NASA Exploration Team (NEXT)
In-Space Transportation Overview

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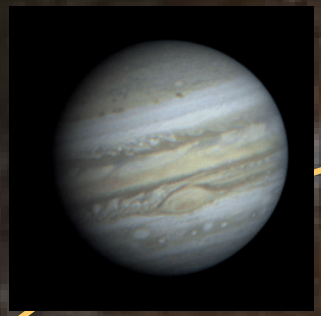
Stepping Stones





Go anywhere, anytime

Sustainable Planetary Surfaces





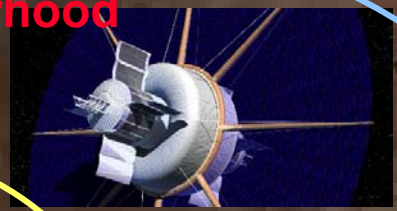
Accessible Planetary Surface

Earth's Neighborhood



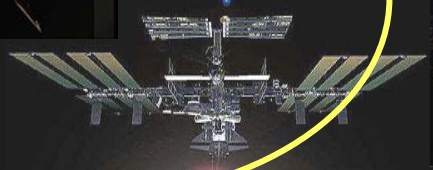






Earth and LEO







Enabling the Strategy

The Hurdles

- **Space Transportation**
  - Safe, fast, and efficient
- **Affordable, Abundant Power**
  - Solar and nuclear
- **Crew Health and Safety**
  - Countermeasures and medical autonomy
- **Optimized Robotic and Human Operations**
  - Dramatically higher productivity; on-site intelligence
- **Space Systems Performance**
  - Advanced materials, low-mass, self-healing, self-assembly, self-sufficiency…

What must we know to make informed decisions?

The Criteria

- **Compelling science objectives and benefits**
- **Knowledge about destinations**
- **Reliable and affordable mission concepts**
- **Acceptable technology readiness achieved**
- **Validation of capabilities for deep space missions**
- **Identified opportunities for partnership/leadership**
- **Inspiring and engaging to students and the public**

Exploration of Earth's Neighborhood

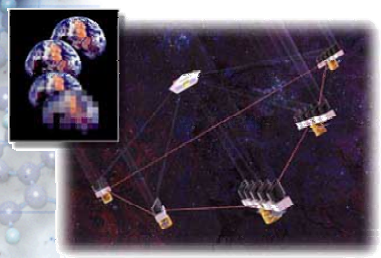


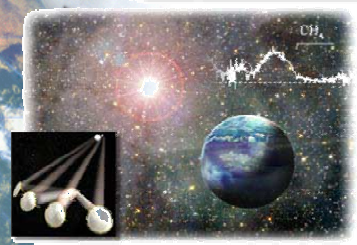
Exploration of Earth's Neighborhood



Human Mars Exploration

- Technology Development
- Deep-Space Operational Experience
- Mission Staging

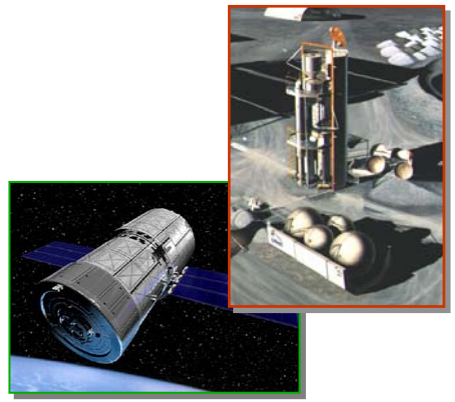




Construct, Deploy, and Service Advanced Astronomical Instruments

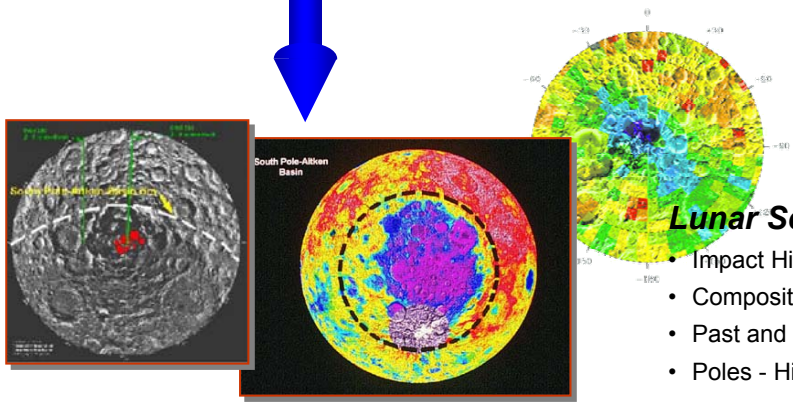
- Detect Biological Activity on Extra-Solar Planets
- Image Surfaces of Extra-Solar Planets
- Search for Location and Mechanism of Solar Flares
- Increase Lead Time and Accuracy for Geospace Forecasts

"Earth's Neighborhood" Capabilities



Commercialization Opportunities

- Lunar Oxygen or Water Production
- Regolith Materials Processing
- Fuel Depot



Lunar Science

- Impact History in Near-Earth Space
- Composition of Lunar Mantle
- Past and Current Solar Activity
- Poles - History of Volatiles in Solar System

