MARS HUMAN EXPLORATION REFERENCE MISSION

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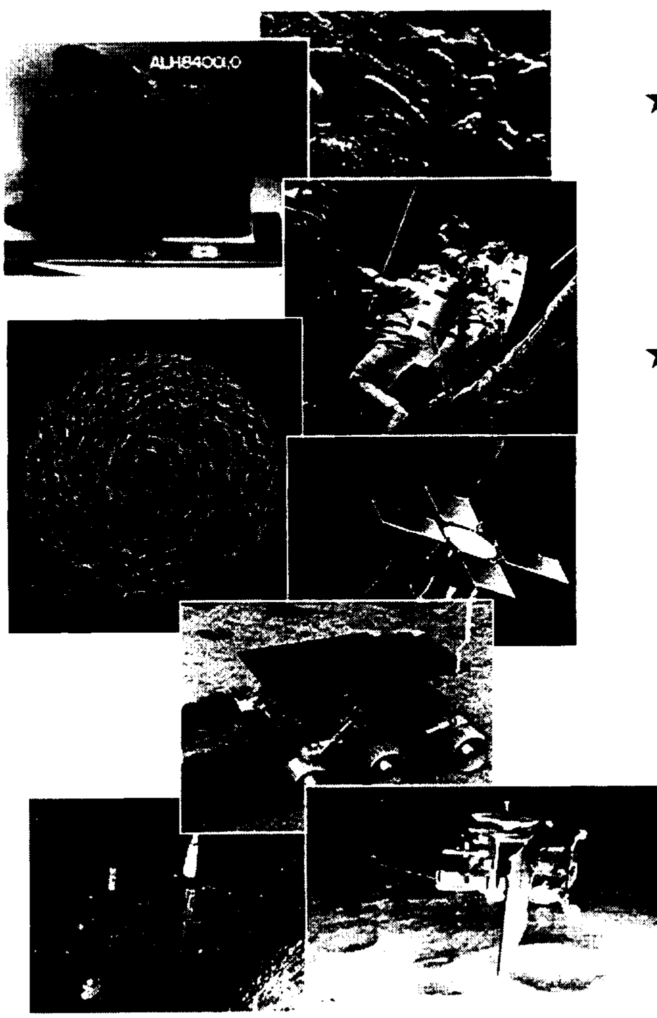
Human Space Exploration -- Next Steps

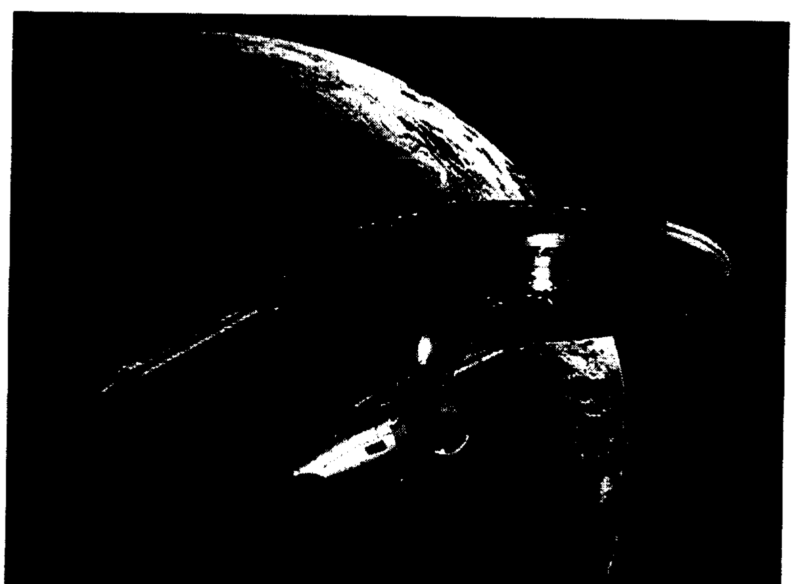


- ★ The Opportunity - An explosion of recent discoveries
  - Allan Hills Meteorite
  - Pathfinder
  - Clementine
- ★ The Challenge - Affordable human exploration
  - Significant reductions in cost
  - Efficient mission approaches
  - Development of leveraging technologies
  - Mars knowledge return
  - Enable a mission in early 2010's

Increase Knowledge

- Today's Exploration program focuses on understanding planetary and asteroid environments for what they can teach us about life on Earth
- Human capabilities will tremendously extend the scientific breadth and depth of the Exploration program
  - Sample selection, rapid analysis, and reselection
  - Operate sophisticated *in-situ* laboratories and observe, react to data, modify strategies, retest, verify and *think*
  - Repair, adjust, and control robotic science activities with no time delay
  - Access sites that are too challenging for robotic missions
  - *In-situ* sample screening, analysis, preservation and selection for return to Earth
  - Assessment of resources and technologies through experience

