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THE "CASE FOR MARS" CONCEPT

J.R. French
Jet Propulsion Laboratory
Pasadena, California

ABSTRACT

The Case for Mars workshops conducted in 1984 (Ref.1) dealt with a program to establish a permanent scientific research base at Mars. The participants, some of whom are listed in Appendix A, viewed a Mars base as the much needed long-term focus for the space program. A permanent base was chosen rather than the more conventional concept of a series of individual missions to different sites because the permanent base offers much greater scientific return plus greater crew safety and the potential for growth into a true colony. This paper summarizes the results of the workshops.

The Mars base will strive for self-sufficiency and autonomy from Earth. Martian resources will be used to provide life support materials and consumables. The Martian atmosphere will provide a convenient source of volatiles: CO_2, N_2, and water. Rocket propellant, fuels for surface and air vehicles and possibly power plants, breathable air, and fertilizers will be manufactured from the Mars atmosphere. Food will be grown on Mars using Martian regolith as a growth substrate.

A permanent human presence will be maintained on Mars beginning with the first manned landing via a strategy of crew overlap. This permanent presence will ensure safety and reliablity of systems through continuous tending, maintenance, and expansion of the base's equipment and systems. A permanent base will allow the development of a substantial facility on Mars for the same cost (in terms of Earth departure mass) as a series of temporary camps. A base equipped with surface rovers, airplanes, and the ability to manufacture consumables and propellant will provide far more extensive planetary exploration over a given period of years than would an Apollo-style approach.

SCIENCE AND EXPLORATION

A human presence on Mars will accelerate and enhance scientific exploration of the planet. Humans have unique capabilities which are difficult or impossible to automate. These features, along with the inherent flexibility of people, make the in-situ human the best possible tool for Mars science.

Prior to a manned landing, automated precursor missions are required to investigate the Mars environment and select an optimal location for the permanent base. The base must be located in an accessible area suitable for a landing field, and must be near areas of scientific interest. Martian resources will be used for base operations. Thus the chemistry, mineralogy, and the state and distribution of volatiles on the Martian surface, particularly water, must be assessed globally and locally. The meteorological environment of Mars must be studied to forecast the likelihood of dust storms in the base location, and characterize the local, regional and global weather.

A precursor program to accomplish these objectives includes the planned Mars Geoscience Climatology Orbiter (MGCO). An orbiter mission to provide high resolution images of candidate base site areas is also needed. A network of surface weather stations supported by low resolution orbital imaging of cloud features is desirable for several Mars years in advance of the manned mission. A series of unmanned rover and sample return missions is needed to collect samples of Mars materials from prospective base sites and bring them to Earth for analysis.

An alternative possibility is for the precursor missions to be manned. The crew for the first few (say three) landings would evaluate the most promising sites and bring back samples. The next mission (fourth?) would then return to the best site to begin base establishment. In this scenario, unmanned rover/sample return would probably be unnecessary since the manned missions would do the same thing. A high resolution orbital precursor might be sufficient to choose the first landing sites.

Assuming unmanned precursor missions, the initial human landing at the base site will certify the safety and habitability of the base location, provide ground truth about the presence of water and other raw materials for base operations, set up resource extraction equipment, and establish meteorological stations in support of future manned landings. Permanent scientific research facilities will be the next priority, after these survival technologies are deployed. Facilities for research in atmospheric science will provide weather observation and reporting as well as climate, atmospheric dynamics, and atmospheric chemistry studies.

Geoscience research capabilities will include surface exploration, seismic and drilling equipment, manned and teleoperated rover vehicles, and laboratory equipment for geochemical and petrological study of samples. Life science research on Mars will search for present or past life, supported by appropriate laboratory capabilities.

MISSION STRATEGY

The mission strategy is directed toward support of a permanently inhabited Mars base with crew rotation and resupply at each Earth-to-Mars launch opportunity. In order to minimize the total mass departing Earth orbit to support the base and to provide Earth return capability for the crew being rotated home, a Mars powered flyby and return to Earth is performed by the Deep Space Habitat vehicle (Figures 1a and 1b). Arriving crew members separate from the habitat in Mars Shuttle vehicles (Figure 2) while on the approach leg. The Shuttles proceed to Mars and land at the base using a combination of aerodynamic braking and rocket thrust (Figure 3). To get into an Earth - return trajectory, the deep space habitat vehicle performs (unmanned) a propulsive maneuver as it flies by the planet. Returning crewmembers depart Mars in their Shuttles which rendezvous with the Habitat vehicle on the outbound leg departing Mars. In preparation for the next habitat flyby (two years later), the Mars Shuttles at the base are refueled using $CO\text{-}O_2$ propellant manufactured from Mars CO_2 (Figure 4).

While the newly arrived crew takes up its duties at the base, the returning crew rides back to Earth in the Deep Space Habitat. Arriving at Earth, the crew enters the Mars Shuttles and aerobrakes down to the Space Station, and the Habitat vehicle makes a final use of its propulsion system to enter a loose elliptical orbit around Earth from which it is later recovered for refurbishment and reuse.

Each mission of the Habitat/Mars Shuttle assembly delivers fifteen crew members to Mars. In the early stages of the program, a lesser number (say nine) of the base crew will return to Earth. This will not only provide growth but also a highly desirable continuity in base operation.

VEHICLES

Three new major vehicles are involved in execution of the mission strategy developed in this paper. These are: Mars Shuttle, the Deep Space Habitat, and the Earth Departure Stage.

