STUDY OF UNMANNED SYSTEMS
TO EVALUATE THE MARTIAN ENVIRONMENT

Volume IV. Summary

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The present report is comprised fo four volumes:

Volume I	Sensitivity Analysis
Volume II	Experiment Requirements
Volume III	Unmanned Spacecraft Design
Volume IV	Summary

1. INTRODUCTION

Previous manned Mars mission studies have indicated that many gaps exist in our knowledge of the environment of Mars, to the extent that basic manned mission modes cannot be selected with certainty and specific designs prepared, because of lack of realistic design criteria. Advanced planning studies for this mission will also be handicapped until more complete data on the planet become available.

As a result, a study of the sensitivity of the manned Mars mission to the Martian and Cismartian environment, and a definition of the experiments and unmanned spacecraft to acquire the necessary environment measurements, was completed for the NASA Ames Research Center under Contract NAS 2-2478.* The general goals of the study were to: identify those environmental factors that can influence the planning and design of the manned Mars mission, and to establish qualitative and quantitative relationships between uncertainties in the environmental factors and the design of the manned systems; designs of unmanned systems to obtain the necessary environmental information were prepared.

2. OBJECTIVES

The objectives of the study are:

1. Identify the Martian environmental factors that influence the planning and design of manned Mars mission systems.
2. Establish the sensitivity of the manned Mars mission system to uncertainty in the Martian and Cismartian environment.
3. Define experiments and instrumentation required to make the necessary measurements of the significant environmental factors.
4. Design unmanned systems to evaluate the Martian and Cismartian environment, based on the priorities established from the sensitivity analyses.

3. ASSUMPTIONS AND METHODS OF APPROACH

Characteristics were established for typical Mars stopover missions for the range of opportunities from 1975 through 1990, nominally using the Mars orbiting rendezvous technique. The spacecraft was assumed to depart from a low-altitude Earth orbit and, after reaching Mars, decelerate into a circular parking orbit using either aerodynamic or retrobraking. After a stopover of 10 days, the spacecraft departs for Earth after recovering the Mars excursion module with its landing party. Alternate modes involving flyby of the planet without stopover, and direct descent to the surface of Mars were considered.

*This contract was performed under the cognizance of Mr. Ray Savin, OART Mission Analysis Division, at the Ames Research Center.

Chemical and nuclear propulsion configurations were included. Overall trip times varied between approximately 400 and 450 days. Weight scaling laws were developed for representative vehicle systems and used as a basis for selecting optimum combinations of calendar dates, flight time and total trip time to minimize total spacecraft weight in Earth orbit.

Having selected typical mission profiles and representative manned spacecraft systems, nominal Martian and Cismartian environments were established, and upper and lower limits estimated for each factor. The principal environmental factors considered were: atmosphere, nuclear cosmic radiation environment, and meteoroids. Although these are the most important factors, several other elements were found to exert an influence on the design of the manned Mars vehicle, for example, winds encountered by the lander craft; the degree and nature of the ionosphere, which can influence communications; the biocontamination environment, which can influence the operations of the lander teams; topological features, which have a strong bearing on the selection of lander sites and the mobility of surface rovers; and a possible ionization layer near the surface of Mars, which can influence the design of electrical equipment in the excursion module. The establishment of ranges of uncertainties in various environmental factors was a principal difficulty in the study.

A sensitivity analysis was performed to determine the changes in overall vehicle weight in Earth orbit to uncertainties in the environment. These sensitivity factors were combined in an appropriate manner to give the overall change in vehicle weight in Earth orbit to specific changes in the Martian or Cismartian environment.

Based upon the results of the sensitivity analyses, the requirements for instrumentation and experiments to acquire the necessary measurements of the Martian environment were established. A list of instruments was prepared to accomplish the required experiments. Existing or developed experiment techniques were specified where these appeared to be adequate, however, in many cases new experimental techniques were called for, particularly in the adequate definition of the meteoroid environment. Necessary and related ground-based experiments, particularly on the effects of nuclear radiation shielding, were also strongly indicated.

The final phase of the study was devoted to the design of unmanned spacecraft to acquire the necessary measurements in the Cismartian and Martian environments. The designs considered include those suitable for launch with the Atlas Agena systems (Mariner IV), extending up to the larger spacecraft suitable for launch with the Saturn IB Centaur-class systems. Various vehicle modes were considered including flyby, flyby with entry capsule or survivable landers and orbiters with entry capsules or survivable landers. Recommendations were then made for a sequence of unmanned missions to acquire the necessary environmental data measurements.

4. RESULTS

A brief summary of results achieved is given below.

Solar Cosmic Radiation

Solar raidation environment models were established and uncertainties estimated. The possible radiation dose to be encountered by the crew as a result of galactic and solar cosmic radiations is indicated in Chart I for a shield thickness of 22 gm/sq cm. Uncertainties in the sources and in the calculations are indicated.

