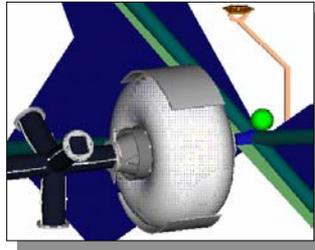


L1 Gateway

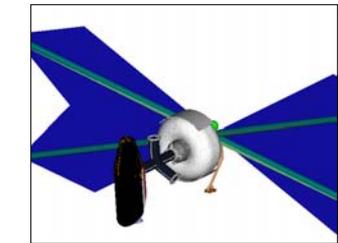


L1/L2 SEP

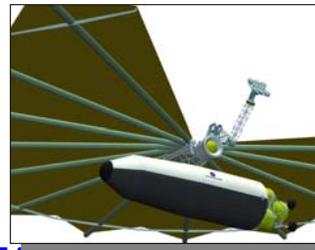
Mars Habitats



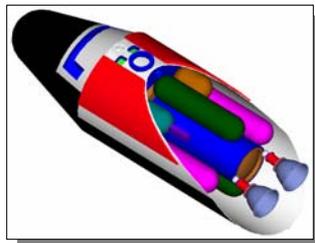
Mars SEP



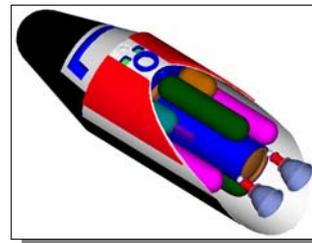
L1 Transfer Vehicle



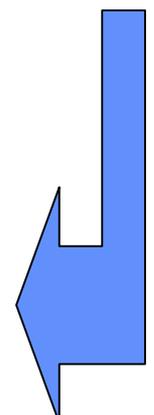
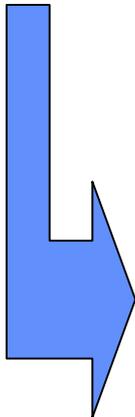
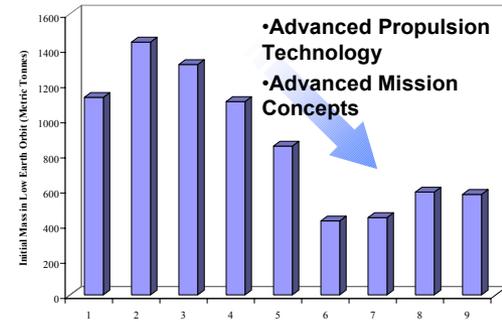
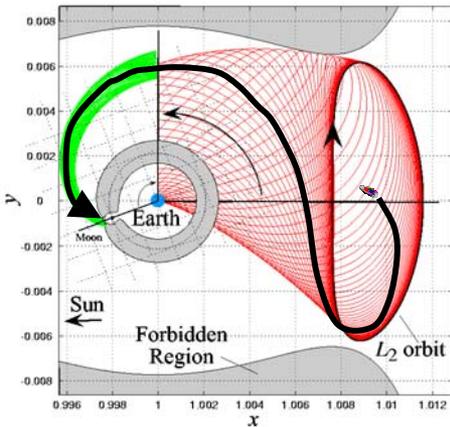
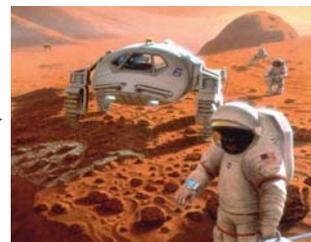
Mars SEP Taxi