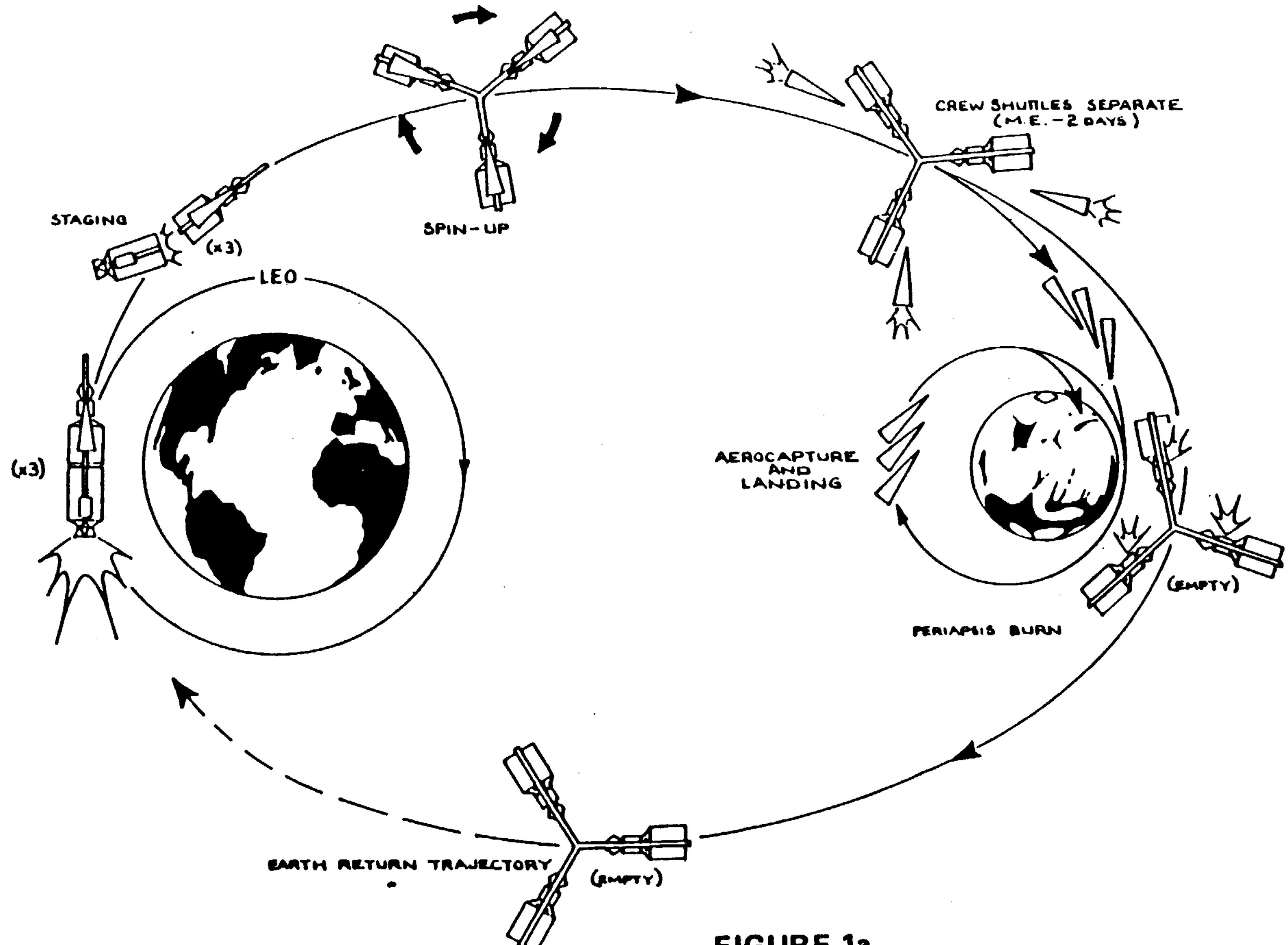
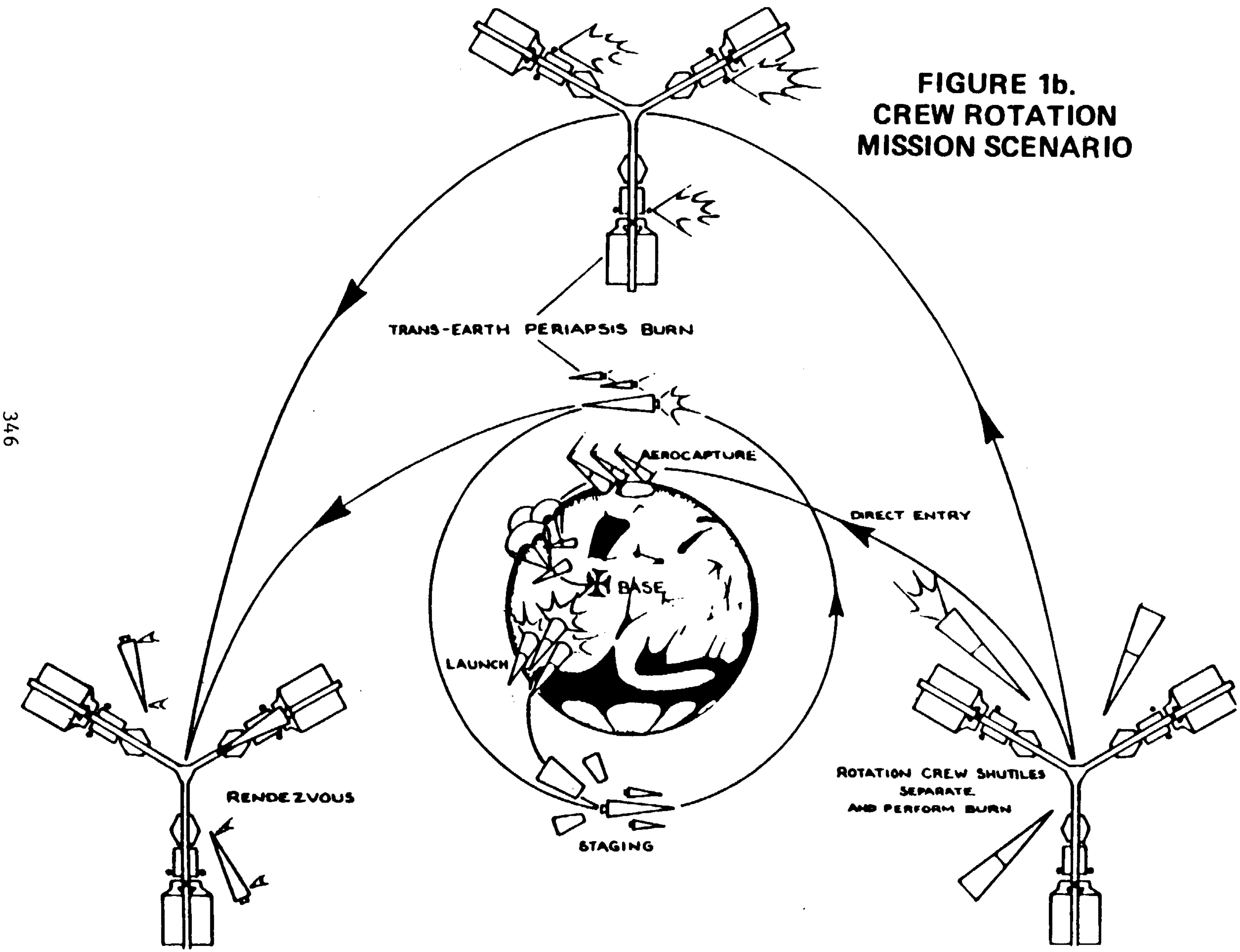


