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PRESENTATION 4.1.4

Humans to Mars in 1999!

Robert Zubrin and David Baker
Martin Marietta Astronautics

Can the United States send humans to Mars during the present decade? Absolutely. We have developed a set of vehicle designs and a mission architecture that can make this possible. Moreover the plan we propose is not merely a "flags and footprints" one shot expedition, but puts into place immediately an economical method of Earth-Mars transportation, real surface exploratory mobility, and significant base capabilities that can rapidly evolve into a mostly self-sufficient Mars colony.

Here's how it works. In December 1996 a single shuttle derived heavy lift launch vehicle such as that shown in fig.1 lifts off from Cape Canaveral and fires a 40 metric ton unmanned payload off on a trajectory to Mars, where it aerobrakes into orbit and lands 8 months later. This unmanned payload consists of the following: (1) an *unfueled* two-stage ascent and Earth return vehicle (fig.2) employing methane/oxygen engines and including a life support system and enough whole food for four people for 9 months, plus some dehydrated emergency rations; (2) 5.8 metric tons of liquid hydrogen; (3) a 100 kWe nuclear reactor mounted within a small methane/oxygen internal combustion driven unpressurized utility truck; (4) a small set of compressors and automated chemical processing unit; and (5) a few small scientific robotic rovers.

As soon as the payload is landed, the reactor is driven a few hundred yards away from the landing site and lowered off the truck into either a natural depression in the terrain or one created by the robots (teleoperated from Earth) with the aid of a few sticks of dynamite. Its radiators are then deployed and a cable run back to the lander. Then the reactor, which has not yet been used, is started up to provide 100 kilowatts of electric power to the site facilities. The compressors are then run to acquire carbon dioxide out of the martian atmosphere (which is 95% CO_2.) With the help of a catalyst, this CO_2 can be made to react with the 5.8 metric tons of hydrogen cargo, transforming it in a few days into 37.7 metric tons of methane and water. This being accomplished, we no longer have to worry about how to store our super-cold liquid hydrogen on the surface of Mars. Next, the chemical plant goes to work, electrolysizing the water into hydrogen and oxygen. The oxygen is stored as a liquid, and the hydrogen is reacted with more CO_2 to create more methane and water, and so forth. Additional oxygen is produced by directly decomposing atmospheric CO_2 into oxygen and carbon monoxide, storing the oxygen and dumping the CO. In the course of a year, about 107 metric tons of methane/oxygen propellant is produced.

This may sound somewhat involved, but actually the chemical processes employed are 19th century technology. The 100 kWe nuclear unit isn't, but we've operated practical nuclear reactors since 1954, and the SP-100 in particular is currently scheduled to be ground tested in 1995, so that with an accelerated program either it or an alternative design can certainly be made ready in time for this mission.

Meanwhile, back on Earth, flight controllers have been watching to make sure that the propellant production operation is completed successfully. If it has, then in January 1999 two more heavy lift boosters will rise from the Cape within a few weeks of each other. One of them has an unmanned payload identical to the one launched in 1996. The other payload is a manned spacecraft (fig.3) looking somewhat like a giant hockey puck 27.5 feet in diameter and 16 feet tall. Its habitation deck contain some 594 square feet of floor space, allowing it to accommodate a crew of four, while an additional deck is available for cargo. With a weight of 38 metric tons (including aerobrake, landing propellant, provisions, and a pressurized methane/oxygen gas turbine/electric driven ground car) it is light enough that the booster upper stage can project it directly onto a six month transfer orbit to Mars without any Earth orbit refueling or assembly.

Once on its way to Mars, the manned habitat pulls away from the expended booster upper stage that launched it, but they are still connected by a tether about 1500 yards long. With the help of this tether, the empty upper stage can be used as a counterweight, and the assembly is spun up at one revolution per minute to provide a level of artificial gravity equal to the 3/8 g found on the surface of Mars. When the manned craft arrives at Mars, the tether and upper stage are discarded, and the ship aerobrakes into orbit and then lands in the immediate vicinity of the now fully fueled ascent vehicle that has been waiting for it since 1997. The landing is safe because the robotic rovers sent out in the advance landing have identified and given extensive characterization of the best landing site in the vicinity, and laid out radar beacons to guide the terminal descent.

In 1976, the United States sent two Viking probes to Mars, and landed them right on their designated target areas. With the help of the landing beacons, superior technology, advance meteorological data from the ground site, and the on the spot decision making capability of a human pilot, we will vastly exceed the degree of landing precision demonstrated by Viking.