The best sensor is the human eye....
.....the best computer is the human mind

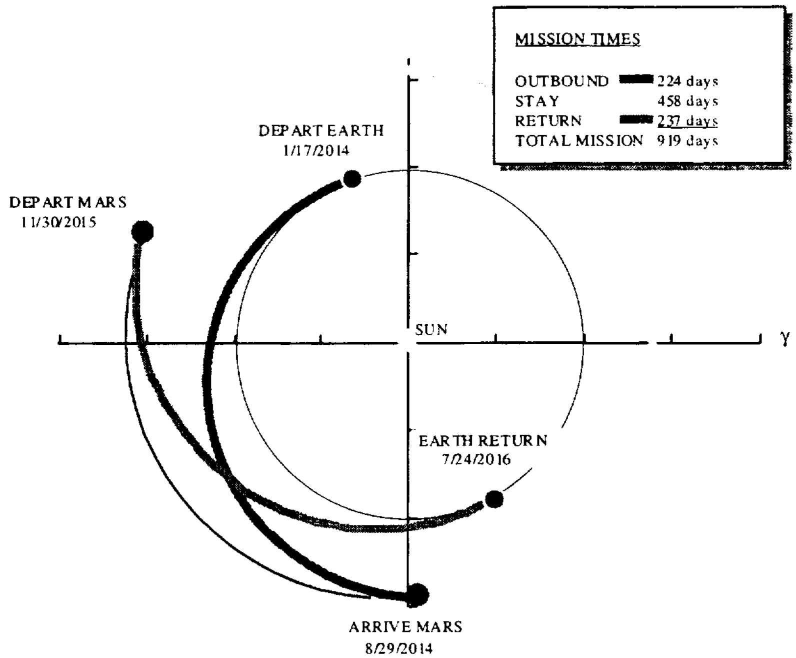


Mars Mission Strategies -- Old Paradigm

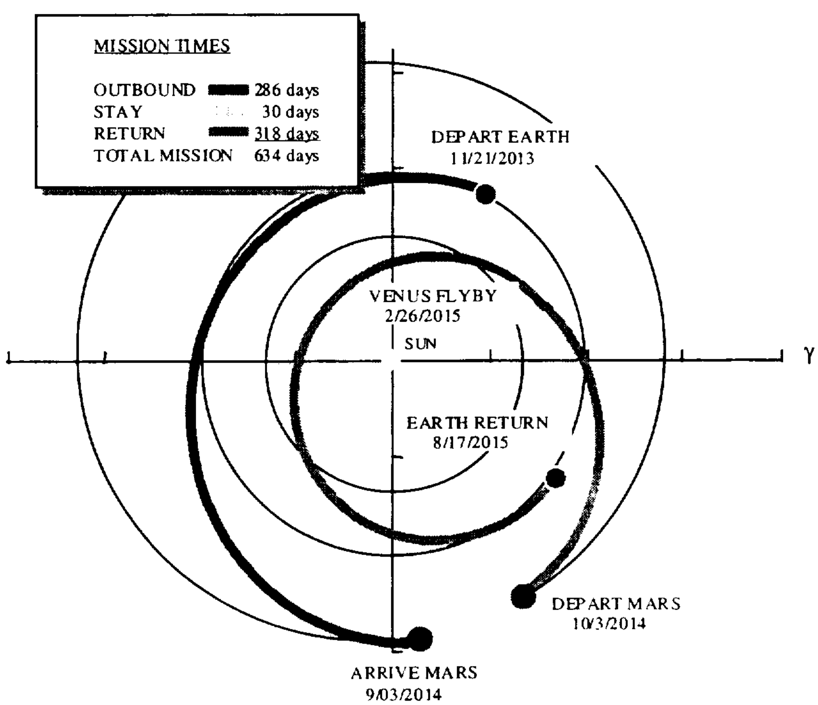
★ Most past Mars studies employ "Starship Enterprise" approach
  - Large "mothership" constructed in Earth orbit, travels to and from Mars orbit
  - Crew takes "shuttlecraft" to surface and explores for a short time
  - If problems occur, abort to Earth

★ Basically incompatible with economical spaceflight and Mars mission objectives
  - "Mothership" requires huge propellant quantities or exotic propulsion technology
  - Complex and risky construction and integration in Earth orbit
  - Short surface stay limits mission objectives
  - "Abort to Earth" implies long duration interplanetary flight times

Mars Trajectory Classes

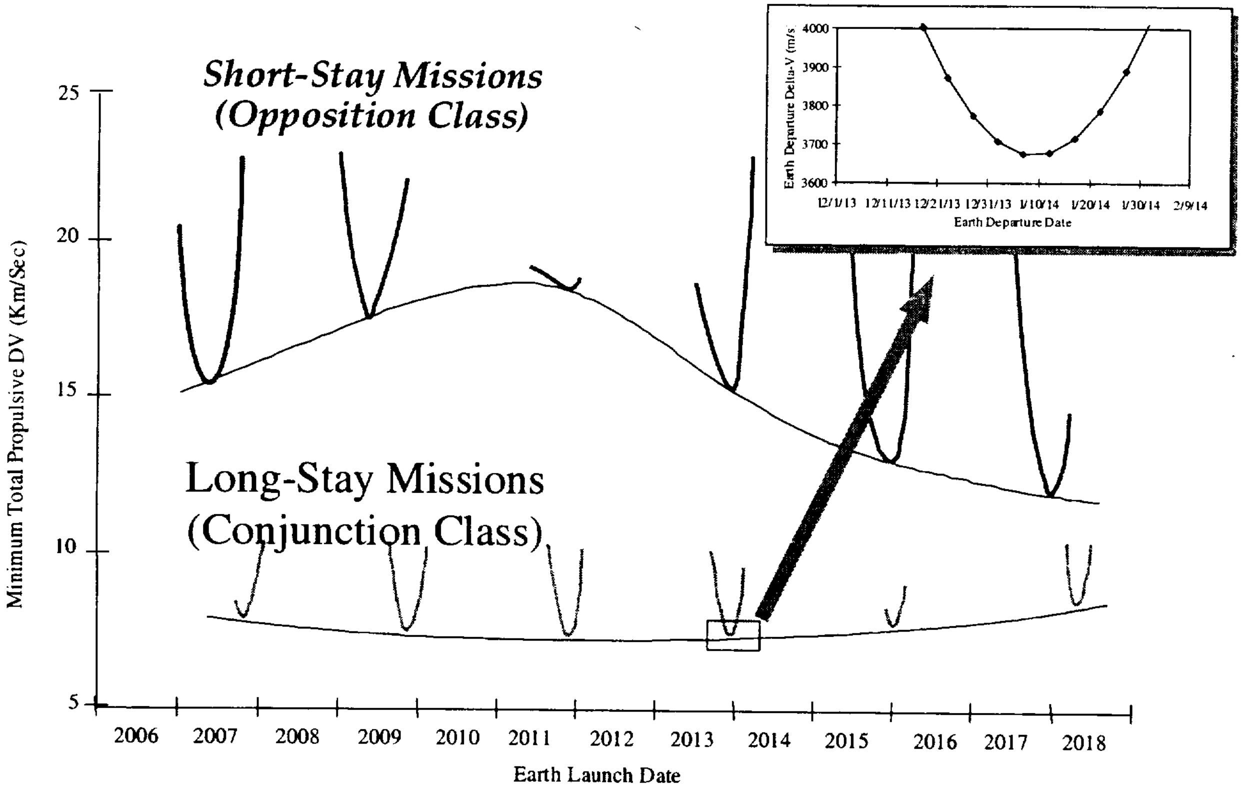


- **Long-Stay Missions**
  - **Variations about the minimum energy mission**
  - **Often referred to as Conjunction Class missions**