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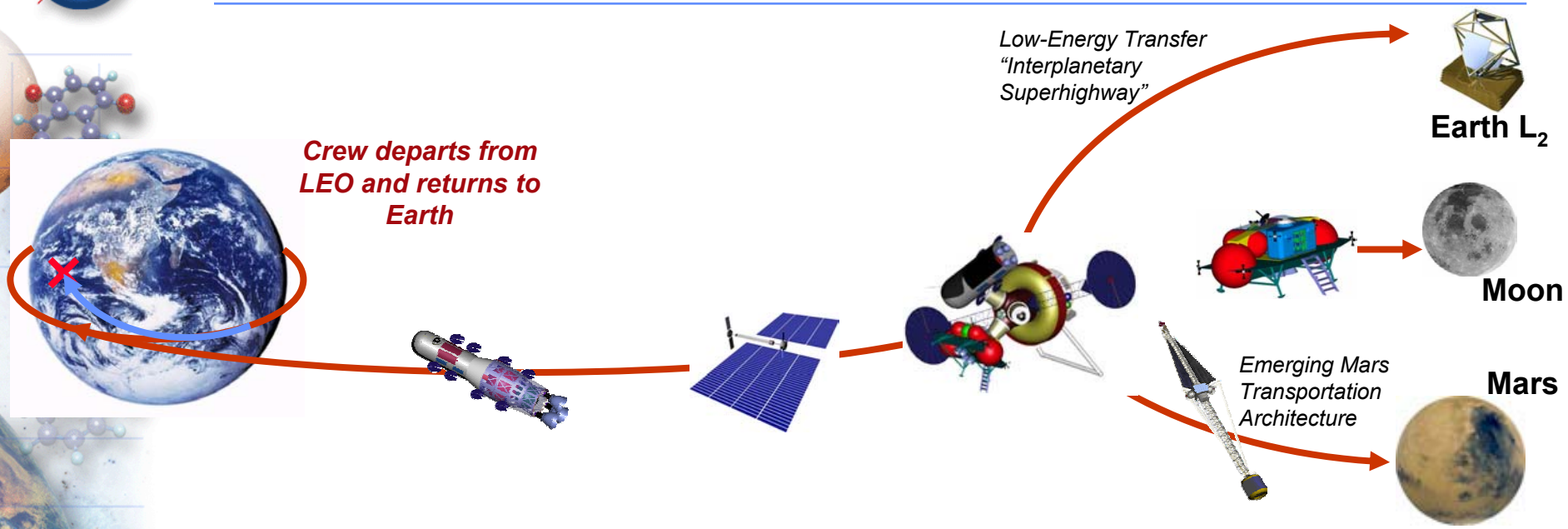
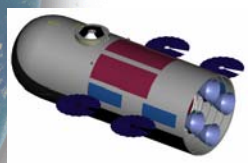
Earth's Neighborhood Architecture & Elements



Architecture

Elements



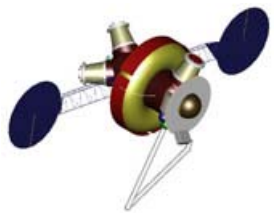
Lunar Transfer Vehicle

- Transports crew between LEO and Lunar L_1 (4-6 day trip)
- Nominal aerocapture+entry with contingency direct Earth return



High-Energy Propulsion Stage

- High-efficiency stage used to deliver cargo from LEO to a final destination.



Earth-Moon L_1 Outpost

- "Gateway" to the Lunar surface
- Outpost for staging missions to Moon, Mars and telescope construction



Lunar Lander

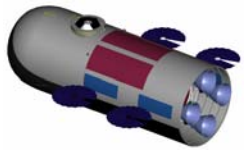
- Transports crew between Outpost and Lunar Surface
- 9-day mission (3 days on Lunar surface)



Lunar Habitat

- 30-day surface habitat placed at Lunar South Pole

Earth's Neighborhood Transportation Elements



In-Space Transportation

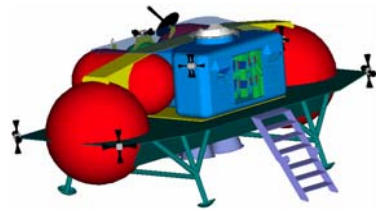
- Deep-space propulsion for capture, orbital maintenance, and element return to Earth
- Key Technologies & Options:
  - Advanced Chemical (CH_4/O_2)
  - Long-term Cyro Storage





High-Energy Injection

- Injects mission payloads from low-Earth orbit (LEO) toward their intended destination
- Key Technologies & Options:
  - Advanced Chemical (H_2/O_2)
  - Solar Electric Propulsion
  - Long-term Cyro Storage



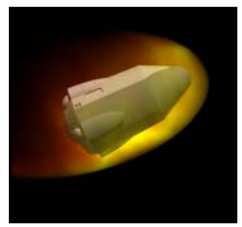
Descent / Ascent

- Deep-space propulsion for descent to and ascent from the lunar surface
- Key Technologies & Options:
  - Advanced Chemical (CH_4/O_2)
  - Long-term Cyro Storage



Earth-to-Orbit (ETO)

- Transports cargo elements and crew from Earth to LEO
- Options:
  - Shuttle-derived
  - Evolved EELV



Earth Return

- High-energy aeroassist for orbital capture and entry of Earth's atmosphere
- Key Technologies & Options:
  - Advanced Ablators