But even if we missed by a considerable distance, the mission plan has built into it three layered fall back options, a defense in depth to assure the safe return of the crew. First, the manned spacecraft carries with it a pressurized rover with a one-way range of 600 miles, so if the landing was not misdirected by a distance greater than this, the crew could still drive over to their return vehicle. Second, if by some inconceivable mischance the crew misses its landing site by a distance greater than 600 miles, they can still direct the second unmanned payload (which has been following them out a few days behind) to land near them. It contains a propellant factory of its own, and can thus act as an emergency backup. Finally, if all else fails, the crew has with them in their habitat enough supplies to last them until a relief expedition can be sent out two years later.

However, assuming that the manned landing has been carried out correctly at the prepared site, and the flight readiness of the 1996/97 ascent vehicle is verified, the 1999 unmanned lander will be directed to a second landing site 500 miles away from the first. There it will begin manufacturing propellant for the second manned mission, which will be sent out in 2001.

Thus each manned Mars mission requires just two heavy lift booster launches; one to deliver a ride home, and the other to create a new outpost or add to a existing base on Mars. This is much more economical than conventional mission plans in which all the propellant is brought from Earth, which typically require 4 to 7 heavy lift booster launches for each mission. The mission plan we propose is better than a conventional plan in another way: we bring all of our crew and their hardware to the surface where they can do their job of exploring Mars and learning how to live on another world. The conventional plan requires leaving a mothership in orbit around Mars, whose crew will accomplish little except soak up cosmic rays. The crew on the surface is protected by Mars' atmosphere from most of the solar flares hazard, and with the help of some sandbags placed on top of their landed habitats, can be protected from cosmic rays as well. The vulnerability of the crew of the orbiting mothership tends to create an incentive to limit the stay time of a conventional mission at Mars. This leads to very inefficient missions. After all, if it takes a year and a half of round trip flight time to travel to Mars, it's rather unreasonable to limit the stay at the destination to 30 days. A not too rough analogy to such a mission would be planning Christmas vacation in Hawaii but arranging the itinerary to include 9 days of transferring around airports going out and back, and half a day at the beach! Yet that is how the conventional mission plans are structured. Worse yet, in their rush to get back from Mars, the conventional mission planners are forced to take disadvantageous high energy orbits which require a lot more propellant as well as a swingby of the planet Venus where the Sun's radiation is twice that at Earth. In the plan we offer, the crew will spend 500 days on the surface of Mars and only 12 to 16 months in round trip interplanetary cruise, traveling via the most efficient, "minimum energy" orbit possible.

During their 500 day stay on the surface of Mars, the crew will be able to accomplish a great deal of exploration. Using 11 of the 107 metric tons of methane/oxygen propellant to power their ground car, they will be able to travel over 10,000 land miles (without propellant recycling) at speeds of over 20 miles an hour, ranging out from their base 300 miles in any direction. If a condenser is added to capture for later recycling the water vapor in the ground car engine exhaust, the 10,000 land miles available to the ground car can be increased ten-fold. Once the second lander's propellant production operation is well underway, they can even drive over to use it as a second base for forays. Thus about 500,000 square miles of territory will be available for exploration for the first mission crew alone. With a crew of four, a large landed habitat/laboratory, and a substantial power source, a large variety of scientific investigations can be accomplished. In addition to searching for past or present life and clues to the planet's geologic history, one key item on the exploratory parties agenda will be to locate pockets of readily exploitable water ice. Once native water is available, it will no longer be necessary to ship hydrogen from Earth, and future missions and settlements can be made independent of Earth for their transportation and life support consumables. But even on this first mission, an inflatable greenhouse can be set up and extended experiments undertaken in growing food crops. If successful, the greenhouse can even be left in operation after the crew departs, allowing research to continue telerobotically from Earth, and perhaps providing future crews with both food and earthly fragrances.

At the conclusion of the 500 days on the surface, the crew will climb into the methane/oxygen ascent vehicle and rocket back to Earth, where they will aerobrake into orbit and rendezvous with either the Space Station or be picked up by a Shuttle. Quarters aboard the ascent vehicle will be somewhat cramped, but no more so than in a the Space Shuttle. The return trip will be carried under zero-gravity conditions, but it will only last about 6 months, and Mir cosmonauts have proven that zero-gravity exposure of such length can be tolerated by humans without excessive physiological harm.