FIGURE 1a
INITIAL MISSION SCENARIO

FIGURE 1b. CREW ROTATION MISSION SCENARIO



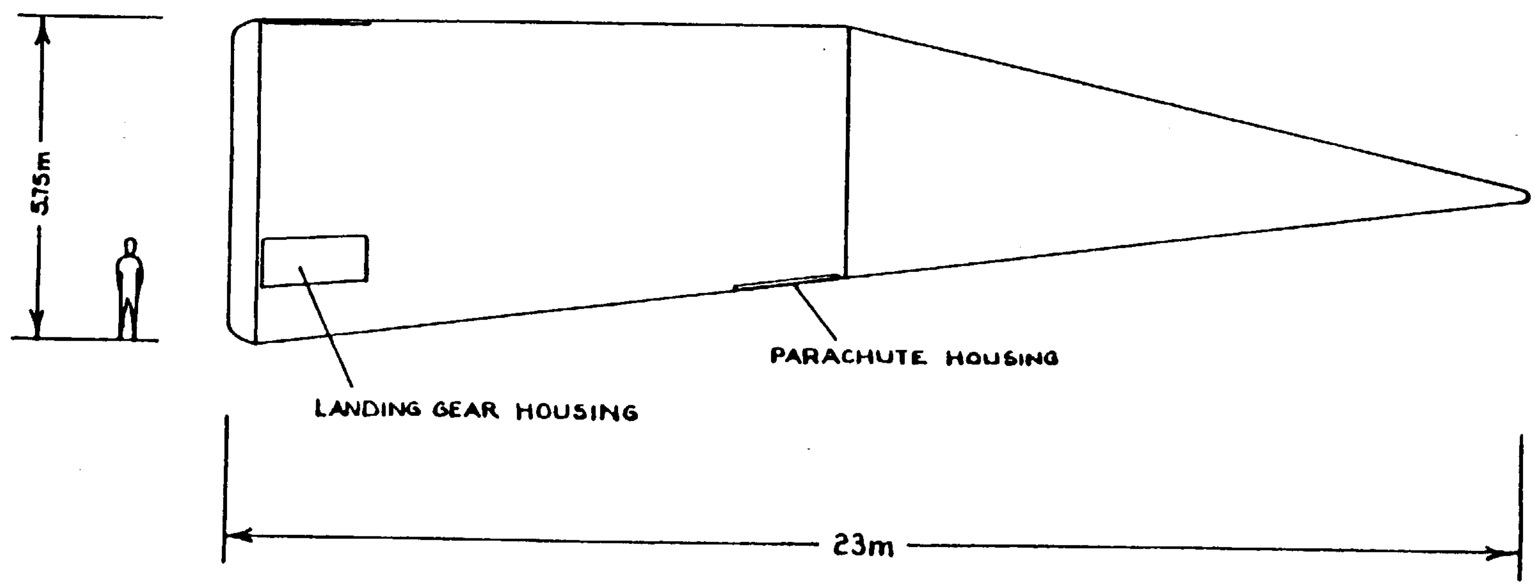


