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MISSION AND SURFACE INFRASTRUCTURE CONCEPTS

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ABSTRACT

This paper identifies and discusses several types of manned Mars surface missions, including sorties, fixed-base, and hybrid missions, which can be envisioned as potentially desirable approaches to the exploration and utilization of Mars. Some of the advantages and disadvantages of each type are discussed briefly. Also, some of the implications of the types of missions on the surface elements' designs are discussed briefly. Typical sets of surface elements are identified for each type of mission, and weights are provided for each element and set.

INTRODUCTION

The types of surface infrastructure elements which are needed are heavily dependent on the nature, duration, and timeframe of the mission. For manned Mars flyby missions or manned Mars orbiter missions, no habitable surface elements would be necessary, but unmanned probes and/or robotic surface explorer vehicles would no doubt be required.

For manned landings (on Phobos, Deimos, or Mars), the types of required infrastructure elements can vary significantly with several factors. One is the timeframe of the mission. For early missions, there is likely to be less emphasis on "permanent" types of infrastructure elements and more emphasis on the elements which are "bare essentials" for landing men and returning them safely. Technology levels will be lower on early missions, and hence equipment on early missions will be less efficient than that on later missions. Hence, weight, volume, power, and other resources will be more critical, which will allow less infrastructure equipment to be taken per flight than on later missions. The only practical types of manned Mars landing missions are those which can be done during favorable planetary alignment periods. The favorable alignments (reference 6) are of either the conjunction or opposition type, and occur about every 2 years. The conjunction-type opportunities require about a 1-year stopover time at Mars, and the opposition-type missions require about a 60-day stopover. The energy requirements for longer or shorter stopover times increase severely for even a few days' change from the optimum times stated. The initial manned Mars landing mission may be of the type having a 60-day stopover, to minimize cost, risk, and complexity of the mission. The opposition-type missions usually have a Space Vehicle (SV) weight penalty compared to the conjunction-type missions, but this is not too great for all-aerobraking concepts.

SURFACE MISSION OPTIONS

There are at least three types of surface exploration/utilization options which are possible (Figure 1): (1) sortie; (2) moving-base; and (3) fixed-base options. In the sortie approach, each mission is directed to a different landing site, with short-distance, limited-round-trip surface traverses being made in that general vicinity for exploration and science investigation purposes. In the fixed-base mode, successive missions are directed to the same site, with fairly extensive round-trip surface traverses being made from the base. The moving-base mode is a hybrid of the other two modes, wherein two or more missions may be directed to one location, then the entire base is moved to another location, etc.

The sortie approach provides flexibility for exploration of surface areas having widely different terrain, climate, etc., on different missions, since widely separated landing locations can be chosen each time. Sortie missions would be more limited in scope and duration than the other missions, since each mission must furnish all its own equipment and resources (no carry-overs from previous missions). The variety of surface features which can be explored during each sortie mission is limited by the landing location, the range and capability of the surface traverse vehicle, and the duration of the mission. The mission complexity of sortie-type missions is probably lower than the others (especially if the scope and duration of the mission is more limited), and the equipment complement is smaller.

The fixed-base concept provides the least variety of surface features across missions (unless surface traverse distances can be extremely great). It does offer significant advantages, however, in the buildup and re-use of equipment from mission-to-mission. It would be