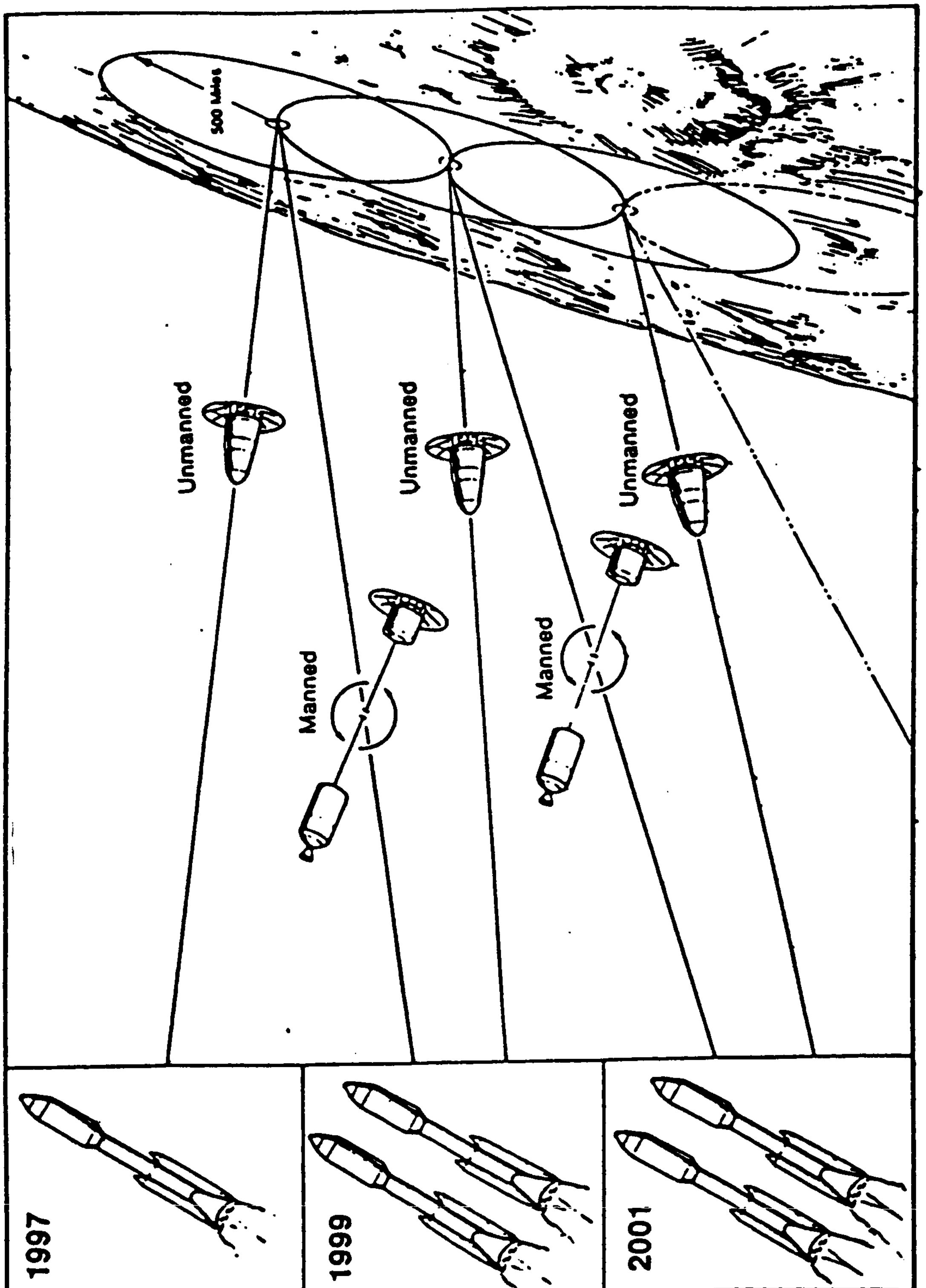
Both the habitat craft and the Earth return vehicle contain water jacketed "storm shelters" that the crew can retreat into in the event of a solar flare. Since the crew only spends 12 to 16 months in space, this reduces the expected radiation dose they will receive over the course of the 3 year round trip mission to about 50 Rem. Such a dose will have no prompt effects, but will increase the probability that an individual contracts cancer at some point later in his or her life by about 1.5%. This is not a risk to be taken lightly, but it can be taken in stride along with the other risks of launch and space travel, and it seems clear that it will not prevent the stepping forward of any number of fully qualified volunteers ready to undertake the hazard for the sake of the prize.