FIGURE 2
MARS SHUTTLE VEHICLE

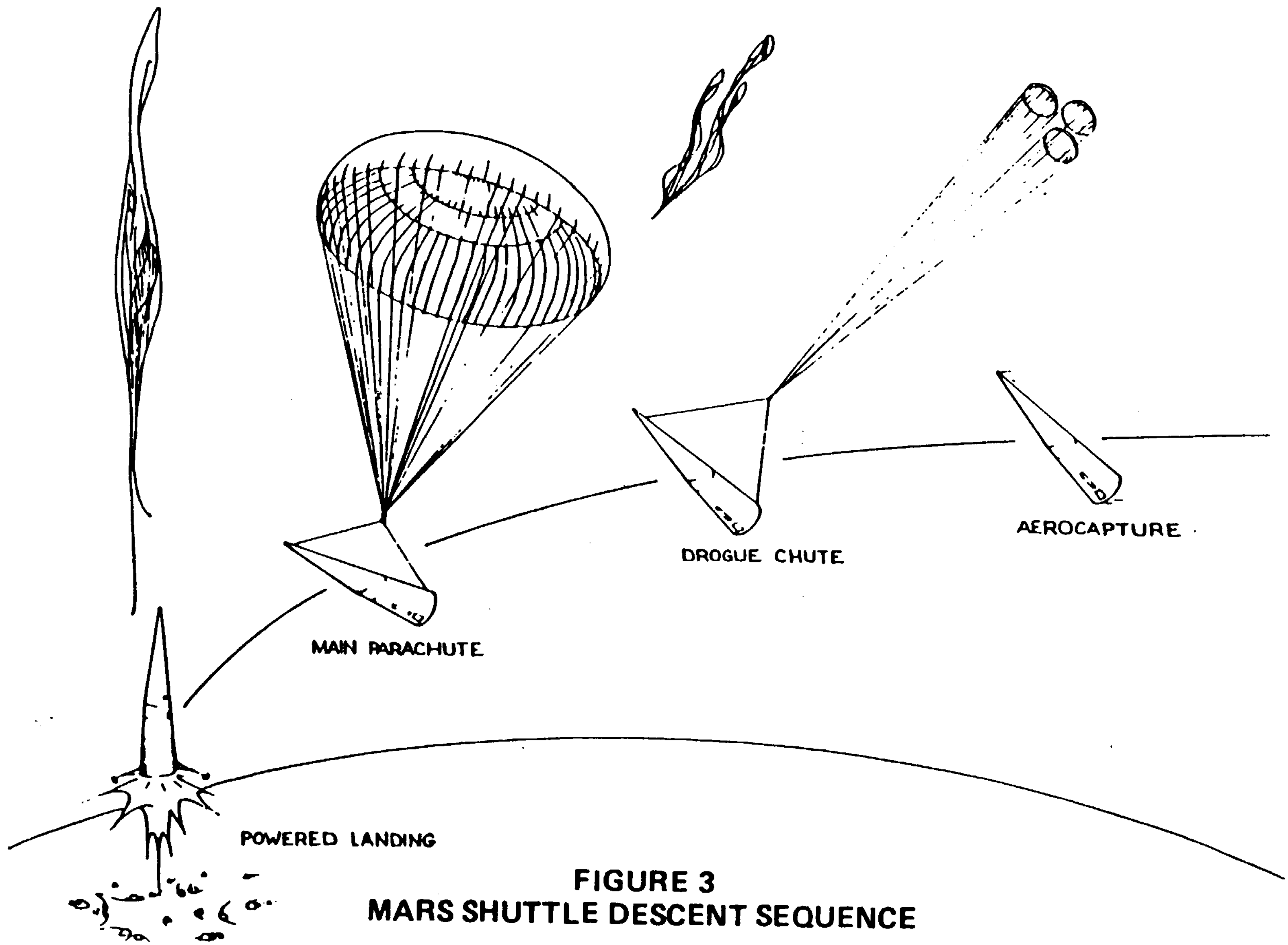
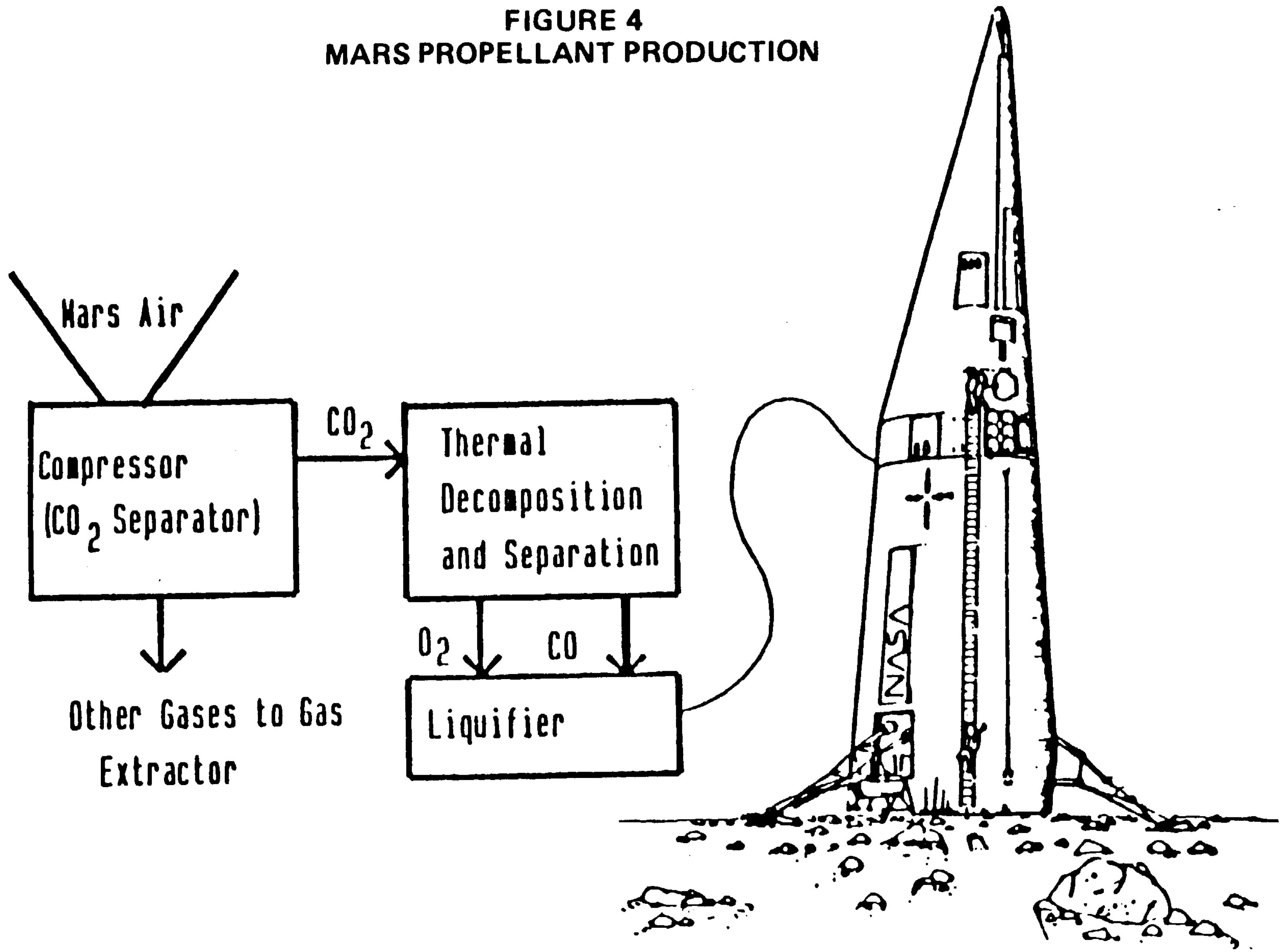