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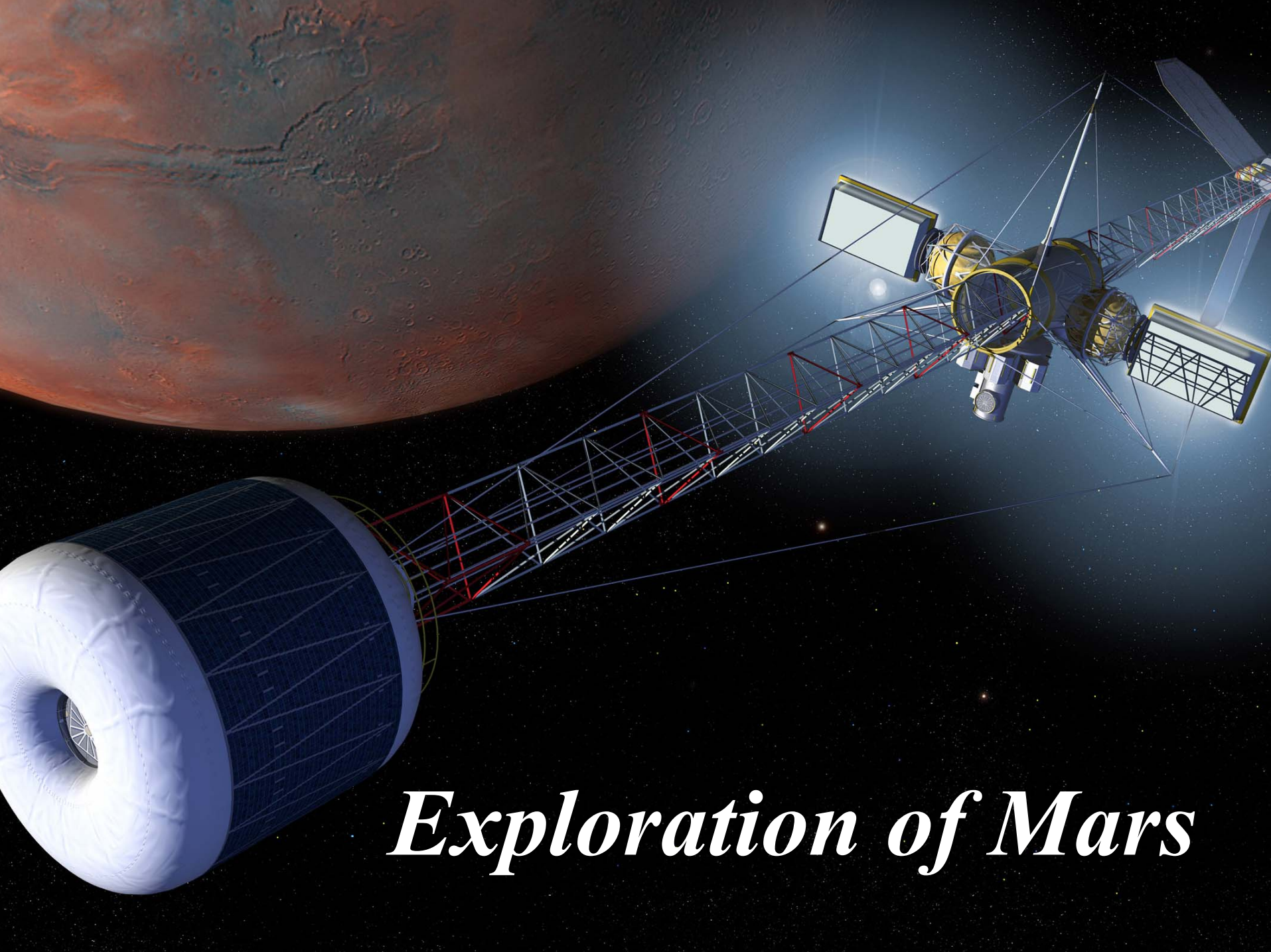
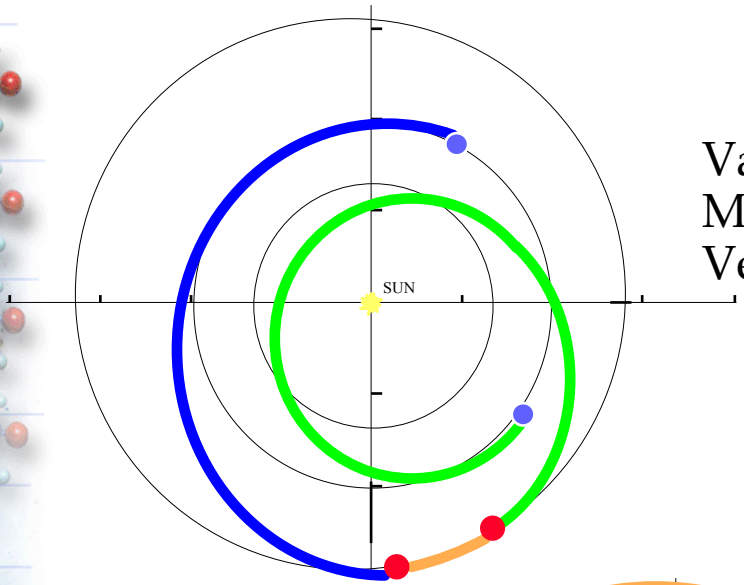
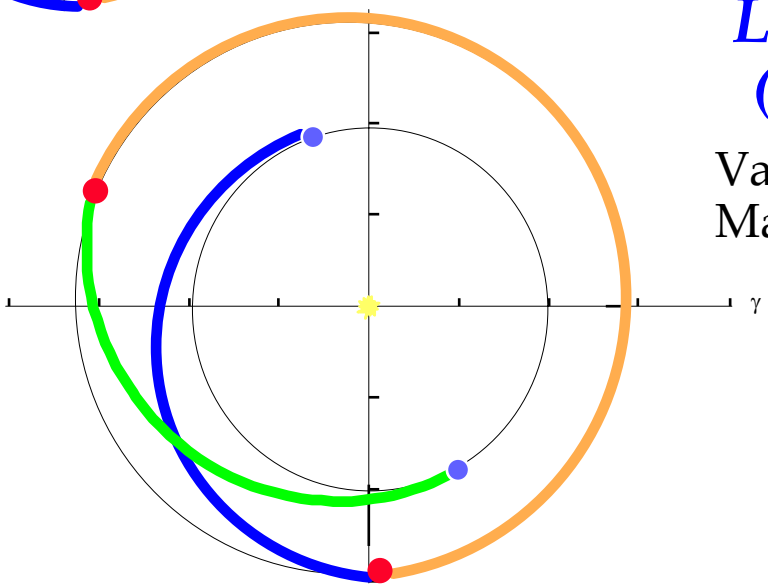