For a year's mission the use of an average flare is justified, and the associated statistical uncertainty in the number of flares is about 15 percent. As noted, one relativistic flare of the February 1956 type was assumed; although this type of flare is rare, it is possible that two such flares would be experienced, introducing an uncertainty of about 40 rads into the expected dose. The primary source of dosage in the trip will be due to 3^+ flare events. A source uncertainty of about 15 rads may be assumed, and a calculation uncertainty of about 60 rads (based upon a survey of several shield effectiveness calculation techniques and upper limits on the amount of secondaries). A total integrated dose of about 179 rads could be experienced from this source.

The total trip dose, nominally 172 rads, could reach 330 rads. If the radiation dose is to be reduced to the original value of 172 rads, shielding thickness should be increased from 22 to 35 gm/sq cm. The spacecraft gross weight in Earth orbit would increase by 3.5 percent as a result.

Additional uncertainties in shield weight are introduced by the assumed crew recovery factor. A 90 percent recovery factor reduces shield thickness to 10 gm/sq cm. A nominal dose with no recovery increases shield thickness to 22 gm/sq cm with a spacecraft weight penalty of 4.8 percent.

Indications are that a 90 percent recovery factor is optimistic because radiation data upon which the recovery factor is based are not applicable to manned planetary missions. It is strongly recommended that a comprehensive Earth-based experiment program be initiated to resolve these uncertainties.

Meteoroid Environment

Meteoroid environment models were established and possible uncertainties in these models assumed based upon the data currently available, principally from Earth-based radar and visual observations of meteoroids. Principal uncertainties lie in the extension of the meteoroid flux models to the flux levels and velocity spectra applicable to interplanetary space between Earth and Mars and to the near-Mars environment.

CHART 1

RADIATION DOSAGES

EVENTS	INTEGRATED DOSE	SOURCE UNCERT.	CALC UNCERT	INTEGR DOSE PLUS UNCERT -
DOSE ON MARS SURFACE				
GALACTIC COSMIC RAYS/WEEK	0.17 RAD	-	-	-
SOLAR COSMIC RAYS/WEEK	0.25 RAD	-	-	-
ONE RELATIVISTIC FLARE	40.0 RAD	-	-	-
TOTAL WEEKLY TRIP DOSE	40.4 RAD	± 40 RAD	+ 24 RAD	104.4 RAD
DOSE IN TRANSIT				
GCR	9 RAD PER YR	-	+ 5 RAD	14 RAD
SCR	104 RAD PER YR	± 15 RAD	+ 60 RAD	179 RAD
TOTAL YEARLY DOSE (RAD)	153	± 55	+ 89	297
TOTAL TRIP DOSE (RAD)	172	± 58	+ 100	330

The influence on the weight of the manned Mars vehicle of uncertainties in the meteoroid models of approximately one order of magnitude were determined. Assuming that the velocity spectra upon which the shielding models are based is correct, vehicle weight penalties can amount to about 7.5 percent. In view of the significant effect on manned system weight applicable experiments must be devised and performed on precursor missions to reduce this uncertainty.

Basically new approaches to the measurement of the meteoroid environment must be established in order to acquire meaningful data for shielding design criteria. The approach to the measurement of the meteoroid environment proposed by TRW (meteoroid flash detector) can yield data on the masses, velocities, and heliocentric trajectory characteristics of the particles, for sizes of particles applicable to the design of the manned system. This approach should be explored for application to precursor missions.

Atmospheric Environment

Atmospheric entry corridors were established for the various atmosphere models and uncertainty in these models (10 to 132 mb). The width of the corridor was established for each model as a function to lift-to-drag ratio capability of the vehicle, so that lift-to-drag ratio requirements could be established for various degrees of uncertainty.

A summary of the corridor capabilities for a vehicle lift-to-drag ratio of 0.3 is given in Chart 2 for an exit velocity of 11,000 fps, which applies to braking into a low altitude circular orbit. Estimates of allowances for rolling maneuvers have been calculated and found to be negligible, assuming sensors capable of detecting relatively low deceleration levels and a 10-second rolling time.