FIGURE 3
MARS SHUTTLE DESCENT SEQUENCE

FIGURE 4
MARS PROPELLANT PRODUCTION



The Mars Shuttle vehicles, as the name implies, are used to transport arriving crew members to the Martian surface from the Deep Space Habitat and to bring homeward bound crew members from Mars to the Habitat. At the end of the return journey, they are also used to bring the crew to the Space Station. For the descent to Mars, the Shuttles depend upon aerodynamic braking to slow them from an entry velocity of 5 to 6 km/sec down to a velocity suitable for parachutes. To provide the required accuracy and control, a relatively high lift - to - drag ratio is needed. A biconic airframe (shaped like a slightly crooked cone) provides this capability. Two versions of the Mars Shuttle are needed; one is a one - way unmanned cargo vehicle (Figure 5) the other a manned version which can be reloaded with propellant on Mars for the return (Figure 6). The initial manned version will be a two stage vehicle, since the $CO-O_2$ propellant manufactured on Mars is of low performance. Later in the program, higher Isp propellants may allow a single stage vehicle. Protection from aerodynamic heating would be provided by a reusable heat shield similar to that used for the Space Shuttle.

The Deep Space Habitat (Figure 7) is composed of three identical sections. Each section is assembled at the Space Station, and consists of two Space Station modules, life support system, consumable storage, and a propulsion system. All this is attached to a boom and tunnel assembly, terminating in a docking adapter which allows the three sections to dock into a pinwheel configuration that is rotated to provide artificial gravity. A crew - type Mars Shuttle is docked along each boom. Each section (with its Mars Shuttle) is boosted separately on a Mars-bound trajectory from low Earth orbit. The three sections rendezvous and dock on the way to Mars, remaining linked for the remainder of the mission.

The Trans-Mars injection stage (Figure 8) is used to boost the Habitat/Mars Shuttle assemblies out of Earth orbit and into the Mars transfer trajectory. It uses adaptations of the Space Shuttle Main Engine for thrust. Tankage for the liquid oxygen/liquid hydrogen propellant is modular to allow each tank to be launched in the Space Shuttle for on-orbit assembly of the stage.

Cargo versions of the Mars Shuttle travel to Mars without being attached to the Habitat. To provide power and other services to the