Exploration of Mars

Mars Mission Trajectory Options



Short-Stay Missions (Opposition Class)

Variations of missions with short Mars surface stays and may include Venus swing-by



Long-Stay Missions (Conjunction Class)

Variations of missions with long Mars surface stays.

Outbound
Surface Stay
Inbound

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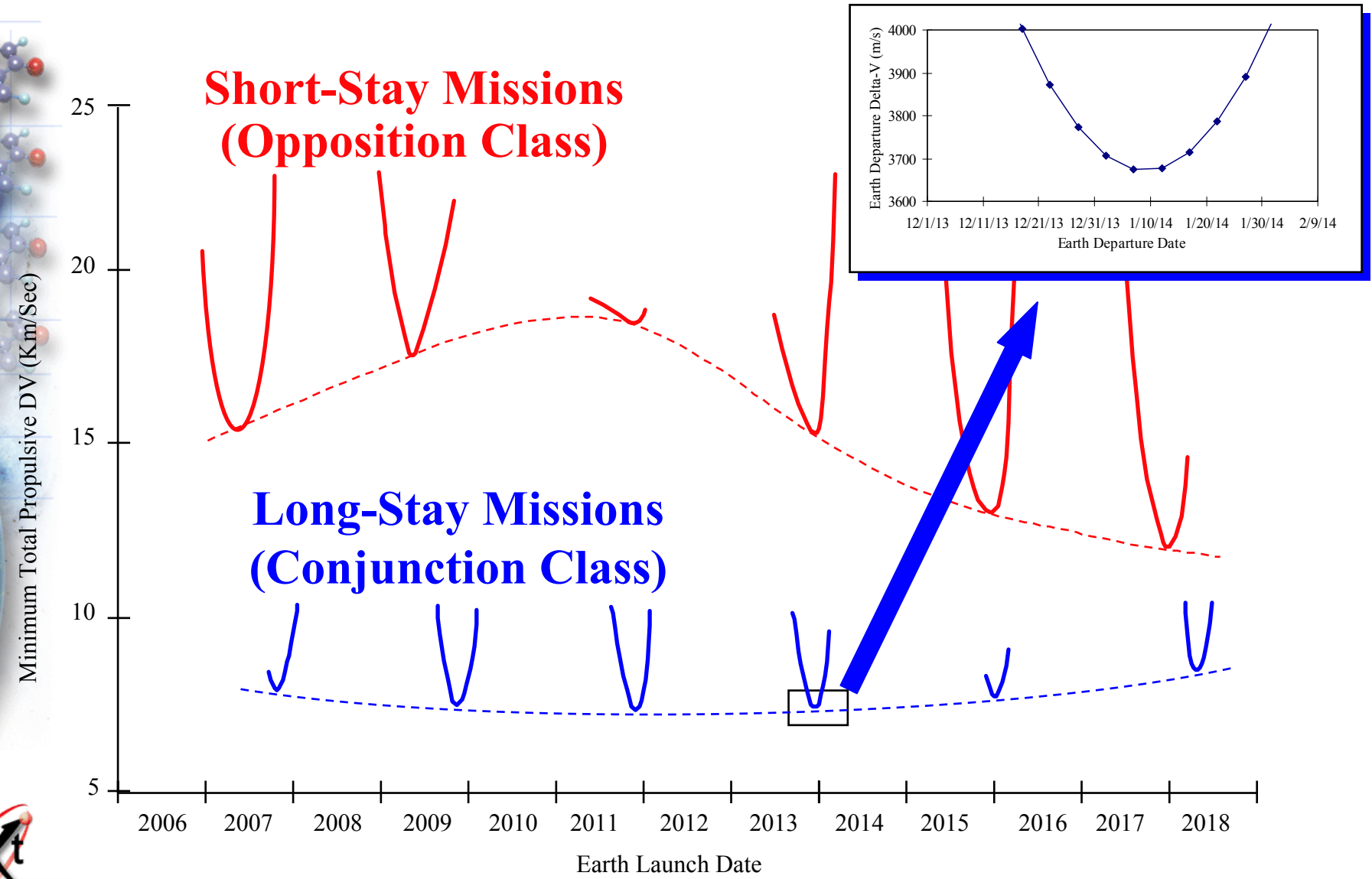
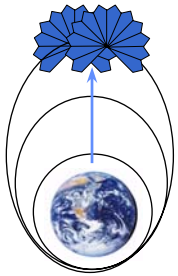
Delta-V Variations