CHART 2
CORRIDOR PERFORMANCE (L/D = 0.3)

MODEL	UNCERTAINTY	CORRIDOR (km)
SCHILLING	NONE	87.2
2	NONE	74.5
3	NONE	66.0
2	10 PERCENT UNCERTAINTY IN SCALE HEIGHT	69.2
2	10 PERCENT UNCERTAINTY IN DENSITY	71.8
2	10 PERCENT UNCERTAINTY IN SCALE HEIGHT AND DENSITY	66.4
2	WORST COMBINATION OF SCHILLING AND MODEL 3 SCALE HEIGHTS	53.7
2	WORST COMBINATION OF SCHILLING AND MODEL 3 DENSITIES	49.4
SCHILLING -3	WORST COMBINATION OF SCHILLING AND MODEL 3 ATMOSPHERES	21.9 (46.4)*

*L/D = 0.4

The corridors for the nominal cases range from 87 km for the upper limit atmosphere and 66 km for the low density (10 mb) atmosphere. If the Model 2 atmosphere is combined in the most adverse manner with the Schilling Upper Limit or Model 3 atmospheres, the corridor is reduced from 74 km to 49 km. If the worst combination of Schilling Upper Limit and Model 3 atmospheres is assumed, the corridor reduces to approximately 22 km (this value increases to 43 km if vehicle lift-to-drag ratio is increased to 0.4).

The corridor values attainable with aero entry systems of moderate lift-to-drag ratio are considerably greater than corridors required for onboard navigation systems, which were shown in prior studies to be of the order of 5 km. Hence, entry vehicles of moderate lift-to-drag ratio capabilities can generate ample corridors for navigation systems using state-of-the-art sensors.

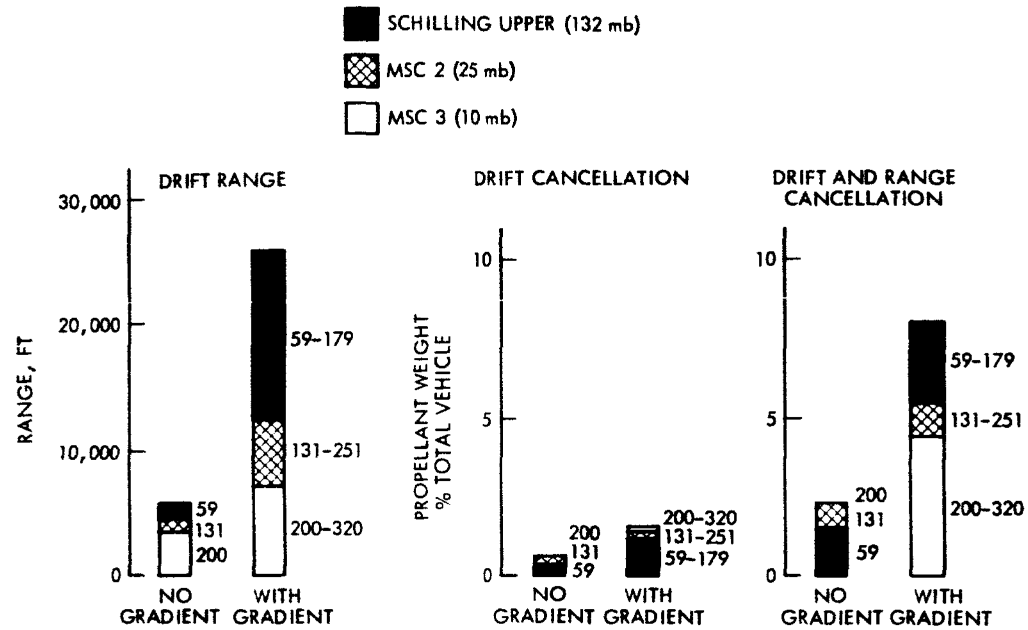
Surface Properties

Winds up to 200 fps were assumed in the analysis of lander performance. Drift velocities at ground impact range from 36 to 76 fps for the Schilling Upper Limit (132 mb) and Model 3 low density (10 mb) atmospheres, respectively, for the extreme model atmospheres. In all cases the excursion module main parachute does not come into full equilibrium with the wind, particularly in the case of the low density atmosphere.

Drift ranges are appreciable for the Schilling atmosphere with maximum wind gradients, although drift range can be nulified by gliding the parachute, which has ample lift-to-drag ratio capability for this purpose. Alternatively, drift range can be cancelled by translational rockets. Propellant weights to cancel drift velocity and drift range are indicated in Chart 3. The penalties are small except for the Schilling Upper Limit atmosphere with maximum wind gradient.

CHART 3

EFFECT OF WINDS



Ascent trajectories were computed to determine the effects of the various atmosphere models on ascent performance. The results indicate that the principal effect on the performance of the ascent maneuver was orbital altitude, which is sensitive to density and was selected to give a minimum life on orbit of 100 days. The gross weight of the vehicle required to return a given payload to orbit was reduced from 58,700 pounds to 45,400 pounds over the range of atmospheres considered. Drag losses were relatively sensitive to uncertainties in the density and scale height of the atmosphere, but have a generally small effect on overall performance.

Surface Ionization Layer

Because of the possible enhanced ionization near the surface of Mars, electrical breakdown may be encountered unless specific measures and test procedures are taken to avoid it. The breakdown may occur in CW or pulsed electromagnetic radiators, at the frequencies given in Chart 4. All power generating systems on surface landers should be tested for breakdown in CO_2 - N_2 atmospheres at reduced pressures.