Lunar, L1 EVA



Mars EVA

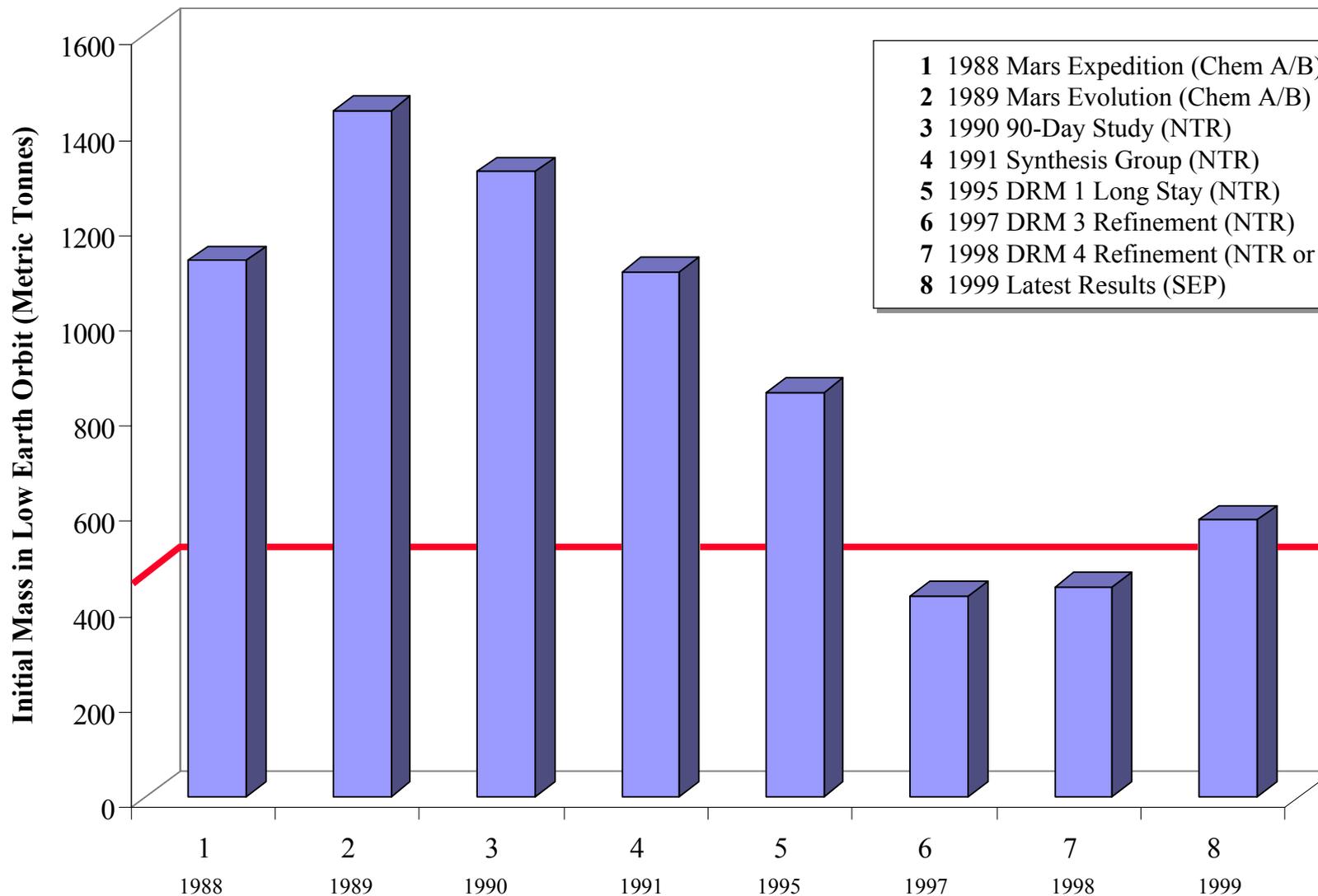




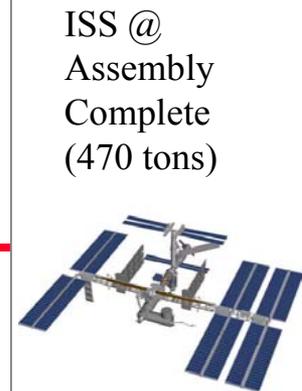
Mars Architecture Mass Comparison



Advanced Development

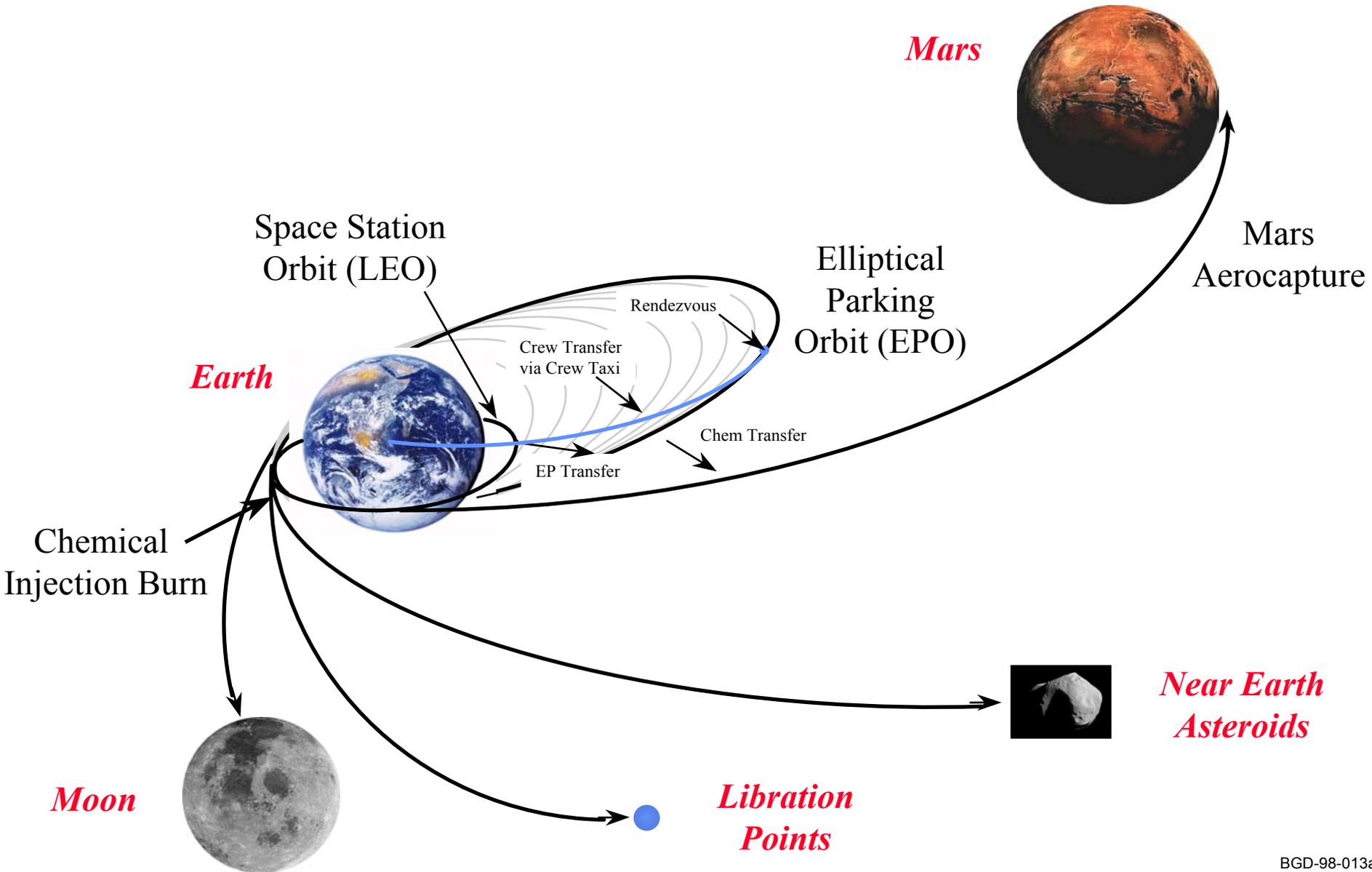


- 1 1988 Mars Expedition (Chem A/B)
- 2 1989 Mars Evolution (Chem A/B)
- 3 1990 90-Day Study (NTR)
- 4 1991 Synthesis Group (NTR)
- 5 1995 DRM 1 Long Stay (NTR)
- 6 1997 DRM 3 Refinement (NTR)
- 7 1998 DRM 4 Refinement (NTR or SEP)
- 8 1999 Latest Results (SEP)