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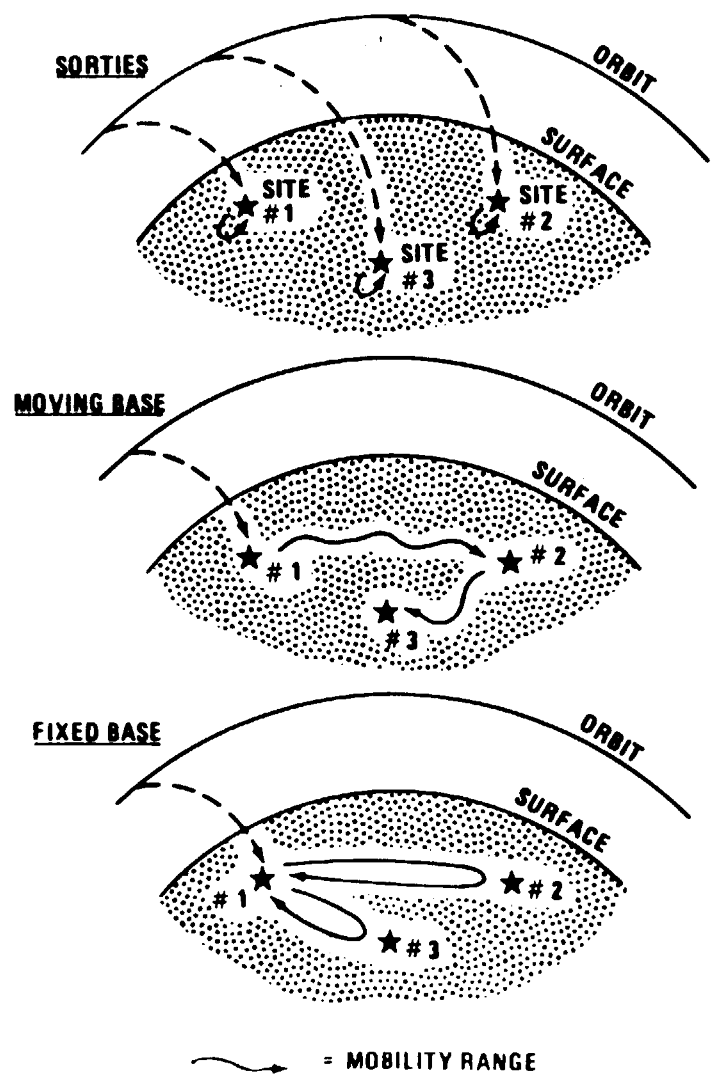
FIGURE 1. MARS SURFACE OPTIONS & COMPARISONS

MARS SURFACE OPTIONS



SURFACE OPTION CONSIDERATIONS

- MISSION COMPLEXITY
- SCIENCE VARIETY & VALUE
  - PER MISSION
  - ACROSS MISSIONS
- SAFETY
- RE-USE OF SURFACE EQUIPMENT
- SUPPORT OF MFG./CONSTR.
- COST

necessary to use this mode for any long-term construction or manufacturing activity.

The moving-base mode lies somewhere between the other two modes in almost every respect, having some of the advantages and disadvantages of both.

In actual practice, the missions may shift from one option to another, and occasionally back again. For example, the earliest missions will probably be of the sortie variety, with later missions trending towards the moving-base or fixed-base variety. It is likely, however, that an occasional sortie mission to a different location might be desired, even after a fixed-base was established at one location. This might be desirable for science/exploration reasons, or to begin establishment of another base.

Many factors will help determine the selection of the surface options to be used. The total number of missions in the program and the flight frequency will have a significant bearing on this. The availability of systems and resources (e.g., flying vehicles and in-situ-manufactured propellants) to allow rapid and easy movement of equipment over great distances would strongly influence selection of surface options. For cases where there is a gap between successive habitation or use of surface equipment previously landed, the advantage of buildup and reuse of such equipment must be traded against the possibility that the equipment might have become damaged or otherwise become inoperable during the interim period.

SURFACE INFRASTRUCTURE ELEMENTS

Design of the surface infrastructure elements must be closely coupled to design of the other elements of the SV (e.g., Mission Module) in some cases. This is strongly dependent on Mars surface stopover duration. For example, on a mission which only has a 60-day stopover, if the lander (e.g., Mars Excursion Module (MEM)) equipment were designed independently from the orbiter (e.g., MM equipment), the lander would only operate for 60 days out of a total mission time of 2 years. It would be a much better use of the lander systems to utilize them for a greater part of the 2-year mission. If, however, the mission were one having a 1-year stopover, there might be more concern about the lifetime of the lander systems if they were operated for the full mission duration.

The division of the crew between Mars surface and Mars orbit operations will be a factor in design of the lander. On an early sortie mission of the 60-day-stopover variety, half the crew may be sent to the surface in the lander and the other half may stay in the orbiter. On a 1-year-stopover mission, the entire crew may be sent to the surface. Obviously, the split of the crew accommodations equipment between lander and orbiter would vary significantly between these two types of missions.