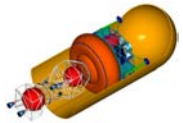


Mars Long-Stay Mission Overview Option
(Solar Electric Propulsion Option)



1 Habitat Lander and Descent/Ascent Vehicles delivered to Low Earth Orbit. Solar Electric Propulsion stages spirals cargo to High Earth Orbit. Chemical injection used at perigee. (Option: SEPs spiral back to LEO for reuse).

2 Surface Habitat and exploration gear aerocaptures into Mars orbit



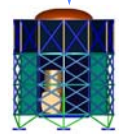
2 Descent/Ascent Vehicle aerocaptures and remains in Mars orbit for the crew

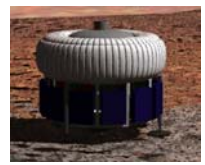


3 Surface Habitat lands and performs initial setup and checkout - Initial outpost established

6 Crew rendezvous with Descent/Ascent Vehicle in Mars Orbit then lands in vicinity of Habitat Lander

7 Crew lands on surface. 30 days provided to satisfy "long-stay" criteria.

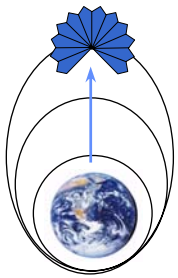




Mars Surface

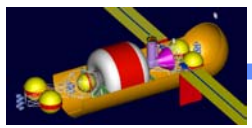
8 In-depth regional exploration (500-600 days). Crew ascends and rendezvous with waiting Transit Habitat

6 Habitat remains in Mars orbit

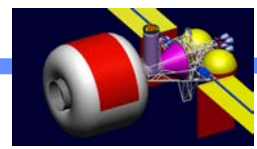


4 Transit Habitat vehicle delivered to LEO. SEP spirals Transit Habitat to High Earth Orbit. Crew delivered to vehicle via crew taxi. (Option: SEP spirals back to LEO for reuse).

5 Crew travels to Mars in "fast transit" 180-206 day transfer. Aerocaptures into Mars orbit



9 Crew returns to Earth on "fast transit" 180-206 day transfer.



10 Direct capsule entry at Earth

Earth

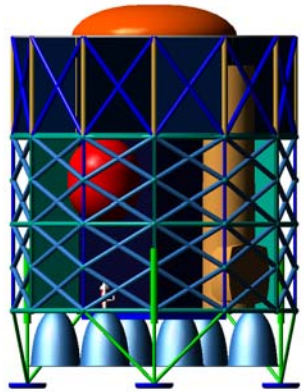
Total mission duration: 892-945 days
Time on Mars surface: 500-600 days

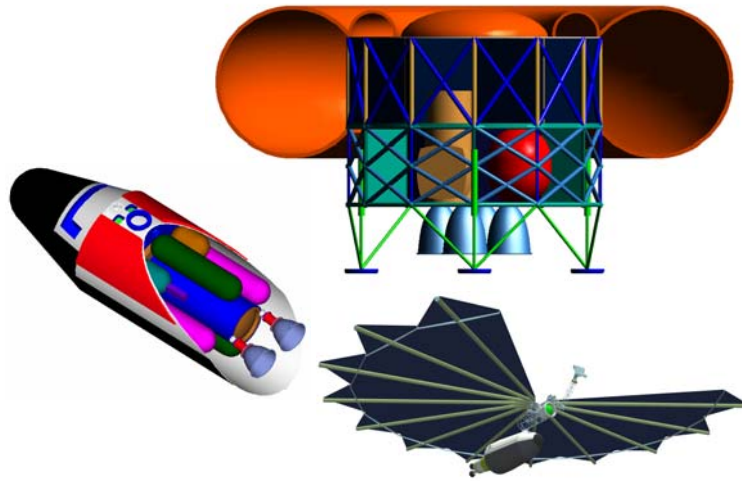
Ref. Johnson Space Center

Mars Architecture

Key Attributes

- Crew of 4-6
- Short (30-day) initial visits for focused local science evolving to long (500-day) stays for extensive regional exploration
- Total mission durations range from 365 to 950 days.
- Capability to go to Mars any opportunity
- Maximum use of capabilities developed for Earth's Neighborhood
- Ability to introduce new technologies as they are developed
- Advanced transportation and enhanced launch capacity required to reduce risk and architecture cost







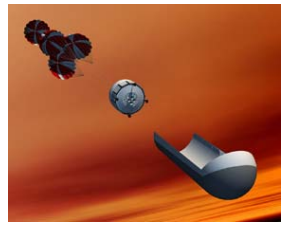
Mars Exploration Transportation Elements