High Earth Orbit Staging Mission Scenarios

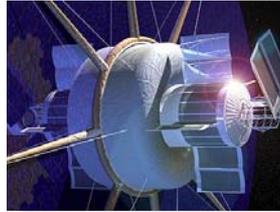


Earth to Orbit Transportation



- Moon (follow on)
- Asteroids
- Mars

Interplanetary Habitation



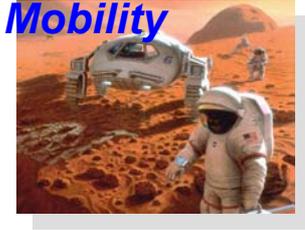
- Moon
- Sun-Earth Libration
- Asteroids
- Mars

Crew Taxi / Return



- Moon
- Sun-Earth Libration
- Asteroids
- Mars

EVA & Surface Mobility



- Moon
- Mars
- Asteroids

Advanced Space Transportation Options

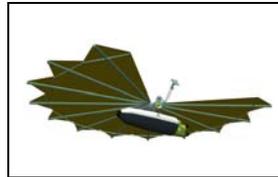


Advanced Chemical “Small”

- Moon (follow on)
- Sun-Earth Libration

“Large”

- Asteroids
- Mars



Electric Propulsion <500 kWe

- Moon
- Sun-Earth Libration
- Mars Outpost

>1 MWe

- Asteroids
- Mars



Nuclear Thermal

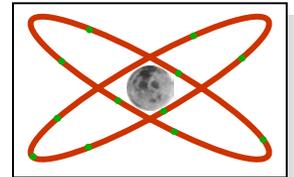
- Asteroids
- Mars
- Moon (follow-on)