An artist's concept of a Mars base is shown in Figure 2. Some of the infrastructure elements shown here (greenhouses, Habitability Modules, etc.) are more applicable to the fixed-base surface option, but other equipment (rover, lander/departure stages, etc.), are applicable to any of the surface options. More discussion is provided on this subject in later paragraphs. Several of the infrastructure elements are depicted with the large-diameter aerobraking shells still attached, but these shells could be removed if necessary. It might be desirable to remove these large structures for potential use as living quarters, storage shelters, etc. An artist's concept of living quarters made from such structures is shown in Figure 3.

Table 1 identifies a set of typical surface elements for each type of surface option. As shown, the sortie concept would be the most simplistic of the three, the fixed-base concept would be the most complex, and the moving base concept would lie somewhere between the other two concepts in terms of the amount and complexity of equipment required. Where items have checkmarks enclosed in parentheses, an early version of the item would probably be needed or desired as an element of that type of surface option.

The lander/departure element would be the MEM, or a growth version of it. A number of different concepts of the MEM have been defined in past studies, including Apollo Command Module derivatives, biconic vehicles, etc. Data for some of these are shown, along with the MEM defined in this study, in references 1, 7, and 8. In the fixed-base mode of operation (and possibly the moving-base mode), the spent MEM descent stages could be used as storage areas, or could possibly be joined together to serve as a habitability volume.