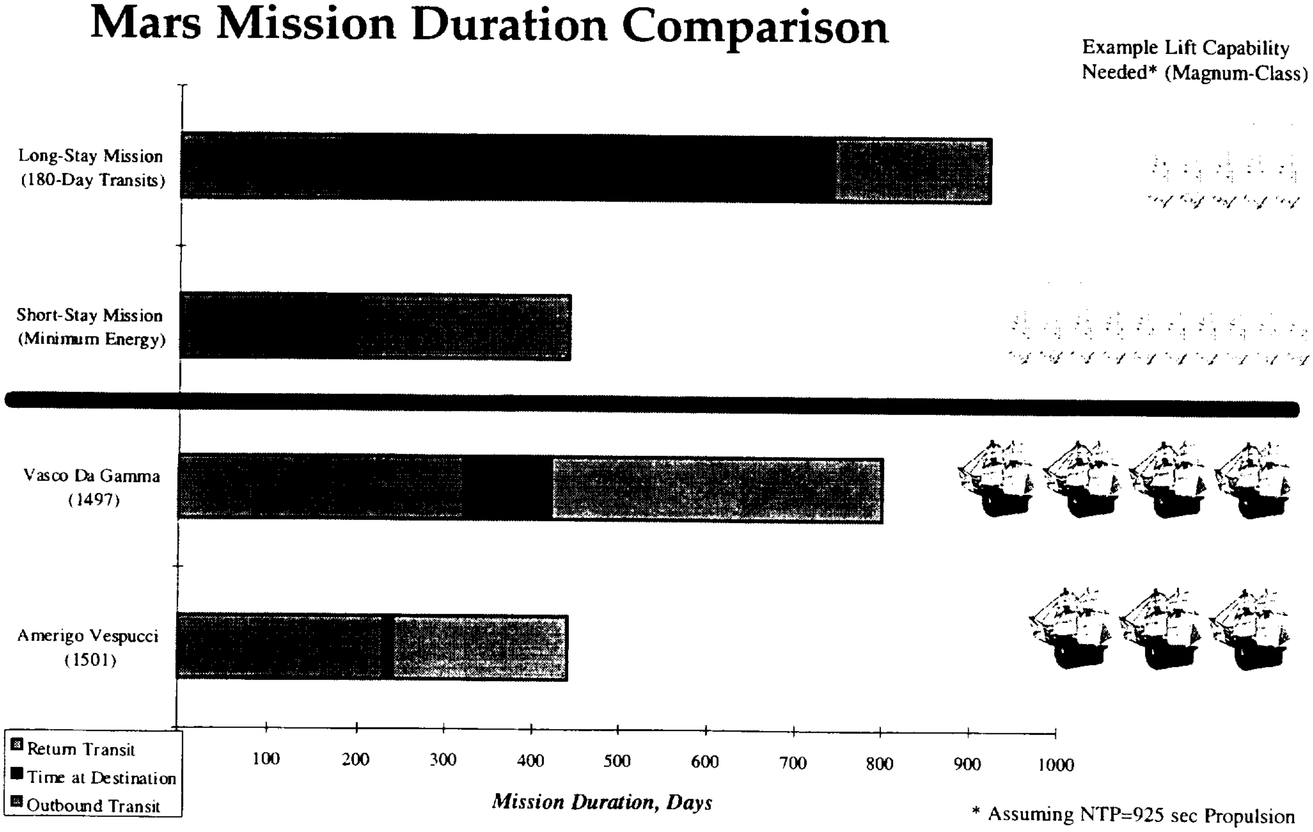


- **Short-Stay Missions**
  - **Variations of missions with short Mars surface stays and may include Venus swing-by**
  - **Often referred to as Opposition Class missions**

Delta-V Variations



Mars Mission Duration Comparison

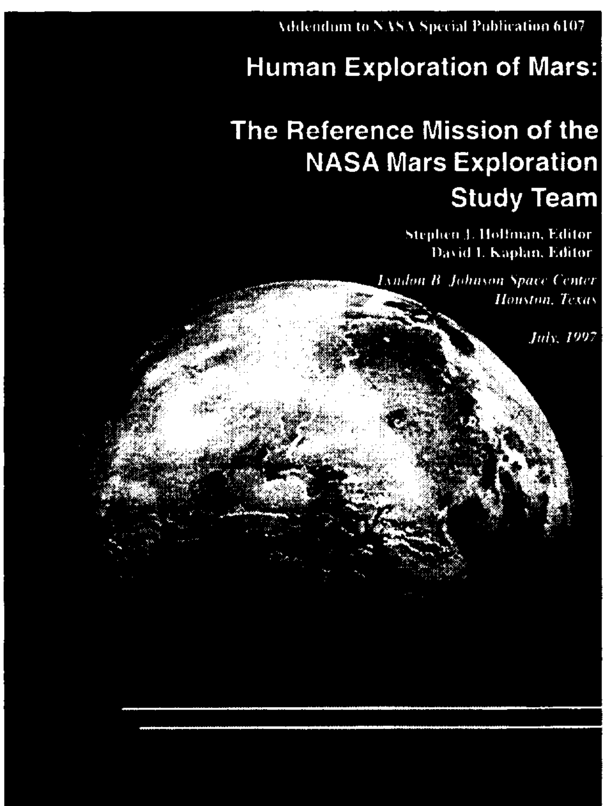


New Approach

- ★ Key in new paradigm is shifting focus from interplanetary spaceflight to planetary surface
  - Make Mars the safest place in the solar system
  - Pre-deploy assets to Mars, ensure operational before crew departs
- ★ Planetary departure / return windows can allow critical operational advantages
  - Pre-deployed assets for "next" crew available as redundant elements for "current" crew
- ★ Redundancy through "forward deployment" rather than "abort to Earth"

Mass Reduction Strategies

- Major component of economical human esploration of Mars is through the reduction of mass. Current mass reductions achieved by:
  1. Utilizing energy-efficient trajectories to pre-deploy mission assets
  2. Proper application of advanced technologies
  3. Achieving proper tradeoffs of mass and power
     - Advanced Space Propulsion
     - Utilizing locally produced propellants (In-Situ Resource Utilization)
     - Employing advanced (bioregenerative) life support systems to close air, water, and potentially food loops