In-Situ Resource Utilization

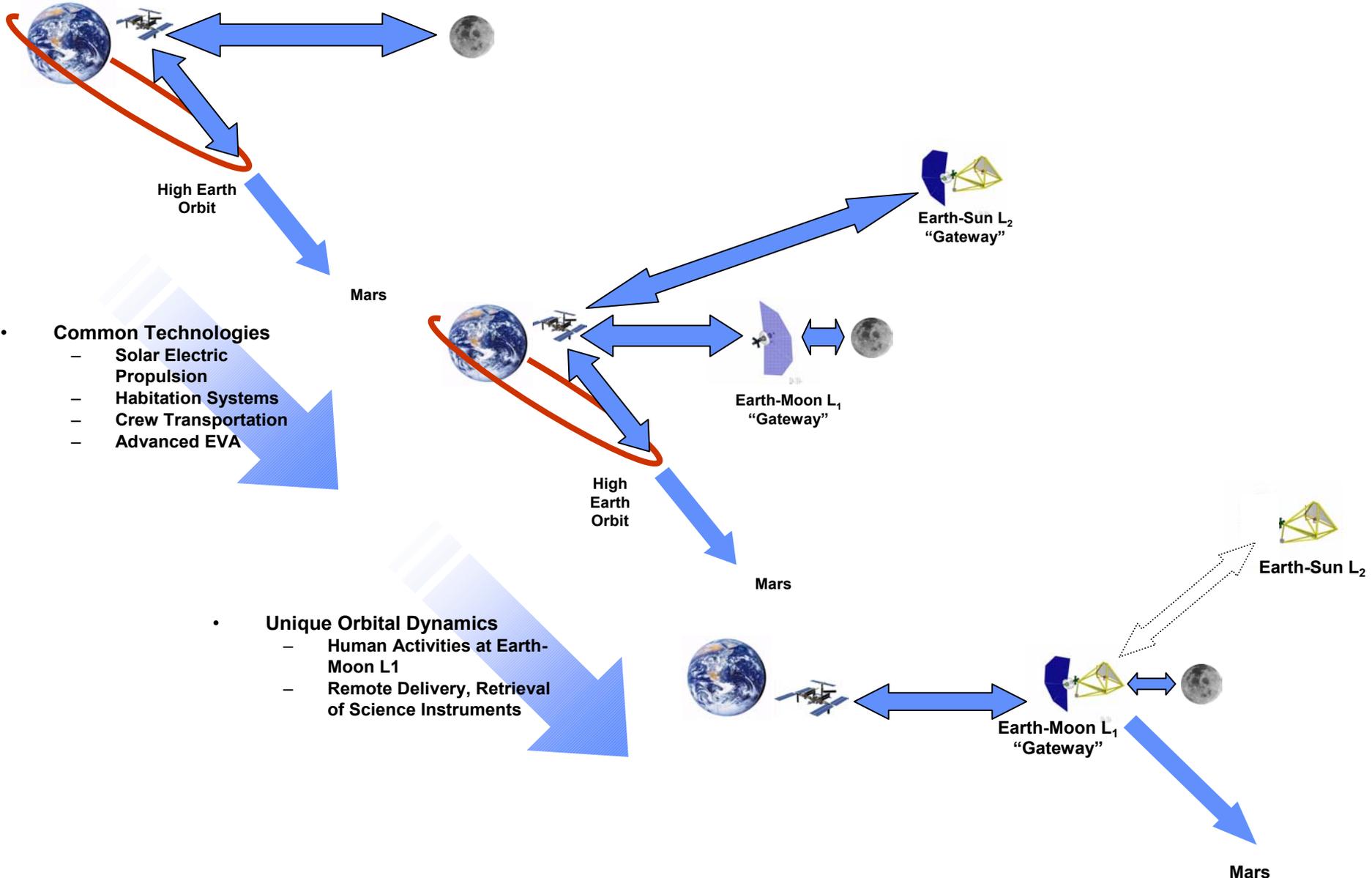


- Moon
- Mars

Com/Nav Infrastructure



- Moon
- Mars



- **Common Technologies**
 - Solar Electric Propulsion
 - Habitation Systems
 - Crew Transportation
 - Advanced EVA

- **Unique Orbital Dynamics**
 - Human Activities at Earth-Moon L₁
 - Remote Delivery, Retrieval of Science Instruments