Should the surface ionization reach levels of the order of 10^6/sq cm the validity of the data on the atmosphere to be acquired by Mariner IV may be in doubt. This effect is severe primarily for Argon atmospheres, but can be serious for nitrogen atmospheres for short periods after solar events. Performing the occultation experiment at two radio frequencies will determine whether or not surface ionization is present.

CHART 4

ELECTRICAL BREAKDOWN

- CW BREAKDOWN (10 MB ATMOSPHERE)

FREQUENCY (MEGACYCLES)	BREAKDOWN POWER DENSITY (WATTS/CM^2)
10,000	500
3,000	40
1,000	6

- PULSED BREAKDOWN (10 MB ATMOSPHERE)
  BREAKDOWN AT 1000 WATTS/CM^2
  - (1) PULSE DURATION 3×10^{-6} SEC
  - (11) FREQUENCY 8500 MEGACYCLE
- ALL POWER GENERATING SYSTEMS FOR MARS MISSION SHOULD BE TESTED FOR BREAKDOWN IN CO_2, N_2 ATMOSPHERES AT REDUCED PRESSURE

Surface Properties

The results of a landing stability analysis indicate that surface slope angle has a strong influence on leg diameter if the coefficient of friction is high (see Chart 5). This effect can be reduced by reducing the coefficient of friction. An increase in drift velocity does not have a large effect on gear design.

Reducing sink velocity has a pronounced effect, and should be achieved if possible by equipping the lander vehicle with either mechanical or electronic vertical sink sensors. The impact velocity of 9.8 fps corresponds to a rocket shutoff altitude of 4 ft.

CHART 5

LANDING STABILITY ANALYSIS

Case	Vert Vel (fps)	Horiz Vel (fps)	Slope (deg)	Decel (⊕ g)	Coeff of Fric	Leg Diam (ft)
1 (Nom)	19.7	3.3	10	6	1.0	43
2	19.7	3.3	20	6	1.0	54
3	19.7	3.3	30	6	1.0	65
4	19.7	6.6	10	6	1.0	46
5	9.8	3.3	10	6	1.0	33
6	19.7	3.3	10	6	0.5	35
7	19.7	6.6	10	6	0.5	35
8	9.8	3.3	30	6	0.5	37
9*	19.7	3.3	10	6	1.0	43

*DOWNHILL LEG STRIKES OBSTACLE

Reducing the coefficient of friction has a pronounced effect on stability, particularly for large slope angles. Although the coefficient of friction of the natural terrain may not be known, an artificial coefficient of friction can be provided by proper selection of crushable materials in the pads. Materials for this purpose yield under relatively low shear loads, but remain stiff to normal loads.

An obstacle on the downhill slope has little effect on system stability. However, an encounter with an obstacle during free fall would cause a significant increase in angular velocity, and dangerously impair the chances for a stable landing.

Soil parameters that affect the performance or trafficability of the surface rover include terrain slope, bumps and mechanical features such as wheel width, wheel diameter and vehicle weight. Soil properties also affect the trafficability of the surface rover, including the friction of the soil, the soil density, and cohesion and sinkage factors. Generally speaking, the trafficability or drawbar pull is a function of the rolling resistence, which is determined by the coefficient of friction of the soil; by the drag of the soil, which is a function of its coefficient of cohesion; by the work of compaction, which is a function of the sinkage factor of the soil; and by the bulldozing resistance, which is a complex function involving several propertieis. Hence, trafficability is not a function solely of the surface bearing strength of the soil.

Typical rover vehicle designs were anlayzed for sensitivity to various soil and terrain properties (see Chart 6). The results indicate that the coefficient of friction does not have a large effect on trafficability except at low values; soil density on the other hand may have a significant effect if density values increase to 0.08 to 0.10 psi. Low values of k_c, which are typical of very weak soils, have a disastrous effect on draw bar pull. Likewise, a very small degree of cohensiveness would reduce trafficability to 0. The sinkage factor, n, also has a significant influence.

Sensitivity to vehicle design parameters indicates that effective wheel diameter has a significant influence on trafficability, but that the weight of the vehicle and the wheel width are not critical.

If cohesive type soils are anticipated, indeed, soils with any degree of cohesiveness, a track-type vehicle should be considered.

In view of the sensitivity of the vehicle performance to uncertainties in soil properties, vehicle designs should be adopted which are least sensitive to adverse soil conditions, that is, track-type vehicles. Although some sacrifice in range would be involved with this vehicle design, the vehicle would be able to accommodate a wider range of soil conditions.