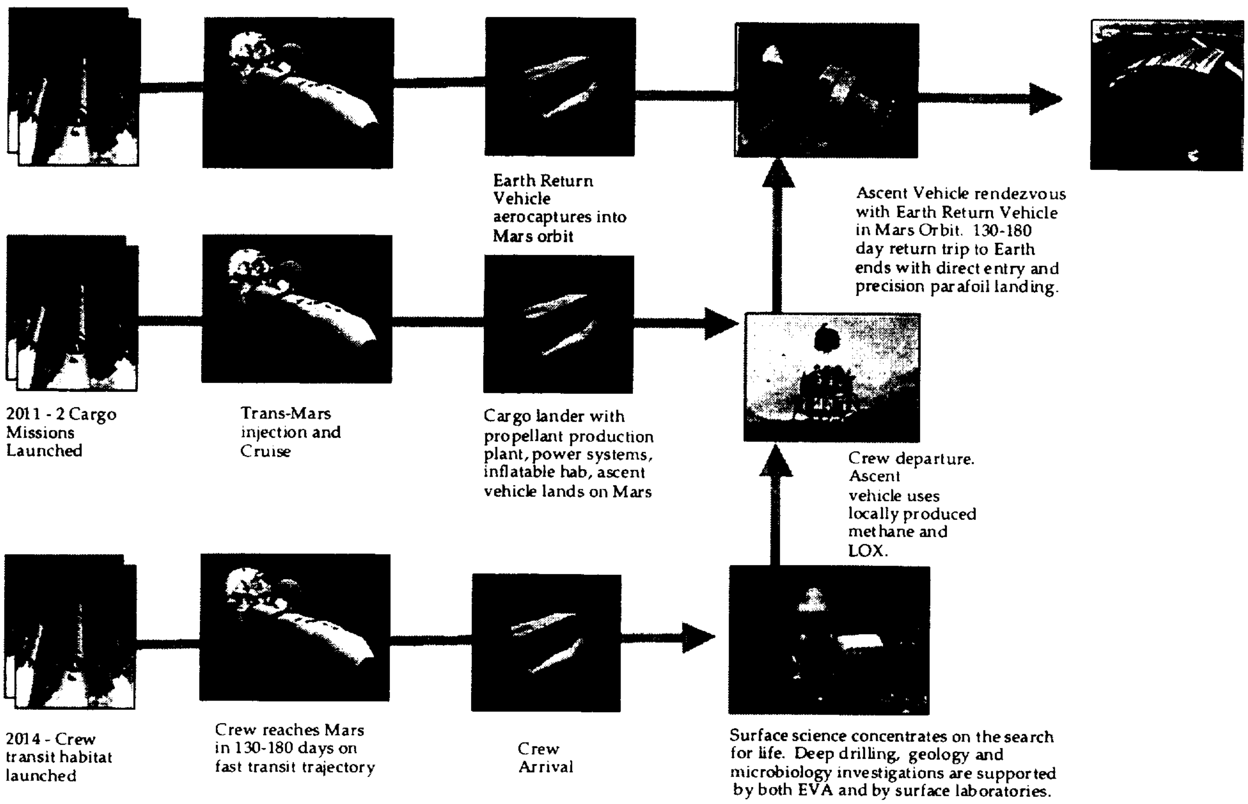


www-sn.jsc.nasa.gov/marsref/

Mars Reference Mission

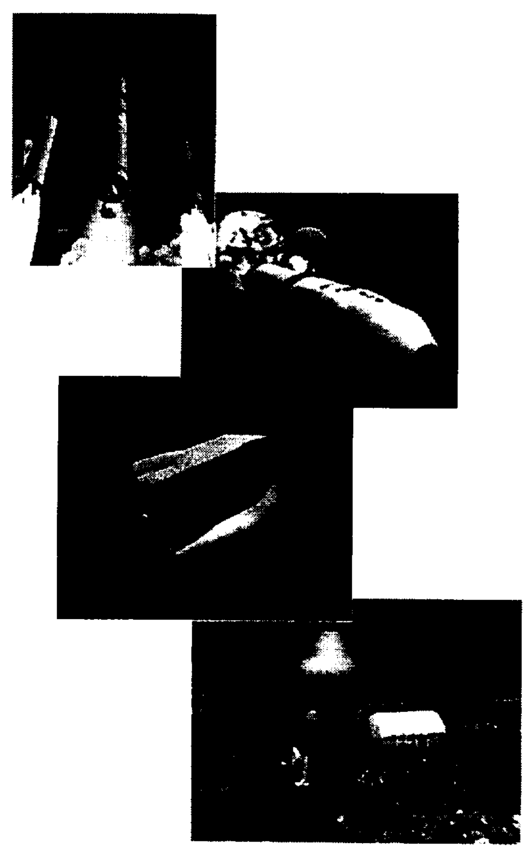
- Exploration mission planners maintain "Reference Mission"
- Represents current "best" strategy for human Mars missions
- Purpose is to serve as benchmark against which competing architectures can be measured
- Constantly updated as we learn
- Probably does not represent the way we will end up going to Mars

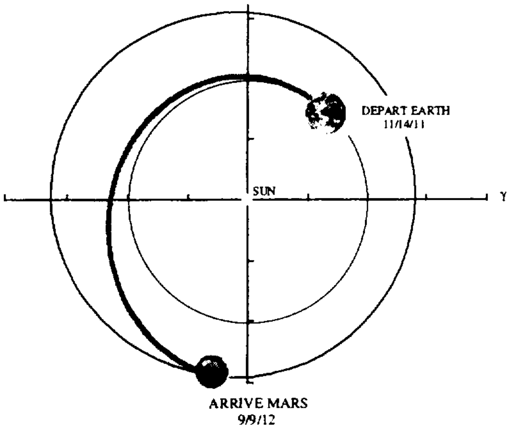
Reference Mission Scenario Overview



Forward Deployment Strategy

- Twenty-six months prior to crew departure for Mars, predeploy:
  - Mars-Earth transit vehicle to Mars orbit
  - Mars ascent vehicle and exploration gear to Martian surface
  - Mars science lab to Martian surface
- Crew travels to Mars on "fast" (six month) trajectory
  - Reduces risks associated with zero-g, radiation
  - Land in transit habitat which becomes part of Mars infra-structure
  - Sufficient habitation and exploration resources for 18 month stay





Cargo Missions

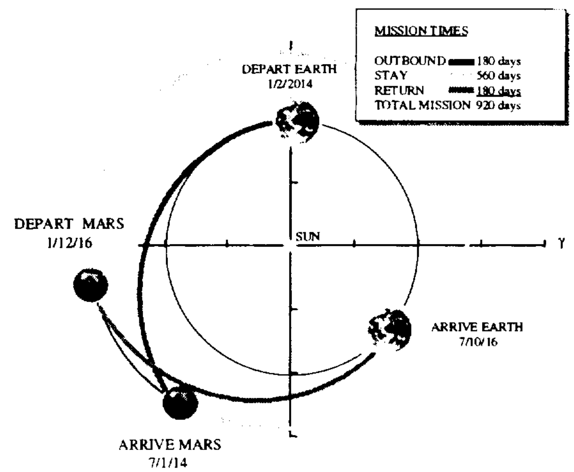
Two Cargo Missions (2011)

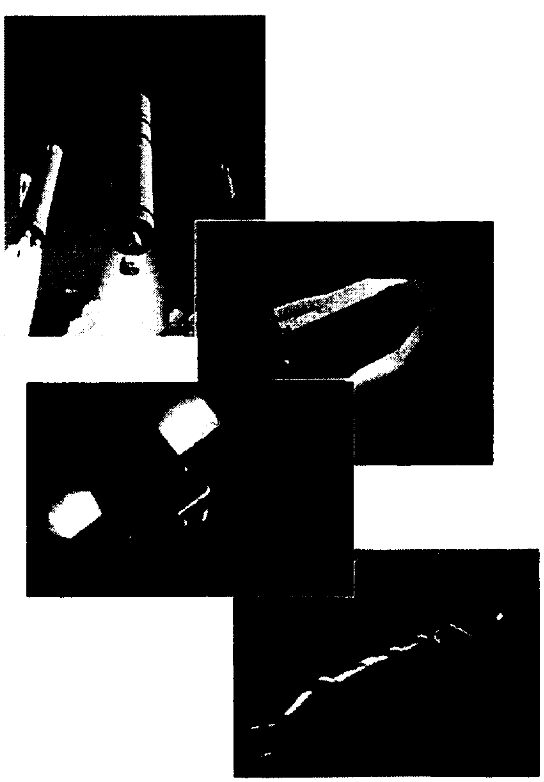
- Leave Earth November 4, 2011
  TMI DV = 3590 m/s
- 310-day outbound trip
- Arrive at Mars September 9, 2012
- Aerocapture into 1-Sol orbit
- Descent vehicle descends to surface
- Return vehicle remains in orbit