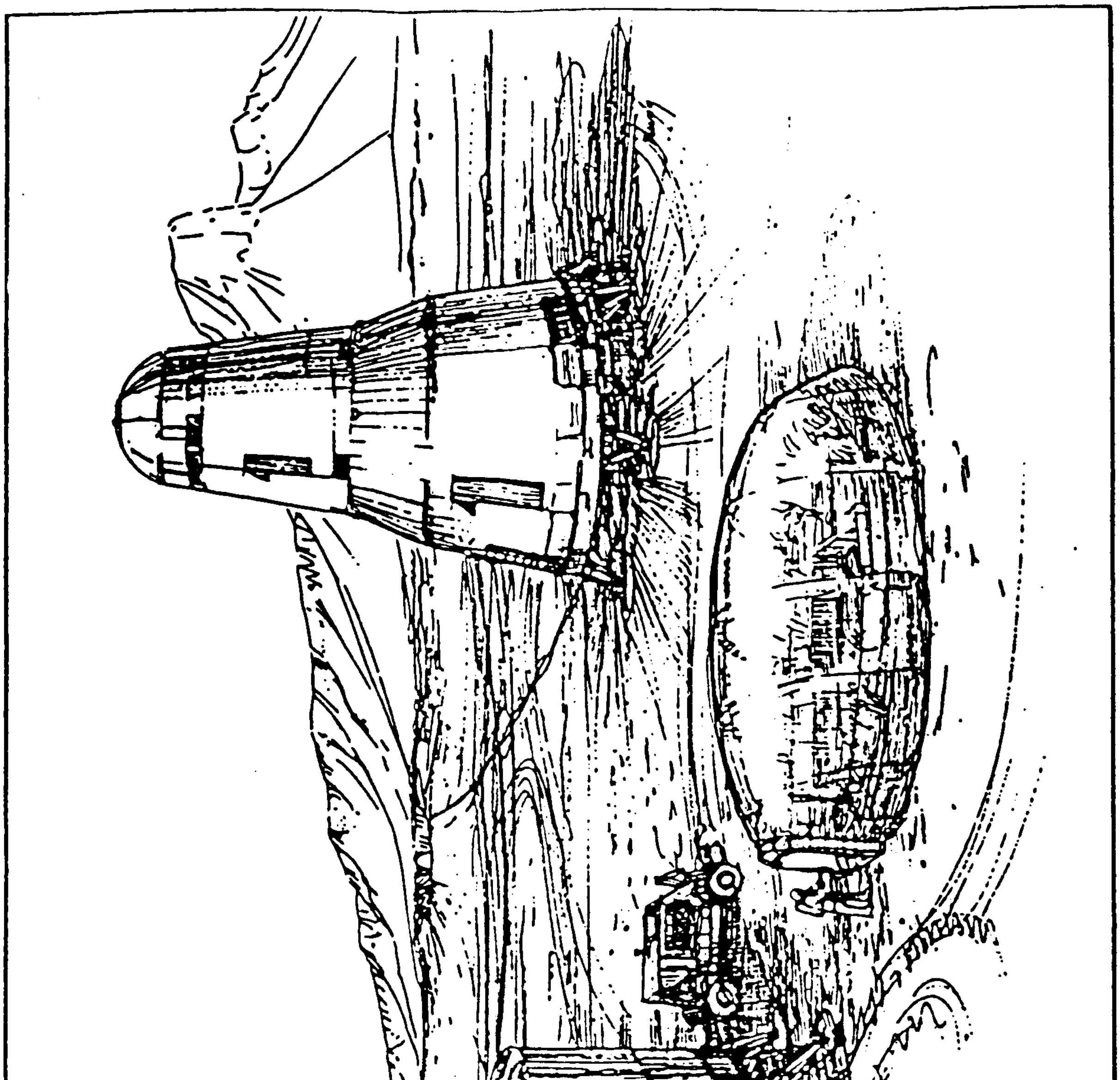
Not too long after the mission 1 crew has departed Mars, the mission 2 crew will arrive and land their habitat near the unmanned ascent vehicle that had been sent out following the mission 1 crew in 1999. Accompanying them will be a third unmanned ascent vehicle/fuel factory payload which will be landed at a new site 500 miles further along, to be used for return by the mission 3 crew which will depart Earth in 2003. Thus every two years a new base will be established and its vicinity explored, and before long a string of small bases will dot the map of Mars, separated by distances within the capability of available ground transportation. Rapid crew transfer between inhabited bases separated by long distances will be made possible by the introduction of a small rocket propelled flying vehicle. Just as towns in the western United States developed around forts and outposts, some of these Martian outposts will be seeds for future Martian towns. As information returns about each site, future missions may be sent back to selected prior landing sites and larger bases will begin to grow as warranted. With just two boosters being launched every two years, the total launch requirement needed to sustain this program of exploration averages to only one launch per year!