Manned Vehicle Sensitivity Summary

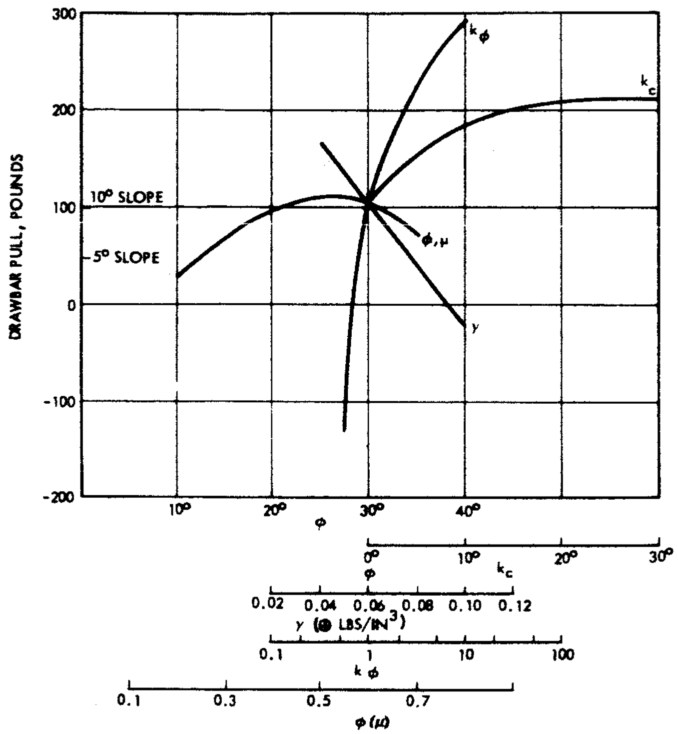
The results of the analyses of mission-environment interactions were combined with the sensitivity factors to obtain overall effects on spacecraft gross weight. The results are shown in Chart 7.

Uncertainties in the atmosphere of the order of 10 percent will cause small changes in the design weight of the main spacecraft aero entry system. Under the worst possible conditions, the aero entry system would be required to accommodate both the Schilling Upper Limit atmosphere <u>and</u> the Model 3