Piloted Mission

Piloted Mission (2014)

- Leave Earth January 2, 2014
  TMI DV = 3680 m/s
- 180-day outbound trip
- Arrive at Mars July 1, 2014
- Aerocapture into 1-Sol orbit
- 560-day stay on the Martian surface
- Leave Mars January 12, 2016
- TEI DV = 1080 m/s
- 180-day inbound trip
- Arrive at Earth July 10, 2016
- Direct entry to Earth's surface

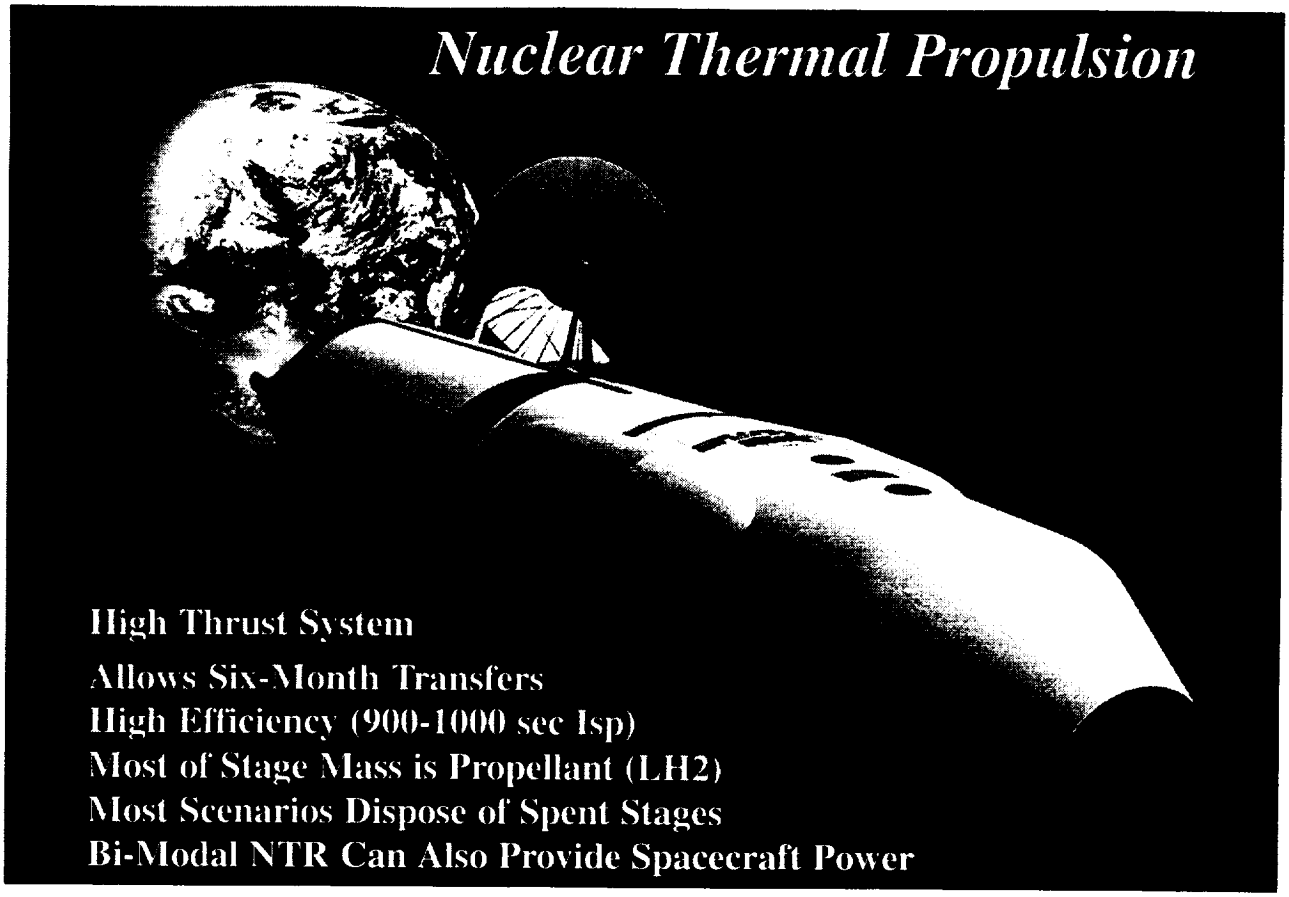


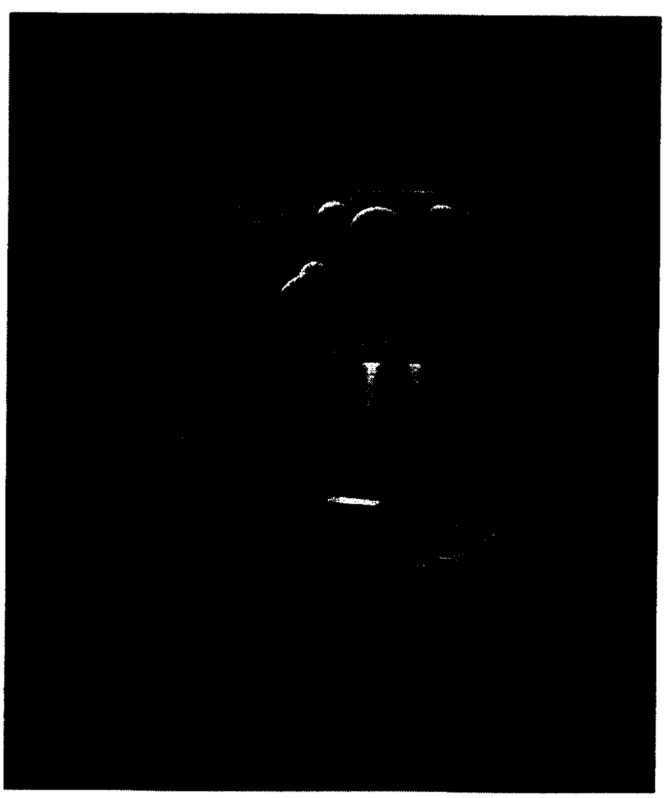


Space Transportation

Examining all mission phases for cost-effective transportation options and additional customers