FIGURE 2. MARS BASE

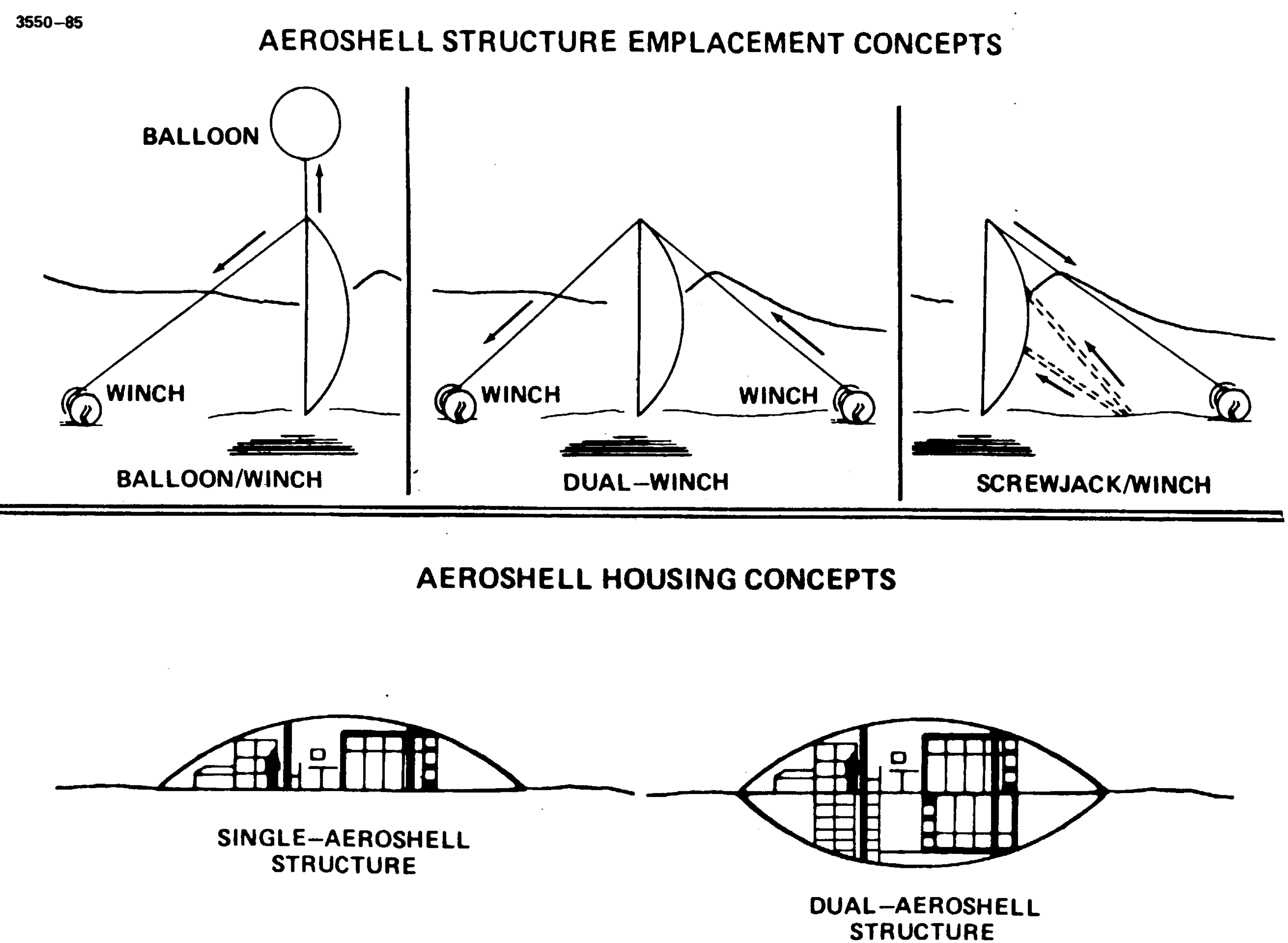


FIGURE 3. AEROSHELL UTILIZATION CONCEPTS

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TABLE 1. SURFACE COMPLEMENTS

TYPICAL SURFACE ELEMENTS	SORTIE	MOVING–BASE	FIXED–BASE
• LANDER/DEPARTURE	√	√	√
• HAB FACILITY		(√)	√
• LAB FACILITY		(√)	√
• POWER FACILITY			√
• GREENHOUSE			√
• IRPU'S		(√)	√
• ROVER			
– SMALL	√		
– LARGE		√	√
• "POGO" VEHICLE	?	√	√
• AIRPLANE			?
• DRILLS/MINING	(√)	(√)	√
• CONSTRUCTION		(√)	√
• SOIL MOVER		(√)	√
• CRANE	(√)	(√)	√
• PORTABLE SCIENCE	√	√	√
• COMMUN. RELAY	√	√	√

(√) LIMITED OR EARLY VERSIONS

The early habitability and laboratory facilities might be modules derived from Space Station (SS) modules, but later ones may be made from other elements such as the large aerobraking shells as previously noted (Figure 3) or from in-situ-produced materials ("concrete", etc.) The power facility item might be a nuclear reactor or nuclear isotope power generator; other possibilities would include fuel cells operated from in-situ-produced reactants and some sort of solar-energy system. Reference 2 describes some of these options in more detail.

The greenhouse would be an element only of the fixed-base surface option. A definition of it is provided in reference 3. For the greenhouse, an inflatable plastic structure on a pad could be used. The structure would be optically transparent with a UV filter. It would be pressurized and would require a night-time cover. Due to the thin atmosphere, no support structure would be required, even during high winds.

The In-situ Resource Production Units (IRPU's) are elements which would produce such products as propellants, breathable gases, fuel cell reactants, or water. Typical units have been defined in references 2 and 3. The small rover is an upgraded version of the MSFC-developed Lunar Roving Vehicle (LRV) which was used on several Apollo missions. It is discussed in reference 4. This vehicle requires the passengers to wear space suits, and it has a limited traverse range and cargo capacity.

The large rover is essentially a small Hab/Lab Module on a tracked undercarriage. It has a traverse capability on the order of 100 km and 30 days, and is piloted by the crew from within the module. The Molab was a vehicle of this sort, which is discussed in reference 4. The "pogo" vehicles are propulsively-powered vehicles which can vary in size from a 1-man backpack to a platform capable of transporting modules or other large elements. These are discussed in reference 4. These elements have the advantages of being insensitive to obstacle size during traverses, require no horizontal takeoff and landing strip, and can traverse great distances in a short time. They will require a large amount of propellant, however, and are thus more practical if a local source of propellant can be utilized.

The airplane is a remotely-piloted vehicle which will contain science equipment and will be used to explore regions which would be difficult or impossible for man to explore directly. One disadvantage it has is the requirement for a takeoff and landing strip. The airplane is discussed in references 4 and 9.

The "drills/mining" equipment item listed in Table 1 is intended to include only the larger size equipment of this nature. Smaller drills are included under the "portable science" item. The larger equipment would be used for taking deep core samples, for implanting deep seismic charges and sensors, etc. The mining equipment would be used for digging tunnels, for extracting minerals, etc.