CHART 6

TRAFFICABILITY SENSITIVITY

k_ϕ, k_c, ϕ, γ



TRAFFICABILITY SENSITIVITY
W, b, D

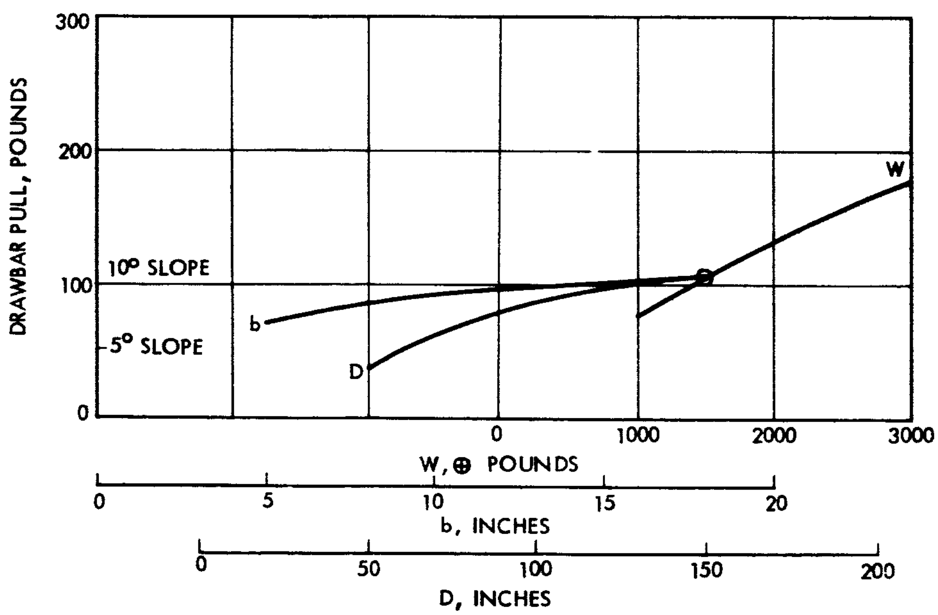


CHART 7

SENSITIVITY ANALYSIS

C ARRIVE EARTH - AERO
A DEPART MARS - CHEM
C ARRIVE MARS - AERO
A DEPART EARTH - CHEM

% CHANGE IN EARTH ORBIT WEIGHT

	AERO AT MARS			RETRO AT MARS		FLYBY		DIRECT	
	CACA		NANA	CCCA	NNNA	CA	NA	CACA	NANA
	1982	1986							
UNCERTAINTY IN ATMOSPHERE									
CAPTURE	1.8	1.4	1.3	0	0			0.2	1.7
MEM	2.5	2.3	2.1	1.7	2.1	--	--	4.8	3.8
COMBINED	4.3	3.7	3.4	1.7	2.1	<1.0	<1.0	6.0	4.6
EFFECT OF WINDS									
50% WINDS (GRADIENT)	0.3(0.4)*	0.3(0.4)*	0.3(0.3)*	0.2(0.2)*	0.3(0.3)*			2.4(2.8)*	2.4(2.8)
MAX WINDS (NO GRADIENT)	0.3(0.2)	0.3(0.2)	0.3(0.2)	0.2(0.1)	0.3(0.2)			2.3(1.6)	2.3(1.6)
MAX WINDS (GRADIENT)	0.7(1.1)	0.7(1.0)	0.6(0.9)	0.5(0.7)	0.6(0.9)			5.6(8.0)	5.6(8.0)
MAX WINDS (GRADIENT, NO RANGE MAKEUP)	0.2(0.2)	0.2(0.2)	0.1(0.1)	0.1(0.1)	0.1(0.1)	<1.0	<1.0	1.3(1.2)	1.3(1.2)
MICROMETEOROID DOUBLE THICKNESS	7.5	5.4	4.8	8.9	10.1	14.6	7.9	21.4	20.8
MSC/STL (Cometary)	7.4	5.7	4.8	6.8	7.1	10.0	6.5	14.5	14.3
SOLAR COSMIC RADIATION HALF THICKNESS (90% RECOVERY)	-4.8	-6.5	-3.9	-6.5	-5.0	-9.1	-9.1	-5.2	-5.8
UNCERTAINTY IN SHIELD EFFECTIVENESS & FLUX	3.5	4.7	2.8	4.7	3.6	6.6	6.6	3.7	4.2
TOTAL UNCERTAINTY	8.3	11.2	6.7	11.2	8.6	15.7	15.7	8.9	10.0

*Sch Upper Limit

atmosphere. The resulting increase in spacecraft gross weight would be about 1.8 percent. The excursion module is also sensitive to the atmosphere. Assuming the worst combination of atmospheres the resulting increase in spacecraft gross weight due to allowances in the excursion module design are approximately 2.4 percent. The combined effects of the atmosphere on the spacecraft aero capture system, excursion module decelerator, and ascent propulsion system result in increases in spacecraft gross weight in Earth orbit of about 4.2 percent.

The effect of winds on the overall spacecraft gross weight are small, being less than 1 percent in all cases (except for the direct landers).

The effects of altering the meteoroid protection on spacecraft gross weight are complicated by the multiple shields required for the aero entry system: shields must be placed around the aero entry system during transit to Mars, and jettisoned prior to entry at Mars. A second, inner meteoroid shield is required to protect the spacecraft during the return passage. Combining the total shield weight effects due to uncertainties in the meteoroid environment of approximately 1 order of magnitude, results in a total increase in spacecraft gross weight of about 7.5 percent.

Effects of uncertainties in solar cosmic radiation on spacecraft weight were found to be more severe than any of the environmental factors considered. For the nominal environment and a maximum crew recovery factor the shield thickness is approximately 10 gm/sq cm. If no recovery factor is assumed the shield thickness increases to 22 gm/sq cm, resulting in a spacecraft gross weight penalty of 4.8 percent. In the worst situation of a maximum radiation dose and no crew recovery the shield thickness is increased to 35 gm/sq cm, resulting in a weight penalty of 8.3 percent.

Experiments and Mission Payloads

A priority list for experiments is given in Chart 8 in the order of their importance: solar cosmic radiation environment, meteoroid environment, and atmospheric properties and biocontamination. The priorities were established on the basis of design feasibility, system weight, mission operations, and mission system development requirements.

The experiments are grouped by mission mode, in Chart 9, including interplanetary bus/orbiter, descent capsule and lander. The weights for each experiment are tabulated, and the accumulated payload weights obtained by summing the experiments in the order of their priorities.

Essential data on the atmosphere of Mars can be obtained by three different modes, by spectrometers aboard the orbiting spacecraft, by low weight descent capsules, and by lander-based experiments. Spectrometer measurements from orbiters are relatively complex to perform and are subject to a good deal of interpretation. The accuracy of defining the atmosphere properties in this manner is lowest of the three methods but may be adequate for purposes of designing a manned system. A descent capsule of very modest weight and experiment payload is capable of defining the atmosphere to good accuracies and is particularly useful because of information gained about the altitude variations of the properties of the atmosphere.