- Earth-to-Orbit
  - Second generation Shuttle-derived launcher
  - Other potential customers - DoD Payloads, Next Generation Space Telescope
- Earth Orbit to Mars Orbit
  - Electric Propulsion
  - Nuclear Thermal Propulsion
  - Other potential customers - GEO payloads, Solar Power Satellites ?
- Mars Orbit Injection
  - Aerocapture
- Ascent from Martian Surface
  - In situ propellant production

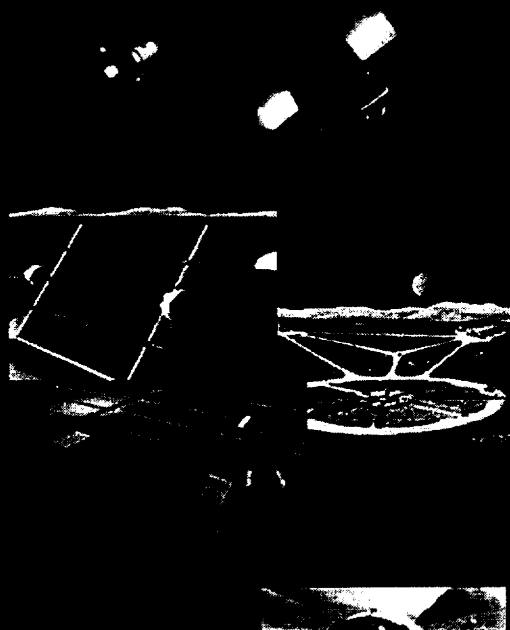




Mars In Situ Resources

- Traditional exploration architectures advocate investigation of Martian resources during "early" human missions
  - Idea is to reduce cost of subsequent missions
- Relying upon in situ resources from the outset presents some advantages
  - Producing ascent propellant greatly reduces required Earth launch mass
  - Producing caches of water and oxygen provides backup to life support systems
  - Can reduce level of closure (and expense) of systems
- Technical risk can be mitigated by robotic tests of Martian resource extraction
  - Could also make sense as a sample return strategy

Power Needs for Exploration



Electric Propulsion

- High Power (500 kWe - 4 MWe)
- Specific Mass (7-10 kg/kWe)
- Solar and Nuclear Power Generation Options
- Radiation Degradation < 35%
- Some Scenarios Include Vehicle Reusability

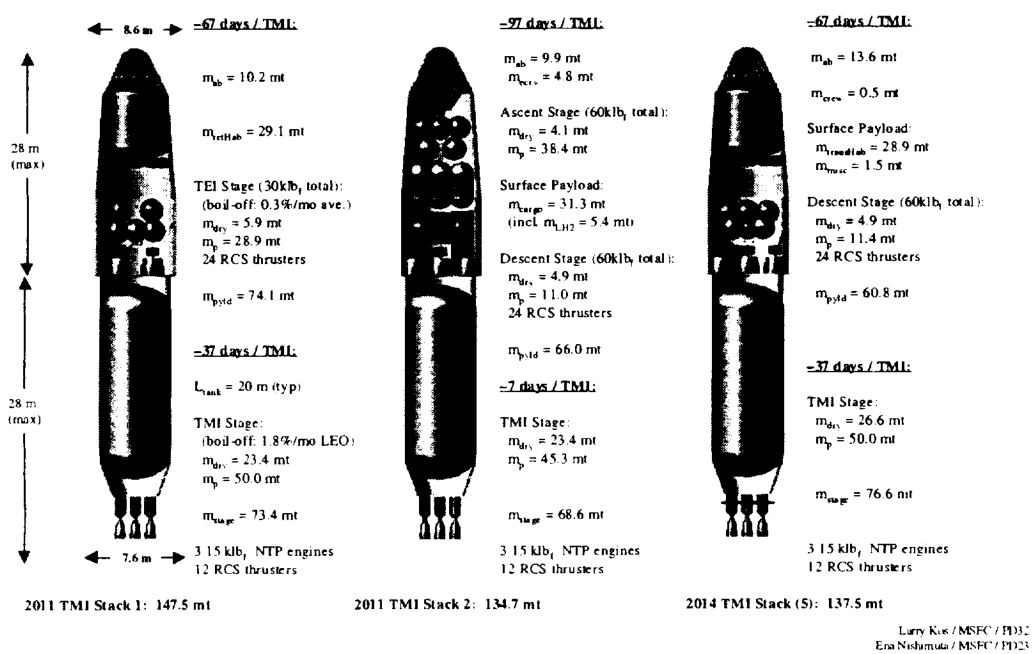
Stationary Power Sources (100+ kWe)

- Multi-year life (7 years)
- Solar and Nuclear Power Generation Options
- 30 kWe Habitats
- 30-60 kWe Regenerative Life Support
- 50 kWe In-Situ Resource Utilization

