endanger the lander crew was beyond the scope of this study; detection and characterization of extraterrestrial life must await the data returned by Voyager.

In the area of unmanned systems, data compaction techniques, the applicability of retrodirective arrays or pointing techniques to enhance antenna directionality (and gain), and development of high power transmitters (and power supplies) for unmanned soft landers must be exploited fully to maximize Voyager data rates. The problem of adequately "mapping" the suspected interplanetary meteoroid environment with a minimum number of missions at a rational cost is a challenge. Concepts which might apply (e. g., magnetometers or other electromagnetic devices to sense solar plasma or magnetic field disturbances induced by meteoroids) warrant attention in the immediate future. Further study is needed to establish the tradeoffs between ultimately designing the manned missions for the uncertain environments and paying the weight and performance penalties as compared to the cost of reducing or eliminating these uncertainties by developing new systems to acquire the requisite data. Such tradeoffs, which again unfortunately were beyond the scope of this study, should consider the resulting probability of mission success as a function of how well the environment could be defined, as well as cost and schedule. A comprehensive picture, therefore, could be obtained to reveal the monetary worth of additional unmanned missions beyond, or in conjunction with Voyager, as a function of the development time, costs, and risks which would be assumed on manned missions based upon designs which employed "incompletely" characterized environments.