At some point after the commencement of this program, a new technology, nuclear thermal rockets (NTR, which was tested in the U.S. during the 1960s under the NERVA and ROVER programs), will come into use that will allow us to greatly increase the payload transferable to Mars with each launch. If we stick with our early plan of two launches per mission, this will allow us to increase our crew complement of each flight to 12 or more. Alternatively, if the size of the missions are kept the same, using NTR will allow us to launch each mission with a single booster, instead of split between two. NTRs can also be designed to use martian CO_2 as their propellant. Since this can be acquired at low energy cost through direct compression out of the atmosphere, rocket vehicles so equipped will give Mars explorers complete global mobility, allowing them to hop around the planet in a craft that can refuel itself each time it lands. With the help of NTR, large habitations and massive amounts of equipment can be sent to Mars. A few such payloads landed at the same site can provide the basis of the first permanent martian settlement during the 2010-2020 decade, with a population on the order of 100 people.

There is nothing in the program we have laid out that cannot be done for reasonable cost during the schedule indicated. The booster we propose uses off the shelf shuttle technology and would also be ideal for supporting lunar missions. The same habitation we propose for Mars could also be used to great advantage on the Moon. The second stage of the Mars ascent vehicle is sized to function equally well as a lunar ascent vehicle. Aerobraking efficiencies and the ability to acquire return propellant directly from Mars' atmosphere actually make Mars missions lighter than equivalent lunar missions! Thus, with a Mars exploration launch requirement of only one launch per year, and a great deal of commonality of the required hardware, there is no reason whatsoever to postpone the exploration of Mars until after several decades of lunar base build up. Rather the two programs can be carried out concurrently.

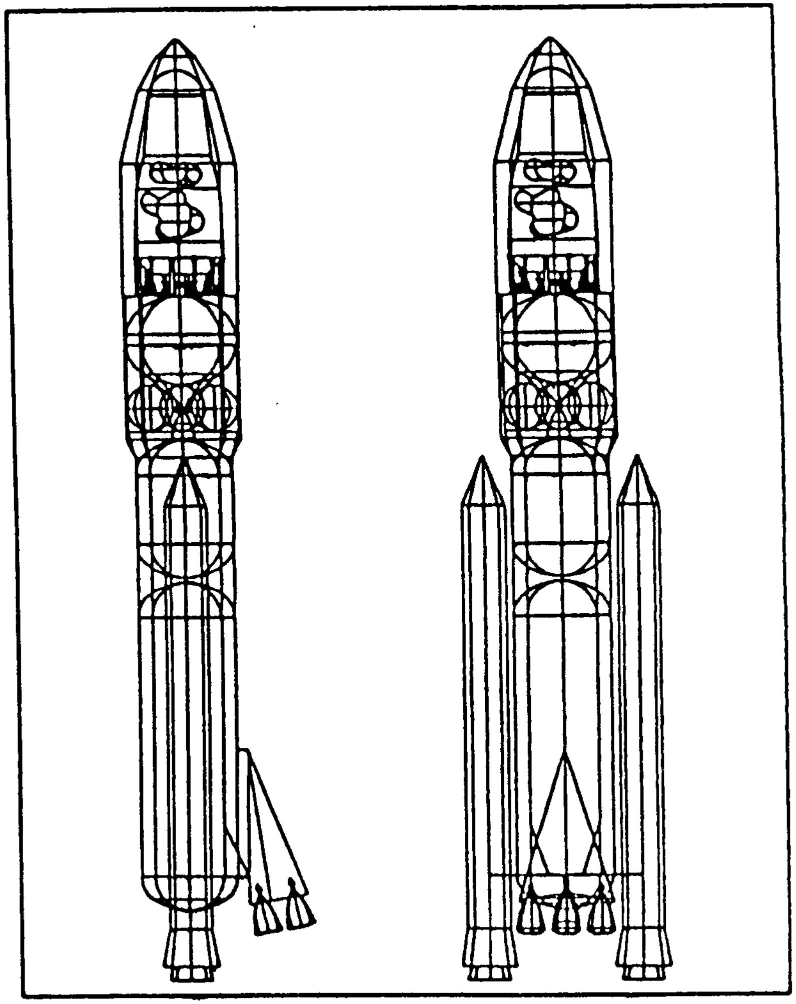
Humans to Mars in 1999! Its possible. Let's do it!