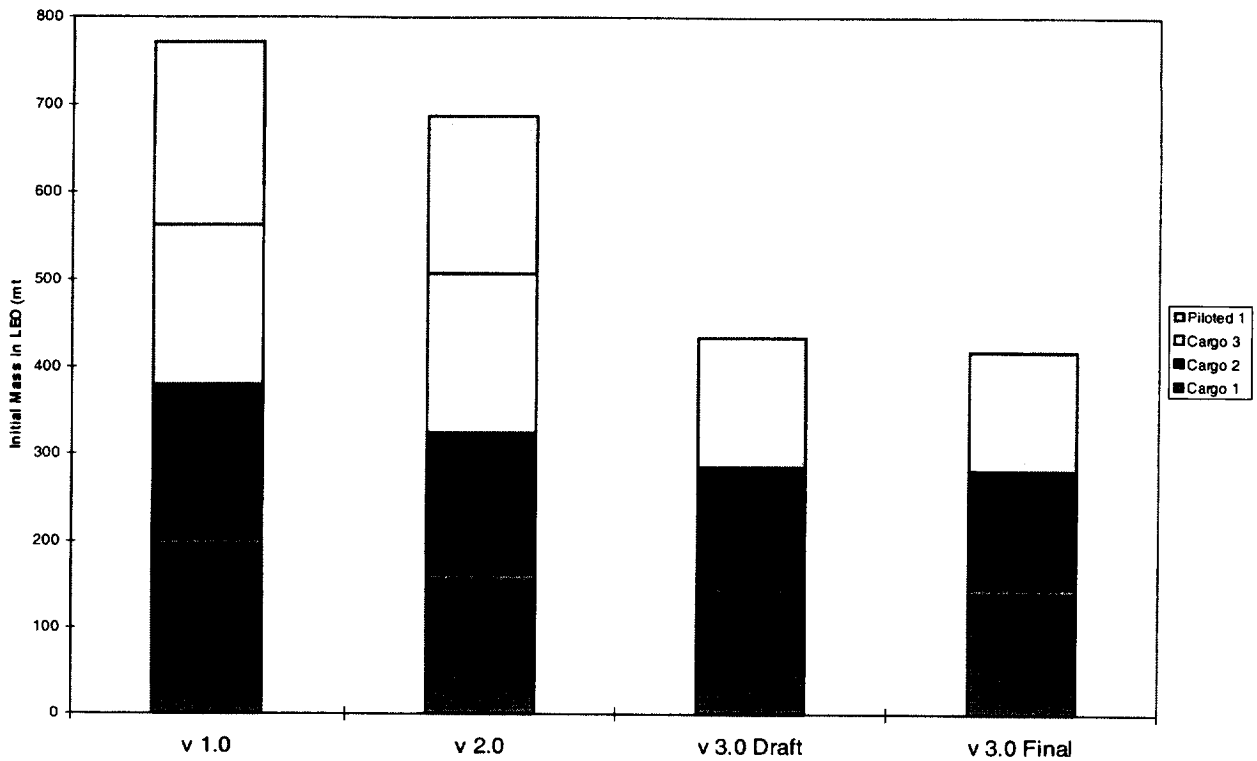
Mobile Power Sources

- Power Sources Include: Dynamic Isotope, Photovoltaic with Regenerative Fuel Cells, Advanced Batteries, and Internal Combustion
- 10 kWe for pressurized rovers
- 10 kWe for universal power cart
- 4 kWe for unpressurized rovers
- 50-100 W for EVA suit

Launch Packaging for Version 3.0



DRM Mass History



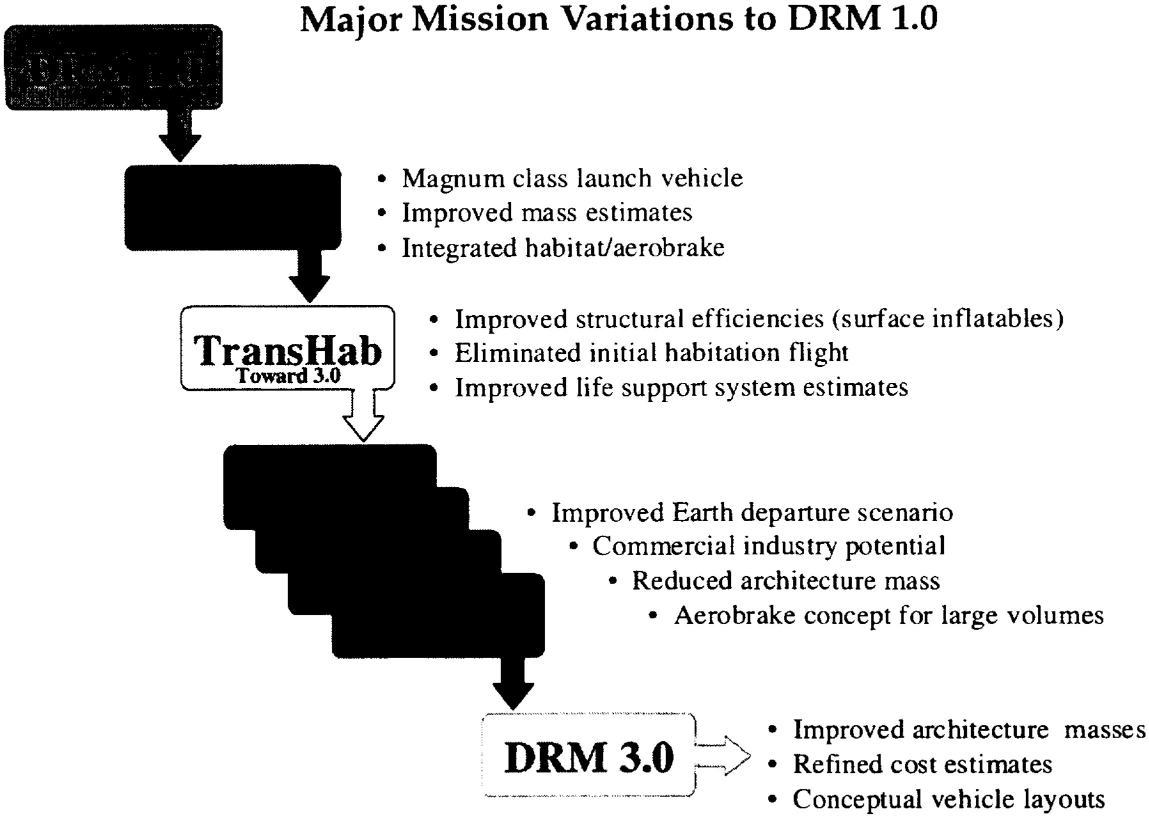
Version 3.0 Mass Summary

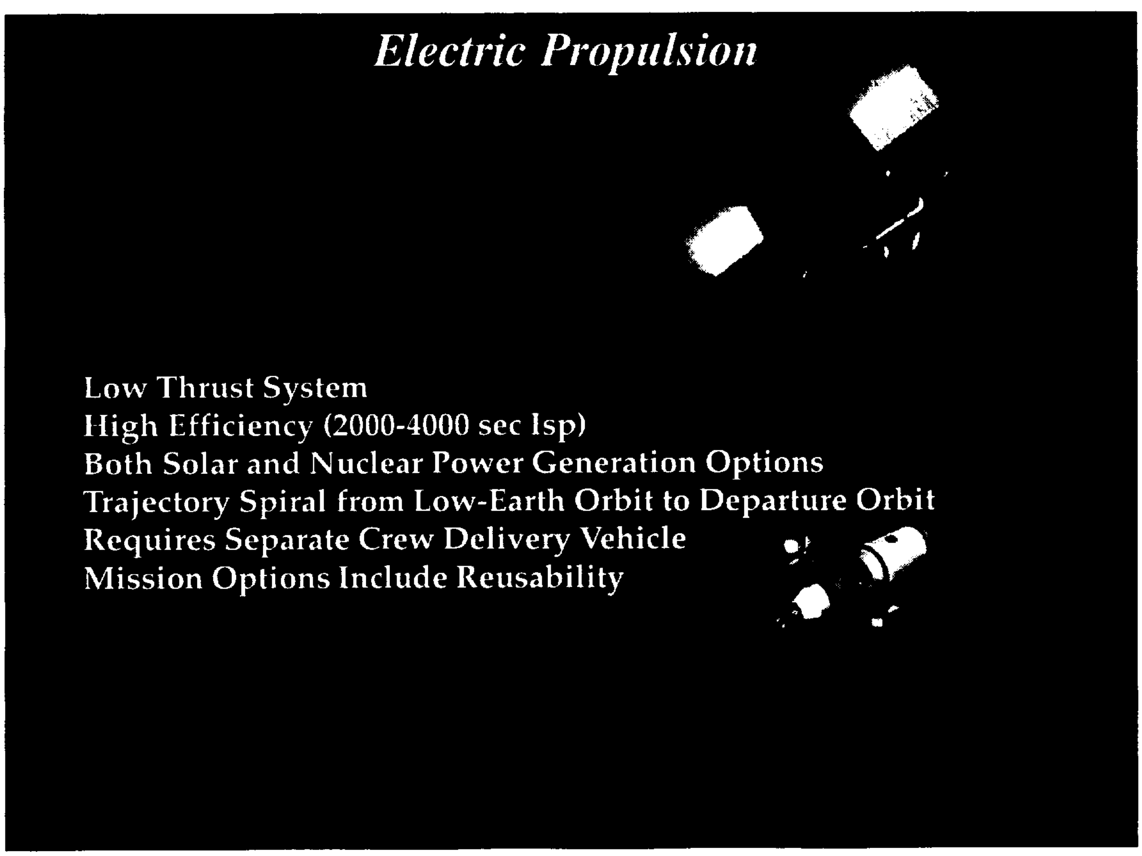
Flight 1: ERV	Reference Version 1.0	Final Version 3.0
Earth Return Vehicle	56 mt	29 mt
TEI Stage	5 mt	6 mt
TEI Propellant	52 mt	29 mt
Aerobrake	17 mt	10 mt
TMI Stage	29 mt	23 mt
TMI Propellant	86 mt	50 mt
TOTAL IMLEO	**246 mt**	**147 mt**