The construction item includes equipment necessary to manufacture building materials as well as equipment needed for erecting or emplacing structures. A soil-mover of some sort will be needed for the fixed-base missions, to support habitability element emplacement, construction activities, road-building, trench digging and filling, etc. A limited-capability version would be desired on moving-base missions. Types of equipment which have been suggested in past studies for this category are draglines, road-graders, backhoes, etc. A crane could be used to lift and emplace any of the larger elements (Hab Modules, etc.) delivered to the surface and would be used in the construction activity, as required. The crane would be used on fixed-base missions, with smaller versions used on other missions.

The portable science equipment includes a myriad of small items of equipment which might be carried in the small rover vehicle or used in the vicinity of the lander, to gather and analyze geological samples, to make weather or environment measurements, etc.

The communications relay is not really a surface element, but is an element which may be required in orbit to support the surface activities. In manned missions to the surface, some elements will be left in Mars orbit for the return trip to Earth. These elements will have communications equipment built in, and can serve as the communications relay for the surface activities when needed. Unmanned missions may or may not have such equipment left in Mars orbit, and so may require that a separate element be provided.

WEIGHTS

In order to estimate weights for the total complements of equipment for the various surface options, assumptions were necessary in a few key areas, and are listed below:

(1) Sortie: 3 men/60 days surface stay/10 kw elect. power

(2) Moving-base: 6 men/1 year surface stay/25 kw elect. power

(3) Fixed-base: 12 men/1 year surface stay/100-200 kw elect. power

Table 2 provides weight data for some of the key elements previously discussed. The top part of the table summarizes the portable science equipment items, some of which might be taken along on surface traverses. The bottom part of this table lists weights for miscellaneous larger elements.

Table 3 provides a weight summary of the equipment necessary to be delivered to the surface of Mars for each of the three surface mission options. Reference 5 uses these weights as requirements for delivery of equipment to the Martian surface, and shows the rates of buildup of cumulative delivered weight to the Martian surface and to LEO as a function of time, for various SV options.

TABLE 2. EQUIPMENT WEIGHTS

PORTABLE SCIENCE EQUIPMENT	WT (LBS)
GRAVIMETER	26
X–RAY DIF/X–RAY FL	99
ELECTRON MICROSCOPE	115
GAS CHROMATOGRAPH	33
SPECTROMETER	33
MAGNETOMETER	64
SMALL DRILL	81
CENTRIFUGE	32
POLARIMETER	13
pH METER & REAGENTS	32
REFRACTOMETER	9
THERMOMETERS	2
SCALES	12
REFRIGERATOR	27
INCUBATOR	21
OVEN/STERILIZER	42
WORK BENCH	55
MICROMANIPULATOR	19
ULTRASONIC CLEANER & SOLVENTS	106
AGITATORS & BLENDORS	8
HAND TOOLS	22
SAMPLE HOLDERS & CONTAINERS	49
ANEMOMETER	15
EXPLOSIVES	344
MICROTOME	19
RTG POWER SUPPLY	87
BAROMETER	15
SEISMOMETER	8
SOIL BEARING STRENGTH	25
POWDERING, DISSOLUTION, OPTICAL ANAL	70
EM PROPERTIES	52
THERMAL PROPERTIES OF SOIL	24
IONOSPHERE STRUCTURE PROPERTIES	88
SOIL SAMPLE BOX	17
TOTAL	1664

MISCELLANEOUS ITEMS	
LARGE DRILL	910
ROVER	600
AIRPLANE	660
MOLAB	3400
CRANE	450
EARTH MOVER	450

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TABLE 3. SUMMARY WEIGHTS OF SURFACE MISSION OPTIONS

	TYPICAL WEIGHTS REQUIRED (LBS)		
TYPICAL SURFACE ELEMENTS	SORTIE	MOVING–BASE	FIXED–BASE
LANDER/DEPARTURE	128000	200000	256000
HAB FACILITY	--	112000	162000
LAB FACILITY	--	50000	50000
POWER FACILITY	--	8730	350000
IN SITU RES PROD UNIT	--	750	2250
PORTABLE SCIENCE	832	1664	1664
TRANSPORTATION ELEMENTS ROVER			
– SMALL	600	600	600
– LARGE	--	--	3400
AIRPLANE JETPACK DERIVATIVE	--	660	660
LARGE DRILL	910	910	910
SOIL MOVERS	--	--	900
GREENHOUSE	--	--	500
TOTALS	130342	375314	828884

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