500 Miles
Unmanned
Unmanned
Unmanned
Manned
Manned
1997
1999
2001



Ares Launch Vehicle Definition

Payload Capabilities (All Weights in tonnes)	
Trans-Mars (C_3 = 15 km^2/sec^2)	47.2
Trans-Lunar (5 day transfer)	59.1
LEO (160 by 160 Nmi, 28.5 degrees)	121.2
Height (m)	82.3
Gross Mass (Without Payload)	2,194.6
Stage-0	
2 Advanced Solid Rocket Boosters	1,214.5
Stage-1	
External Tank (Including Residuals)	35.6
SSME Engine Pod (4 SSME's)	28.6
Usable Propellant in ET	723.5
Total SSME Thrust (kN, 104%)	8,706
Specific Impulse (sec)	453
Staging Relative Velocity (m/s) (LEO to Mars Range)	4232 to 5450
Stage-2 (Ignited Sub-Orbital)	
Usable Propellant	158.8
Inert Mass	13.2
Single Engine Thrust (kN)	1,113
Specific Impulse (sec)	465
Payload Fairing	20.4



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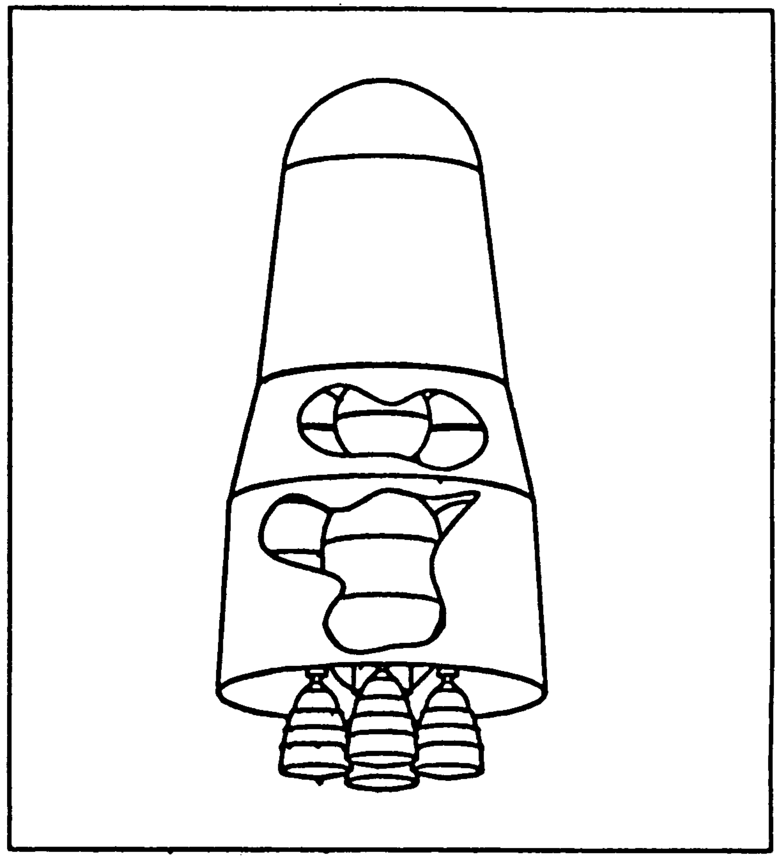
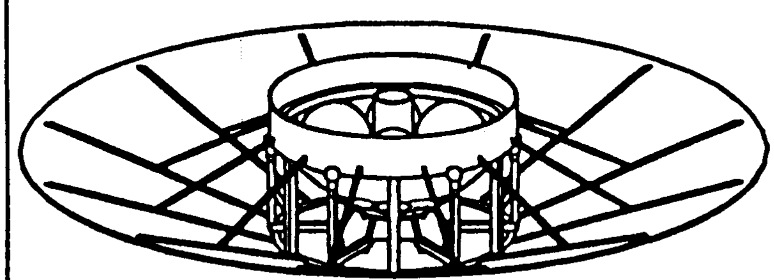
Earth Return Vehicle Definition Sheet