Flight 2: MAV	Reference Version 1.0	Final Version 3.0
Ascent Capsule	6 mt	5 mt
Ascent Stage	3 mt	4 mt
Payload	48 mt	31 mt
Descent Stage	5 mt	4 mt
Descent Propellant	12 mt	11 mt
Aerobrake	17 mt	10 mt
TMI Stage	29 mt	23 mt
TMI Propellant	86 mt	45 mt
TOTAL IMLEO	**205 mt**	**134 mt**

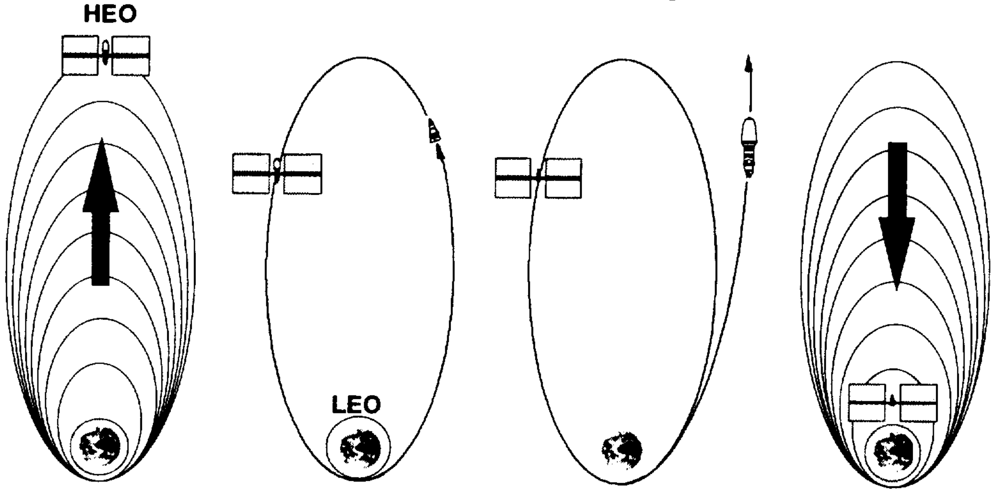
Flight 3: Piloted	Reference Version 1.0	Final Version 3.0
Habitat	53 mt	29 mt
Payload & Crew	2 mt	2 mt
Descent Stage	5 mt	5 mt
Descent Propellant	12 mt	11 mt
Aerobrake	17 mt	14 mt
TMI Stage & Shielding	32 mt	27 mt
TMI Propellant	86 mt	50 mt
TOTAL IMLEO	**208 mt**	**137 mt**

Major Mission Variations to DRM 1.0





Electric Propulsion Earth Departure

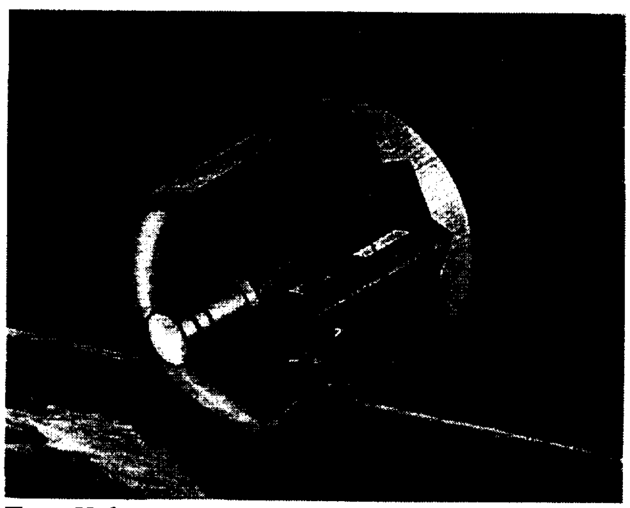


Electric Propulsion (EP) space tug performs low-thrust transfer for Mars-bound cargo to High Earth Orbit (many months transfer)

Crew delivered in "small" chemically-propelled transfer vehicle - X-38 derived (few days rendezvous time)

Remainder of trans-Mars injection performed by chemically-propelled system

Space tug returns for refueling and next assignment (faster or more efficient return since no payload present)

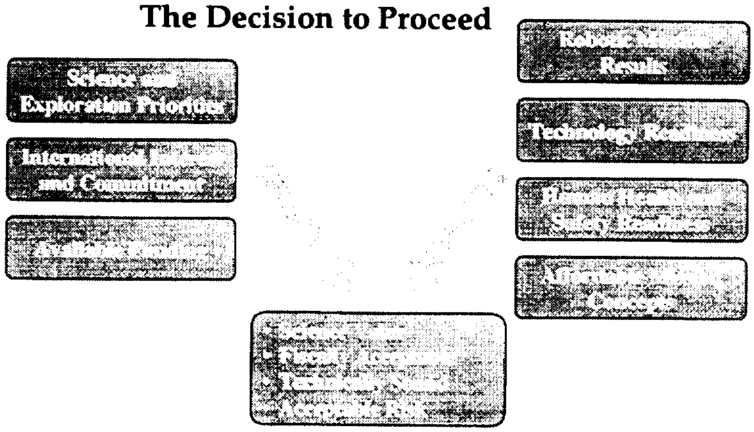


TransHab at ISS

Mars TransHab

- JSC Engineering Directorate investigated the use of inflatable structures for human Mars missions
- Significant improvement in:
  - Structural efficiencies
  - Advanced life support system design
- Advancements incorporated into Mars mission definition (surface)

The Decision to Proceed



Enable an affordable Mission to Mars