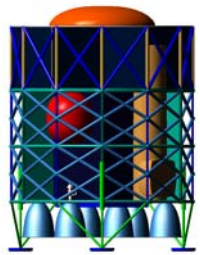




Aeroassist

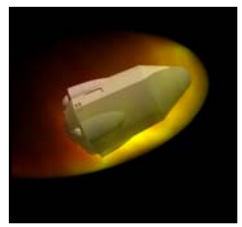
- Utilization of Mars atmosphere for capture, entry, and descent
- Key Technologies & Options:
  - Advanced Ablators
  - Integrated Launch Shroud / Aeroshell





Descent / Ascent

- Deep-space propulsion for descent to, and ascent from, the martian surface
- Key Technologies & Options:
  - Advanced Chemical (CH_4/O_2)
  - Long-term Cyro Storage



Earth Return

- High-energy aeroassist for orbital capture and entry of Earth's atmosphere
- Key Technologies & Options:
  - Advanced Ablators

In-Space Transportation

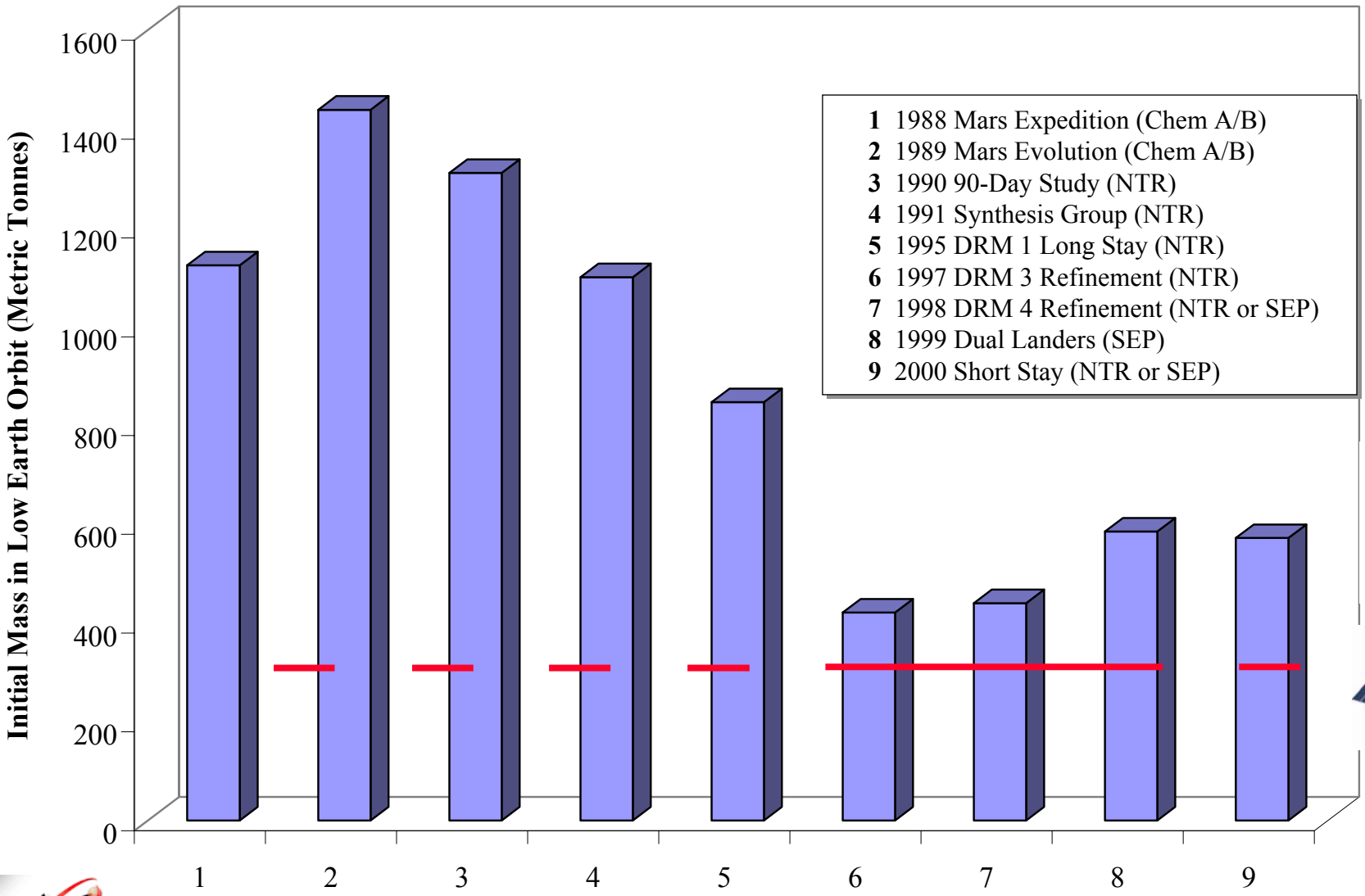
- Deep-space propulsion for element delivery and return to Earth
- Key Technologies & Options:
  - Nuclear Electric Propulsion
  - Solar Electric Propulsion
  - Advanced Chemical



Earth-to-Orbit (ETO)

- Transports cargo elements and crew from Earth to LEO
- Options:
  - Shuttle-derived
  - Clean-sheet approach