CHART 8

	DESIGN FEASIBILITY	WEIGHT PENALTY	OPERATIONAL CRITERIA	DEVELOPMENT CRITERIA	EXPERIMENT ACCURACY
ATMOSPHERE					
THERMO / PRESSURE / TEMPERATURE / CHEMICAL COMP	2	2	1	1	50%
ELECTRICAL PROP	-	2	-	-	
IONOSPHERE	-	2	2	-	
SURFACE IONIZATION	1	1	1	1	
DIURNAL AND SEASONAL EFFECTS	2	2	1	-	
METEOROLOGY					
WINDS	2	1	2	-	50%
CLOUDS	-	-	1	-	
DUST STORMS	1	1	1	-	
CLIMATE	1	-	1	1	
SURFACE CONDITIONS					
SURFACE COMP	2	1	2	2	
SOIL PROPERTIES	2	1	2	2	25%
TOPOGRAPHY	1	1	2	2	
RADIOACTIVITY	1	-	1	1	
SEISMIC ACT	1	-	-	-	
AREOLOGY	(SEE SURFACE CONDITIONS)				
BIOLOGY	2	1	2	2	
RADIATION ENVIRONMENT					
COSMIC RAD SURFACE	2	1	2	1	20%
COSMIC RAD - CISMARTIAN	3	3	3	3	
UV RAD AT SURFACE	1	-	2	-	
METEOROID ENVIRONMENT	2	3	1	1	60%
GENERAL					
ALBEDO - ABSORP	1	1	-	1	
MAG FIELD	1	-	-	-	
GRAV FIELD	1	1	1	-	

3 HIGH PRIORITY
1 LOW PRIORITY

CHART 9

BUS/ORBITER

	RATING	WEIGHT (LBS)	WEIGHT SUMMATION (LBS)
PARTICLE FLUX (HIGH ENERGY	3	10	10
PARTICLE FLUX	3	2.5	12.5
ION CHAMBER	3	1.3	13.8
TRAPPED RADIATION DETECTOR	3	4	18
MAGNETOMETER	3	5	23
METEOROID ENVIRON. (STL)	3	5	28
MICROMETEOROID ENVIRON	3	8	36
TV	3	17	53
UV SPECTROMETER	2	22	75
IONOSPHERE EXP	2	3	78
IR RADIOMETER	1	3	81
IR SPECTROMETER	1	29	110

DESCENT CAPSULE

ACCELEROMETERS	3	1.0	1.0
PRESSURE, TEMP	3	0.5	1.5
GAS COMPOSITION	3	2.0	3.5
TV	3	15	18.5

LANDER

SOLAR COSMIC RADIATION	3	1.3	1.3
CELL GROWTH	3	4	4.3
TURBIDITY AND PH	3	4	8.3
TV	3	17	25.3
MASS SPECTROMETER	2	6	31.3
ANEMOMETER	2	1	32.3
UV DETECTOR	2	0.5	32.8
SURFACE IONIZATION	2	1.5	34.3
SURFACE PROPERTIES	2	13	47.3
SEISMOMETER	2	8	55.3
VISIBLE INTENSITY	1	0.5	55.8
X-RAY DIFFRACTOMETER	1	10	65.8
CORE AND MILL	-	30	95.8

The surface properties experiment should be given priority on the initial landings because of the implications on the design of the surface landers and rover vehicles. These data can be acquired with relatively modest experiment weights, and need not be augmented with complex soil analyzer equipments. A miniturized surface rover, properly instrumented, would constitute a valuable surface properties experiment.

Meteorological experiments involving the use of balloons deployed into the atmosphere yield data of marginal importance in relation to the weight and complexity of the experiments, and probably should not be seriously considered for incorporation into the initial landers. Careful attention must be given to photographic mapping exercises designed to yield cloud cover information because of the serious requirements imposed upon the spacecraft communication system.

Photographic mapping exercises are of vital importance for the scientific studies of the planet as well as for gathering important topological information necessary to select landing sites for the initial manned missions. However, it should be noted that the mapping experiments dominate the spacecraft data gathering, processing and transmission requirements, and must be carefully planned to avoid excessive requirements. High resolution photo capability is mandatory for landing site selection. A photo-mapper package should be considered for an early orbiter mission.

Bio-contamination is a most difficult environmental factor to analyze, and experiments are difficult to propose that are meaningful to the manned mission. Decontamination procedures for the lander crews will be required, and offer a better approach to the problem than do repeated experiments to define the existence and nature of possibly hostile life forms.

Unmanned Spacecraft Systems

Preliminary designs indicate that an orbiter bus weighs approximately 1850 pounds, a survivable lander 700 pounds, and a photo mapper package for use aboard an orbiter approximately 400 pounds. Eighty pounds of experiments are included or can be supported on the bus/orbiter, and 56 pounds on the landers; these scientific payloads include all priority experiments as defined during prior phases of the study.

An effective spacecraft system can be launched by an Atlas Centaur plus kick stage booster. It is possible using this launch system to inject an orbiter plus lander plus high resolution mapper packages in 1971 and 1973; however, in 1975 the payload capability is sufficient to launch an orbiter only, with intermediate resolution mapper capability.