Round Trip Payload	
Crew Cab (All Masses in tonnes)	7.10
RCS System	0.40
Biconic Brake (20%)	2.45
Stage-1 Dry (Expended Mars Suborbital)	6.33
Stage-2 Dry	1.77
Mars-Bound Only Payload	
Hydrogen for Propellant Prod.	5.80
SP-100 Reactor	4.50
Earth-Bound Only Payload	
Crew	0.30
Suits	0.30
Consumables	1.60
Soil Samples	0.10
Stage-1 Propulsion System	
Usable Propellant (From H2 & Atm)	70.16
Inert Mass	8.85
Total Engine Thrust (lbs)	191,784
Specific Impulse (sec)	373
Propellant Type	CH_4/O_2
Stage-2 Propulsion System	
Usable Propellant (From H2 & Atm)	22.17
Inert Mass	2.56
Total Engine Thrust (lbs)	20,382
Specific Impulse (sec)	373
Propellant Type	CH_4/O_2



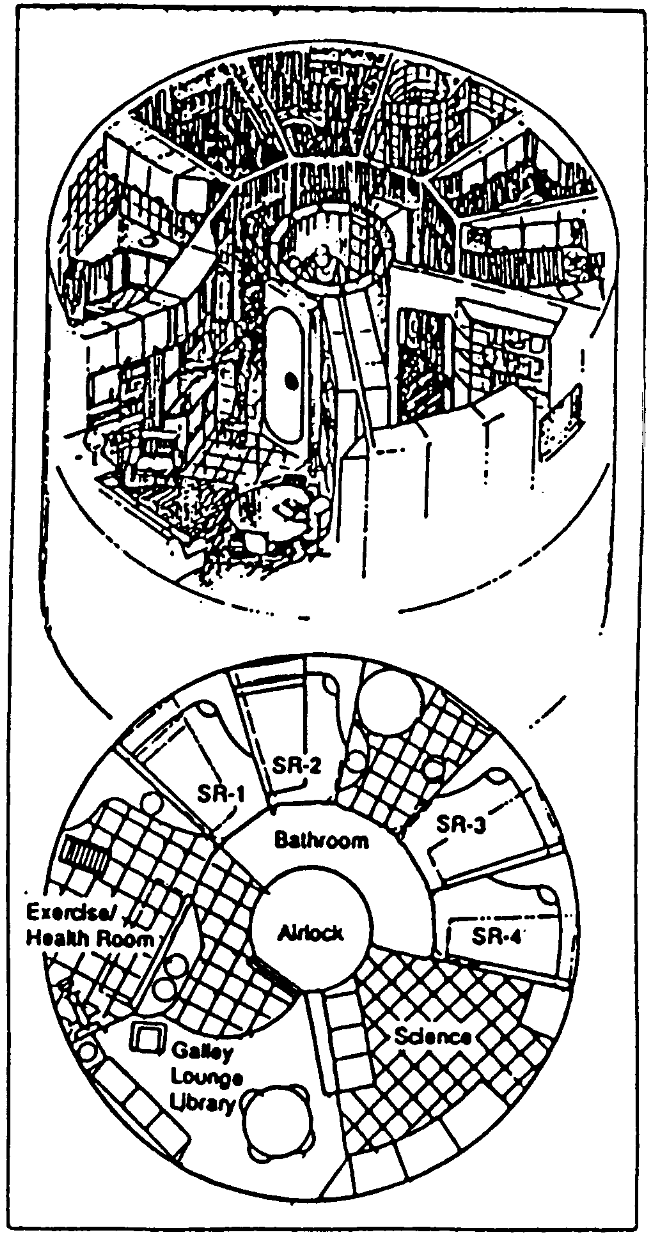
Common Aerobrake and Landing Stage Definition

Gross Mass (All Masses in tonnes)	11.81
Mars Aerobrake (Flex-Fabric)	5.96
(Based on 15% of Gross @ Entry)	
(Diameter is 23 meters Deployed)	
Landing Propulsion Stage	5.85
Usable Propellant	3.85
Inert Mass	2.00
Tanks	0.15
Engine	0.67
Structure	0.23
Landing Legs	0.61
Avionics & Other Fixed Mass	0.20
Unusable Propellant	0.06
Reserve Propellant	0.08
Total Engine Thrust (lbs)	44,267
Specific Impulse (sec)	450
Propellant Type	H_2/O_2