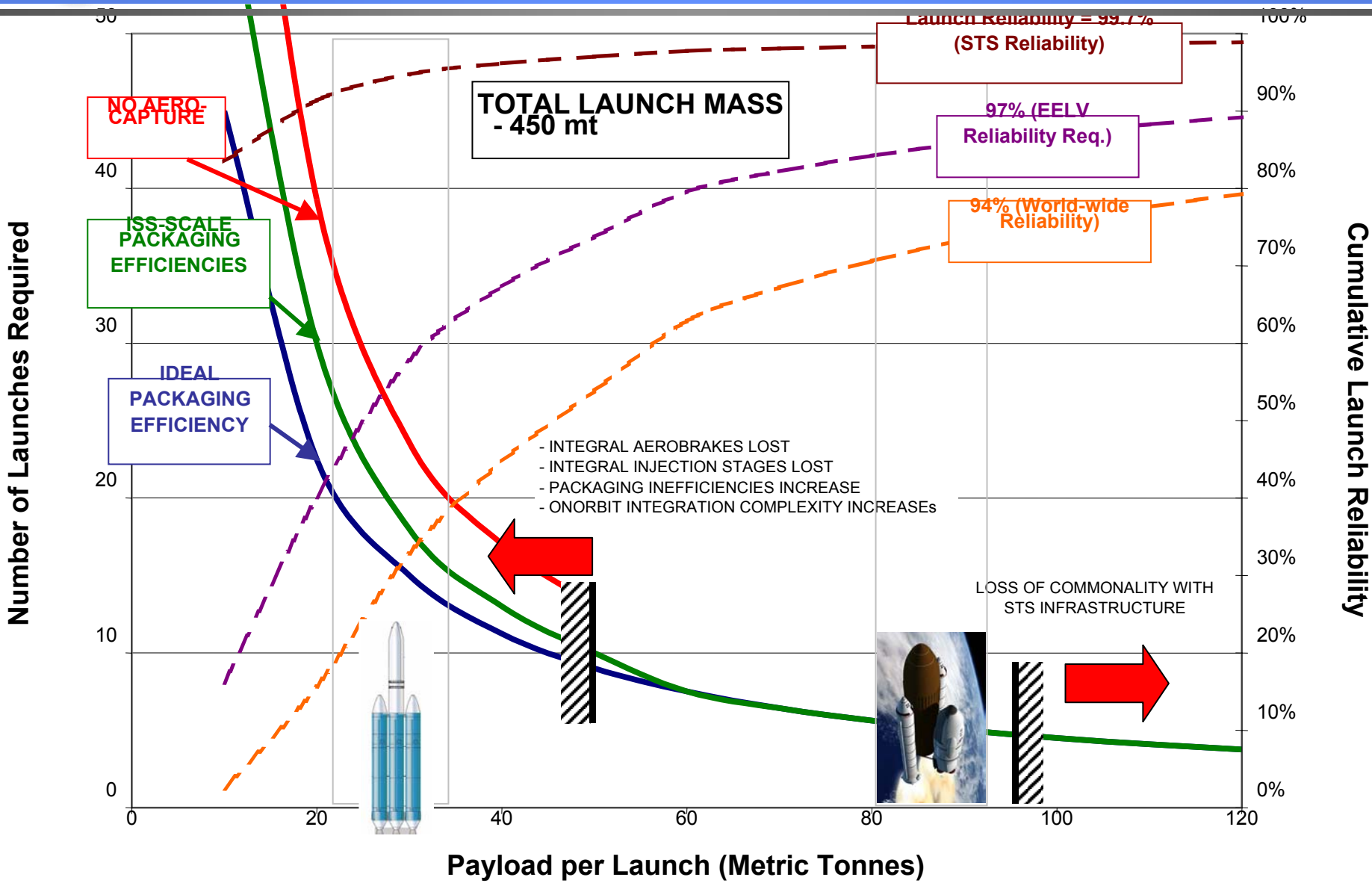
Mars Architecture Mass History



ISS @ Assembly Complete (470 tons)



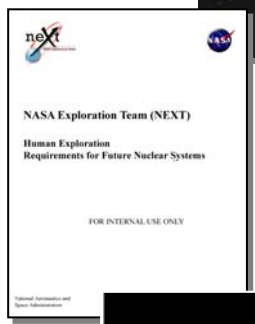
Mars Mission Launches Required and Associated Reliability

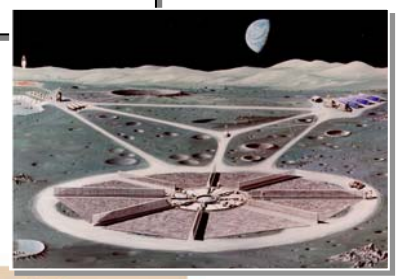


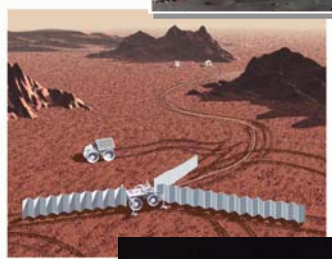
Nuclear Electric Propulsion Advantages

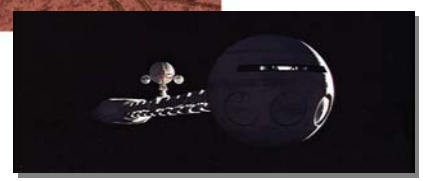
- **High propulsive performance**
  - Captures energetically challenging Mars missions in all opportunities (for ~ same prop mass)
- **High power availability**
  - Robust power for crew, spacecraft systems (<1% of propulsion requirements)
- **Potential technology convergence with advanced robotic exploration and NSI**
  - Reactor, power conversion, thrusters
  - Human exploration nuclear power requirements ready to submit to Nuclear Space Initiative
- **Potential convergence with technology development of surface nuclear power**
  - Moon - > 14 days (non-polar) at fixed location
  - Mars – "long" stay
- **Allows Sustainable, Evolvable Exploration Capability**
  - High reactor energy content and low prop mass fraction allows high degree of vehicle reusability for Mars missions
  - Evolution of power/propulsion possible to even more ambitious missions