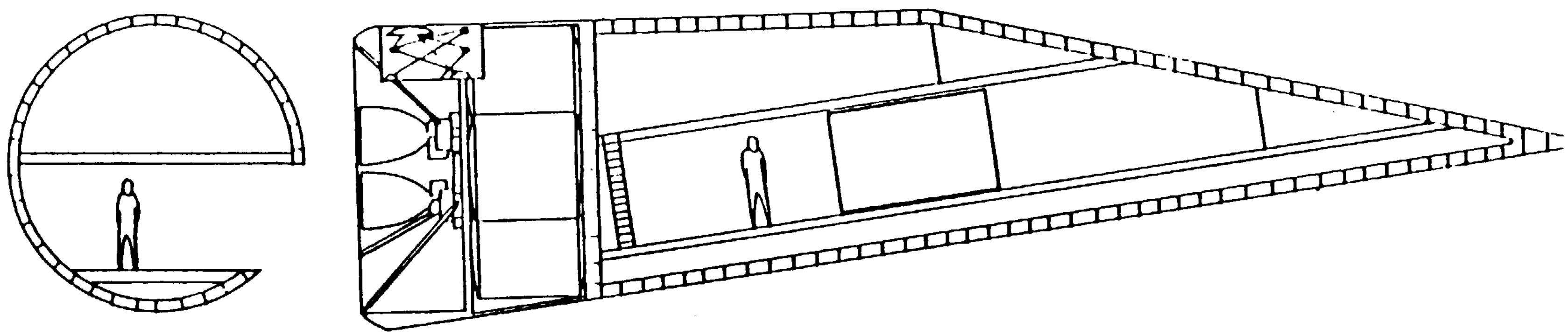


FIGURE 5
CARGO VEHICLE

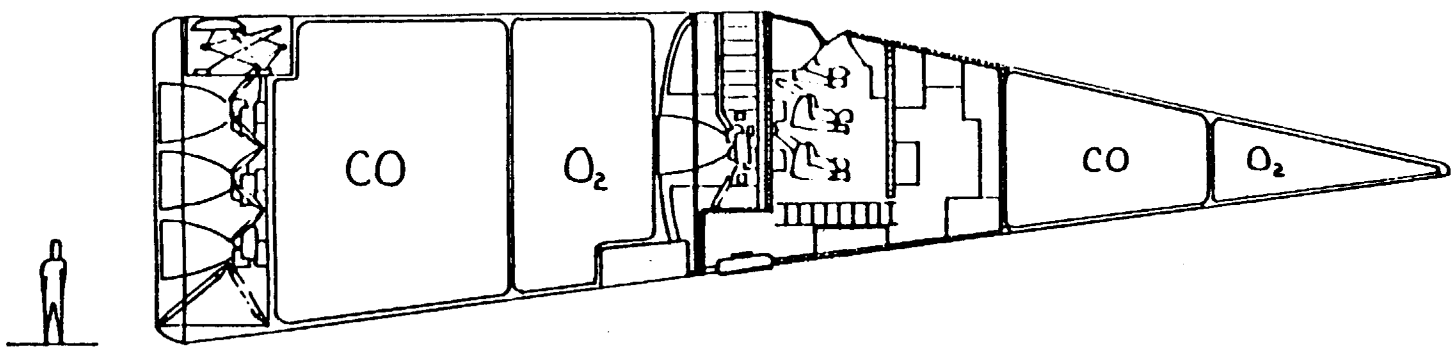


FIGURE 6
CREW SHUTTLE

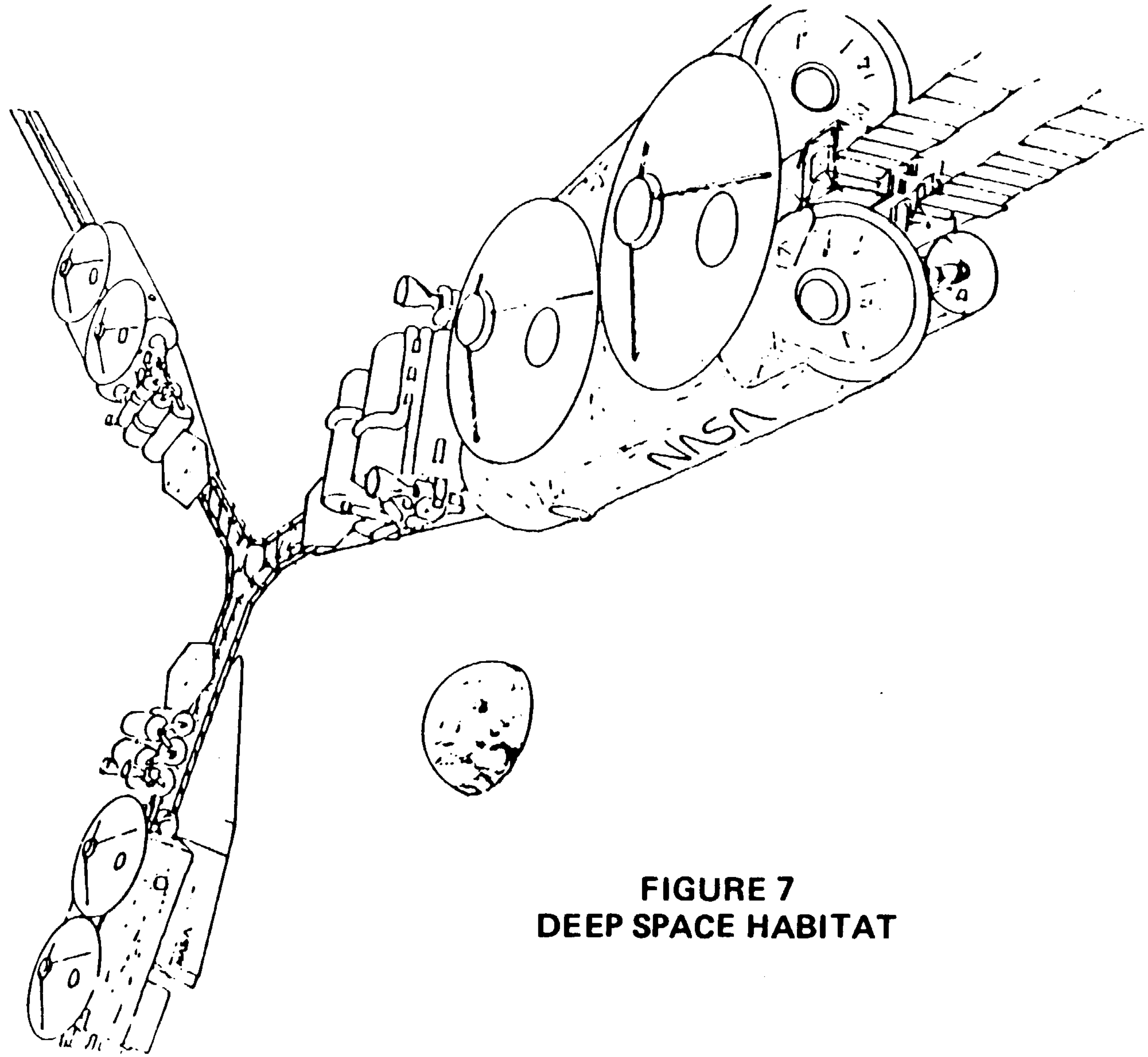
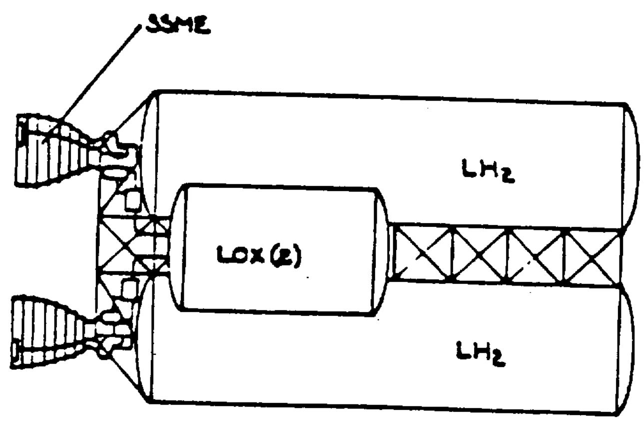