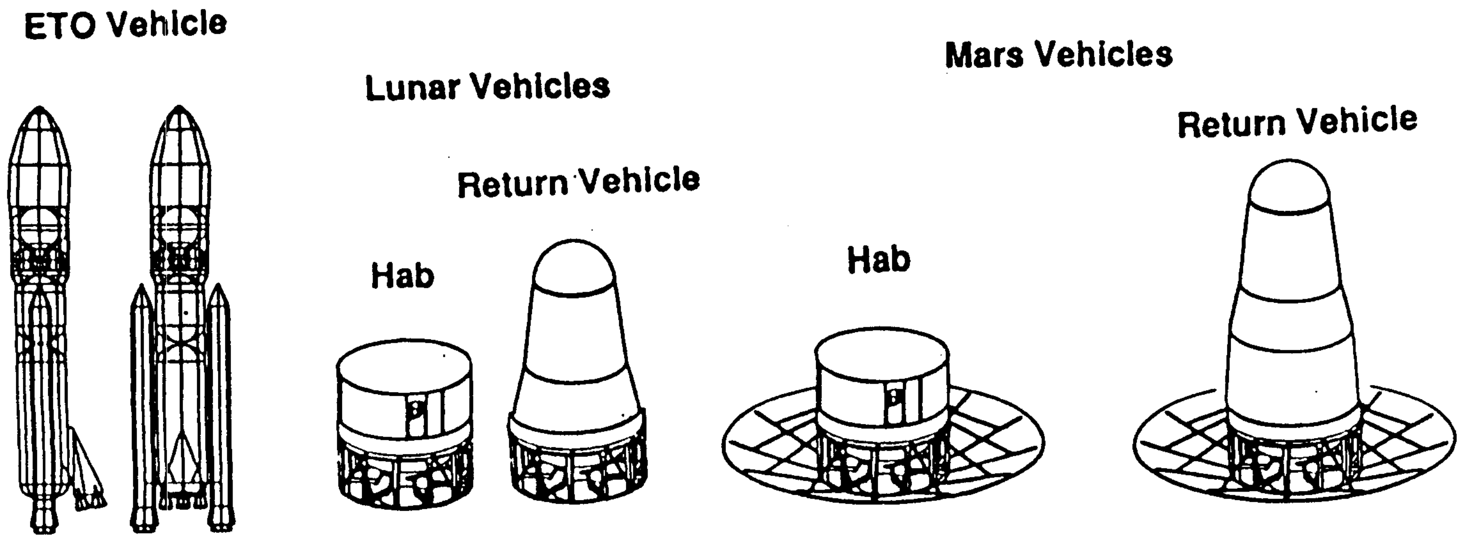


Habitation Mass Definition Sheet

Gross Mass (All Units in tonnes)	26.00
Main Structure (Weldalite)	6.44
Barrel Section Wall	1.97
Decks (3)	2.53
Central Airlock/Rad Shelter	1.54
4 Perimeter Airlock Doors	0.40
Interior Fittings	4.19
Walls	0.08
Furniture	0.45
Science Equipment	0.30
Exercise & Health	0.20
Plumbing & Lighting	0.10
Replacement Air (3 charges)	0.81
Solar Panel on Roof	0.25
Life Support System (Closed for Water and O2)	2.00
Consumables for Crew (Whole Food)	8.76
Crew	0.30
Personal Effects	0.30
Space Suits	0.30
Pressurized Rover	1.60
Deployed Surface Science	0.20
Contingency	3.90



Lunar/Mars Direct Exploration Vehicles



- Common Systems Defined to Explore and Colonize the Moon and Mars
- IMLEO Is the SAME for either Mars or Lunar Missions
- No LEO Assembly Required: Launch Direct to Moon or Mars
- ETO Vehicle Is Inline Shuttle-C with Earth-Escape 2nd Stage on Top
  ETO Configuration Optimized not to LEO but to Earth Escape
- Mars Mission has Simple Tether Application to Achieve 3/8 g Gravity
- Mars Mission Combines Earth Hydrogen with Martian CO_2 to Create
  Methane and Oxygen (One kg of H_2 Creates 18 kg of Propellant)
- Surface Habitation and Crew Return Vehicles are Reusable
- No Orbiting Vehicles at Mars or Moon: All Elements go to Surface

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