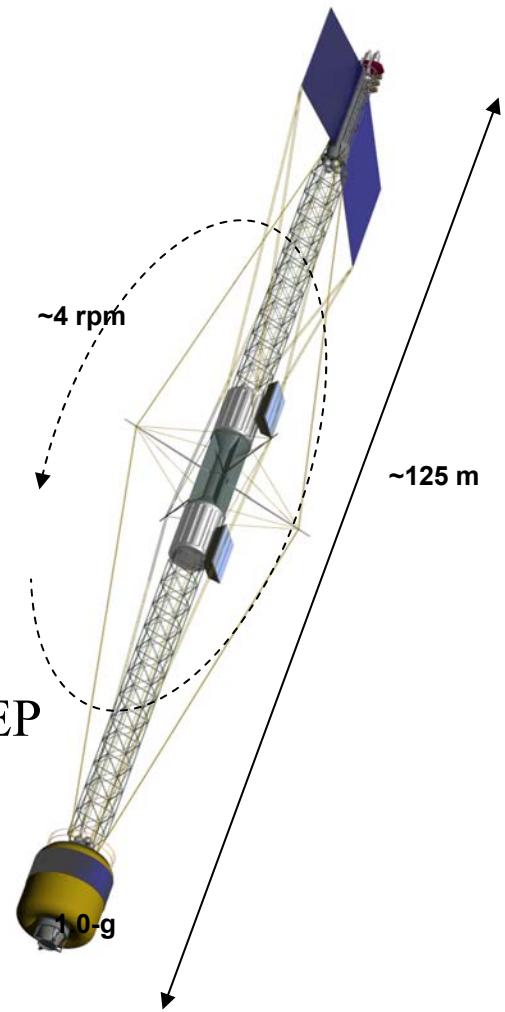






Artificial Gravity (AG) Option

- Alternative to long-duration μ-g crew countermeasures
  - 1-g @ 4 rpm
- May simplify qualification of some spacecraft systems
  - Ameliorates extensive μ-g qualification
- Impacts currently under study
  - Vehicle design
  - Mass penalty
  - Mission capabilities
  - Operational considerations
  - No show-stoppers so far
- Good synergism between AG requirements and NEP vehicle characteristics
  - Booms/masts for rad exposure amelioration and AG moment arm
  - "Power module" as counterweight
- May greatly enhance short-stay missions
  - Crew readaptation time avoided



Key In-Space Transportation Technology Options & Needs

Earth-to-Orbit Launch

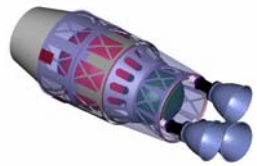


Application: Affordable delivery of cargo elements and crew from Earth to LEO.

Needs: 80-100 mt with payload volumes up to 10 m x 30 m.

Key Options: Shuttle derived or clean sheet approaches

Advanced Chemical Propulsion

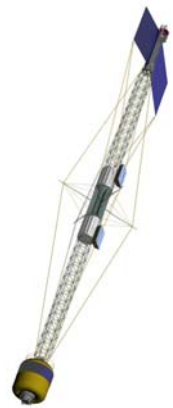


Application: High energy injection stages for transportation of elements in near-Earth space. Advanced chemical engines for descent and ascent at planetary destinations.

Needs: 5-6 klbf throttleable engines which are compatible with utilization of local resources.

Key Options: O2/Methane, O2/Hydrogen

Electric Propulsion

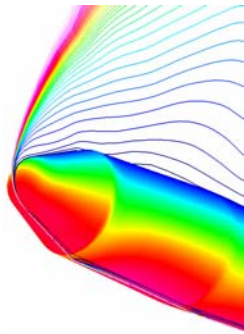


Application: High-efficiency propulsion for delivery of cargo and crew elements from Earth vicinity to planetary destinations & return.

Key Options: 6-20 MWe nuclear electric.

1-3 MWe solar electric (combined with chemical injection stages and aeroassist at Mars).

Key In-Space Transportation Technology Options & Needs



Aeroassist

Application: Utilization of planetary atmospheres (Mars and Earth return) for orbital capture, entry, descent, and landing.

Needs: Arrival speeds of 7.4 km/s (Mars) and 11.0 – 13.5 km/s (Earth return).

Key Options: Advanced ablators. Integrated aeroshell/payload shroud concepts.

Cryogenic Fluid Management

Application: Long-term storage of cryogenic fluids in space and on planetary surfaces.

Needs: Storage of cryogenic fluids (H_2, O_2, CH_4) for up to 1200 days.

Key Options: Combination of passive and active systems.