FIGURE 7
DEEP SPACE HABITAT

FIGURE 8
TRANS–MARS INJECTION STAGE



vehicle during interplanetary flight, a jettisonable service module will be attached. Appendix B provides some characteristics of the vehicles.

HUMAN FACTORS

Human factors encompasses those facts of mission planning and design which affect the physiological and psychological condition and the performance of the Mars Base crewmembers.

Life support facilities must be provided for long-duration spaceflight with primary considerations being mass, volume and reliabiltiy. Recycling of water and breathable gases is essential. Food is primarily transported, with possibly some supplementary food production in flight. Organic waste can be stored for later use as an agricultural commodity at the Mars Base. Development of long - duration life support is seriously lagging behind other technologies relevant to human missions to Mars.

Life support at the Mars Base involves a program of gradually expanding food production and gas recycling capability. Martian water, gases, and possibly regolith will provide most of the raw consumable materials. Greenhouses are used to provide the basic foodstuffs for the Mars Base food chain. Optimum use of organic recycling is encouraged, and the feasibility of microbial processing to provide a variety of biological products and enhance nutritional value and palatablity of food is suggested. The overall facility is envisioned as a managed ecological system relying on biological cycling of materials when possible. This is augmented with chemical and physical subsystems to provide buffering capability against system oscillations. Emergency food supplies are cached in case of system failure.

Medical care must provide for the normal needs of crewmembers over 5 years' mission duration plus the ability to address a variety of foreseeable problems in unknown and hazardous environments of space and the Martian surface. The likelihood of accidents requires the capability to perform at least limited surgical procedures. A carefully selected pharmacopoeia must be included to cover a reasonable range of disease and accident treatments. All crewmembers must be trained in basic rescue and emergency medicine. At least one physician must be included in the crew. Relevant medical questions to be pursued prior to a Mars mission include effects of zero and fractional gravity over long periods of time and ameliorating drugs or techniques, and development of medical devices and techniques appropriate to the space extraterrestrial environments.

Psychological considerations are involved at all stages of mission planning including crew selection and training, selection of command protocols, scheduling of work loads, provision of recreational facilities, ergonomics and the Mars Base design, rotation of crews from mission to mission, mission continuity with changing personnel, and interpersonal relationships.

MARS BASE

The primary function of the Mars Base is to support a continued human presence on the surface and to achieve self - sufficiency through the use of Martian resources. This provides the security and home base from which to conduct the scientific exploration that will become the main thrust of activities on the surface.

The major components and requirements for the Mars Base are shown in Figure 9. The initial crew size is 15 people, with incremental growth over time. Major components include: Habitats derived from cargo vessels; air shells/greenhouses which are lightweight erectable structures which can be pressurized with Mars air; power supplies to provide power to the base and to the resource extraction equipment (the largest power user); rovers, trucks, and other mobility units for construction and field experiments; habitat life support systems which can have considerable inheritance from Space Station Systems and from the resources available on the Martian surface; gas extractors which would obtain breathable air and water from the Mars atmosphere or surface.

Breathable air could include an Ar/N_2 buffer gas mixture. These elements together comprise over 5% of the Martian atmosphere and can be obtained by condensing out the CO_2. Oxygen can be obtained by reducing the atmospheric CO_2. The Mars atmosphere contains water (nearly at saturation), which can be extracted with compression and cooling equipment. Water may also be available from the Mars regolith. Rocket fuel can be made from the CO_2 itself (CO and O) or in combination with water (CH_4 and O_2). An active research program must be established to look at the use of gases and minerals available on Mars in support of the exploration effort.