5. RELATION TO NASA PROGRAMS

The results of the study will influence other NASA programs in the following manner:

1. Experiment payloads have been defined for unmanned precursor probes to acquire measurements of the most significant elements of the Martian and Cismartian environment that strongly affect the design of the manned Mars mission. Consideration should be given to these measurement requirements so that the forthcoming unmanned probes to the planet Mars can be equipped with the experiments needed to make a realistic design and planning program for the manned Mars mission systems.

2. Experiment requirements which are beyond the present state of the art have been proposed, particularly for the measurement of the meteoroid environment. Possible approaches to the measurement of the meteoroid environment based upon new experimental techniques developed at TRW Systems are outlined, and should be given consideration for incorporation into payloads aboard early unmanned flights to Mars. In addition, serious consideration should be given to experiment techniques for a better resolution of the density and scale height of the Martian atmosphere, which has a strong bearing on the feasibility of retrobraking and parachute descent within the Mars atmosphere. Experiment techniques for the measurement of the atmosphere to the accuracy and confidence level required, necessitate the injection of an entry capsule into the Martian atmosphere. Early consideration should be given to the accomplishment of this measurement.

3. It is apparent that the properties of the Martian atmosphere may have a significant effect on the design of unmanned precursor spacecraft, hence, experiments should be conducted at an early date to establish meaningful design criteria for these vehicles as well as for the early manned mission vehicles.

4. The interaction between the interplanetary missions and the presently planned or in-development manned programs should be established as early as possible. Unfortunately, these interactions cannot be defined to a satisfactory degree unless the feasibility of operational modes such as the use of aerodynamic braking in the Martian atmosphere is established. Hence, the feasibility of certain manned planetary mission modes that have a strong effect upon the spacecraft design should be established so that the interrelationship between manned planetary and existing manned programs can be established.

5. The analyses of the sensitivity of manned systems to interplanetary radiation and meteoroid environment have been analyzed, with results that are directly applicable to long duration manned missions in Earth-orbiting stations, or on lunar base stations. Since many of these interactions are identical, experiments designed to make necessary measurements of the Cismartian environment will be directly applicable to the Earth-lunar manned programs as well.

6. SUGGESTIONS FOR FURTHER WORK

The following recommendations for further work are made:

1. A need for extensive Earth-based experiments to determine the effectiveness of solar radiation shielding, and man's tolerance to the solar radiation environment are recommended. The solar radiation environment potentially has a very strong effect upon the feasibility and weight of the manned Mars mission system. Research programs should be established to determine meaningful design criteria in this area.

2. Several areas in which new instrumentation should be developed in order to be able to perform meaningful measurements to the Martian and Cismartian environment are indicated, particularly in the area of defining the meteoroid environment, measurement of surface properties, and TV mapping for selection of landing sites.

3. A bascially new approach to the measurement of the meteoroid environment must be established in order to acquire meaningful data for shielding design purposes. In particular, data on the masses, velocity, and trajectory characteristics of the particles, for sizes of particles applicable to the design of the manned system should be obtained. The approach suggested by TRW Systems for the measurement of meteoroid flux and trajectory characteristics in the vicinity of Mars should be examined further.

4. The experimental measurements of meteoroid environment should be supported with analytical studies to determine the nature and origin of the meteoroid particles. In particular, the efforts described herein to establish the possible contribution of aerodynamic capture of meteoroids in the vicinity of planets should be extended to other planets and to the implications on the meteoroid environment in interplanetary space. In particular, new statistical estimates of the velocity spectra of meteoroids should be made based upon the comprehensive studies of trajectory characteristics of the meteoroids.

5. The design of a surface property experiment using a miniature surface rover should be examined. Since the performance of such a rover is directly affected by surface properties, the surface properties can be deduced by the careful observation of the surface rover as it traverses a typical surface terrain. This type of an experiment is capable of covering a far greater area than can be achieved by core and drill experiments or conventional surface bearing strength experiments in the immediate vicinity of the lander.

6. Careful analysis should be given to the interaction of a possible surface ionization layer on the results of a flyby occultation experiment to determine the properties of the atmosphere. Such analysis would indicate precisely the interrelationship between the possible surface ionization layer and the surface density and scale height as predicted by an occultation experiment. The results of this analysis would help to determine possible discrepancies between measurements of the properties of the atmosphere by Earth-based spectrometers and by the occultation experiment.

7. Much more consideration should be given to the study and development of bio-contamination aspects of the manned lander missions. Decontamination techniques should be established through analytical and experimental programs in order to establish procedures and techniques suitable for application to the manned Mars mission. This is particularly desirable in view of the fact that unmanned precursors will not be able to establish the existence in nature of possible pathogenic life forms on Mars with the satisfactory degree of confidence to permit man to land on the surface without having recourse to decontamination procedures.