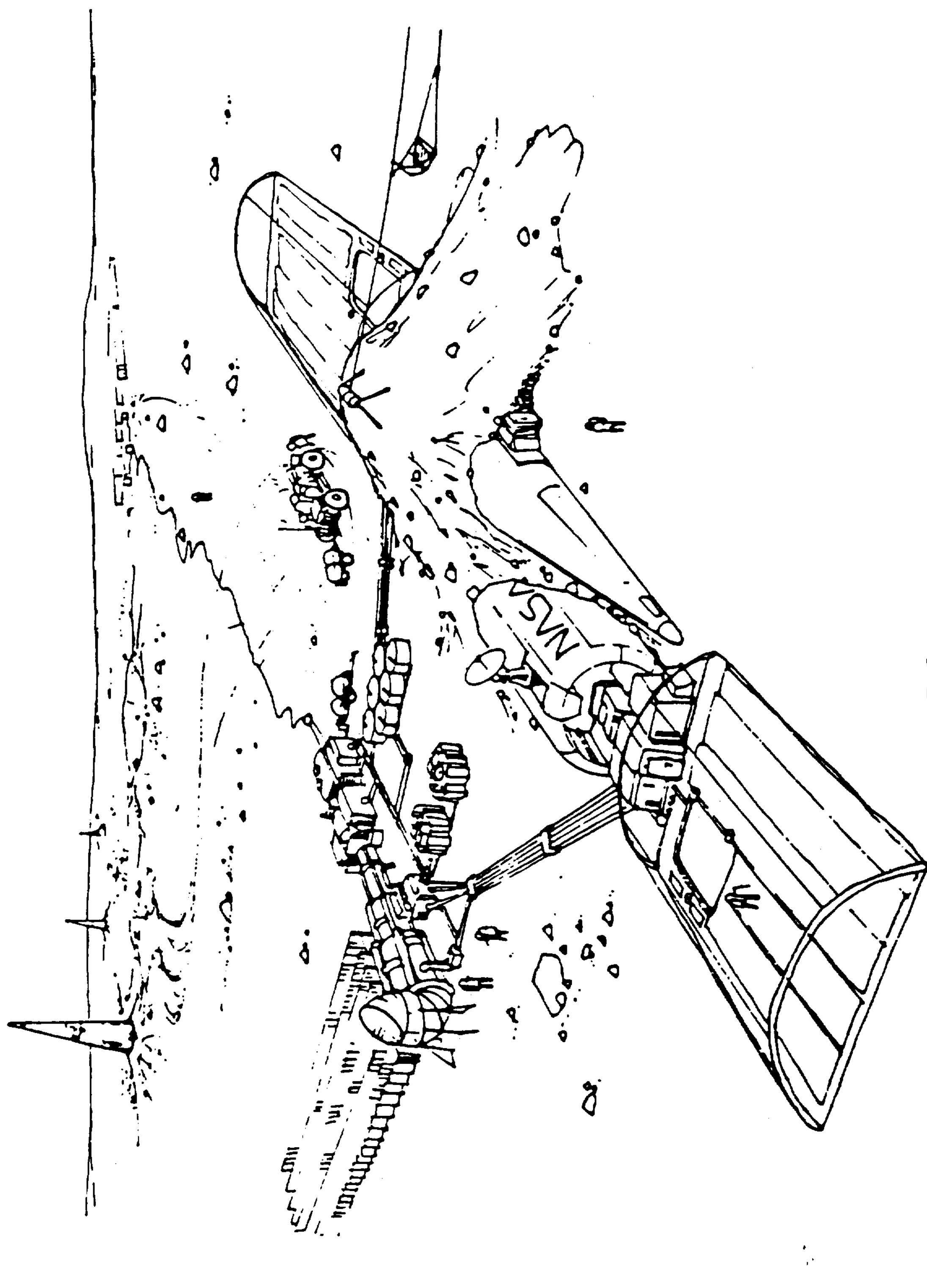


FIGURE 9
MARS BASE

The initial focus of activities at the Mars base must be the development of resource utilization technologies, since the continued presence of the base and the long range science goals are contingent on establishing the resource base.

Some areas that need development in connection with the Mars base include: 1) Power supply suitable to provide the approximately 200 - 400 kwatts needed; 2) Mars suit design; 3) small engines to run on fuel made in-situ; 4) the study of life support and resource utilization.

REFERENCES

1. Preliminary draft report " The Case for Mars: Concept Development for a Mars Research Station " 5 December 1984.

APPENDIX A

AUTHORS OF THE CASE FOR MARS: CONCEPT DEVELOPMENT FOR A MARS RESEARCH STATION

EDITOR

S. M. Welch

PROGRAM JUSTIFICATION DESIGN

S. M. Welch

C. R. Stoker

R. B. Wilson

T. R. Meyer

MARS SCIENCE

C. R. Stoker

R. L. Grossman

P. J. Boston

MISSION/PROFILE SPACECRAFT

J. R. French

R. L. Staehle

S. M. Welch

HUMAN FACTORS/ LIFE SUPPORT

P. J. Boston

T. R. Meyer

MARS BASE DESIGN

C. P. McKay

D. Jones

PHOBOS/DEIMOS MISSIONS

T. Caudill

ARTIST

C. Emmart

APPENDIX B

VEHICLE CHARACTERISTICS

MARS SHUTTLES:

LENGTH: 23m

BASE DIAM: 5.75m

MASS AT EARTH DEPARTURE: 50 TONNES
(includes landing propellant)

MASS AT TOUCHDOWN: 30 TONNES

MANNED VERSION:
CARGO - CREW OF 5 and 5 - 6 TONNES EQUIPMENT
LIFT-OFF MASS: 215 TONNES (PROPELLANT CO/O_2, Isp = 260 sec)

CARGO VERSION:
CARGO - 24 TONNES

DEEP SPACE HABITAT:

EACH MODULE SUPPORTS 5 CREW (10 EMERGENCY)

DEPARTURE MASS PER MODULE 100 TONNES (220,000 lbs.) PLUS 50 TONNES MARS SHUTTLE NORMAL ASSEMBLY THREE COMPLETE MODULES

EARTH DEPARTURE STAGE:

LOADED MASS: 300 TONNES (660,000 LB.) LO_2/LH_2 Isp=465 sec

EMPTY MASS: 20 TONNES (44,000 LB.)

PAYLOAD - ONE MODULE OF DEEP SPACE HABITAT OR 3 CARGO SHUTTLE DELTA V CAPABILITY: 4.4 km/sec