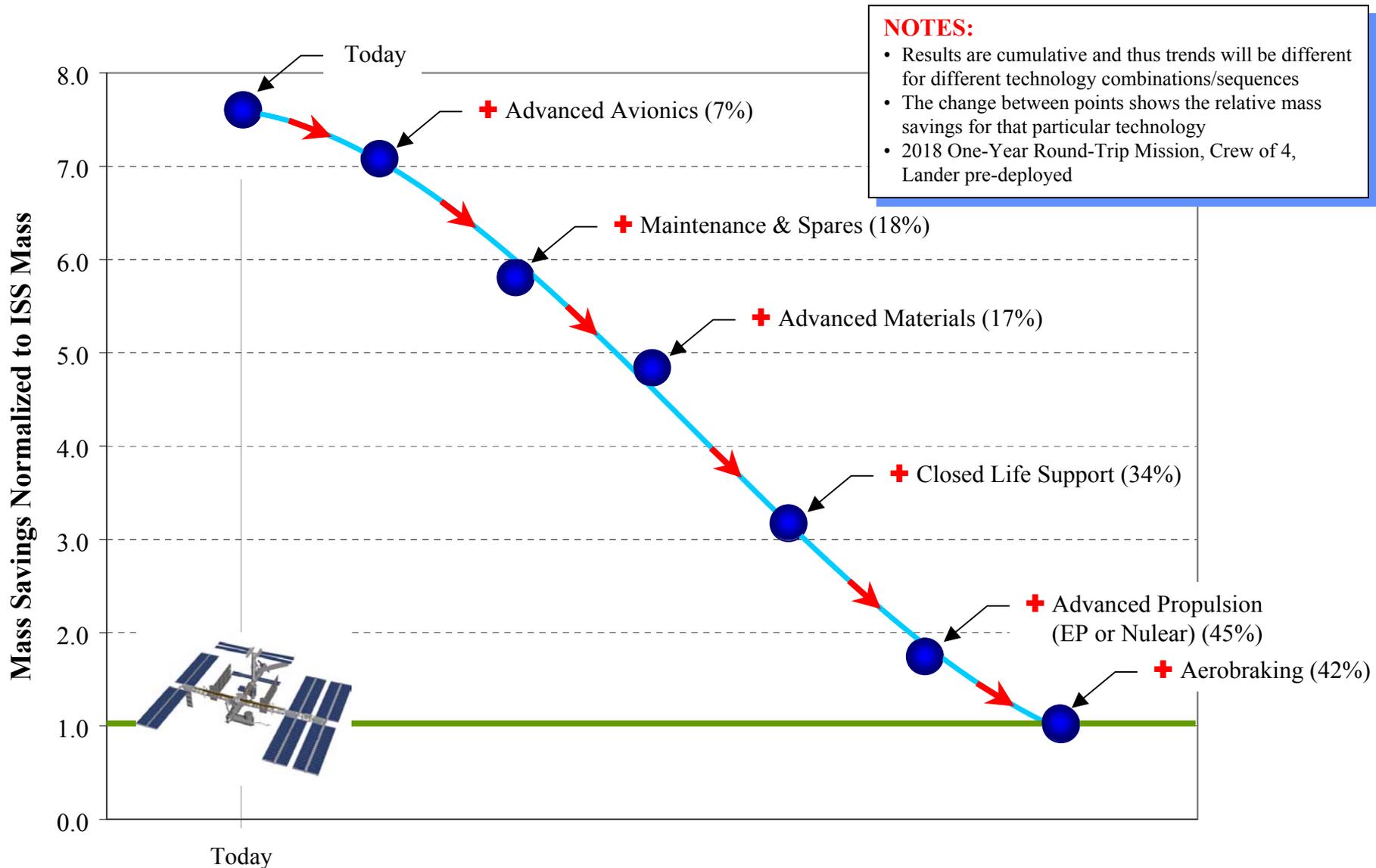


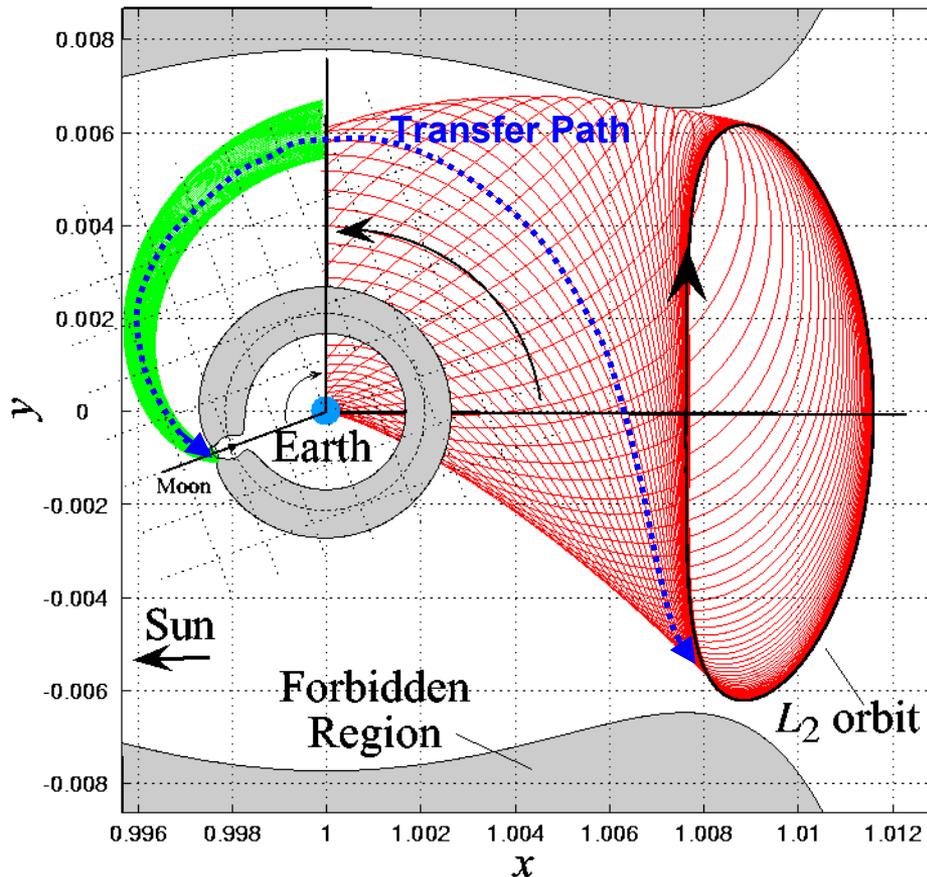
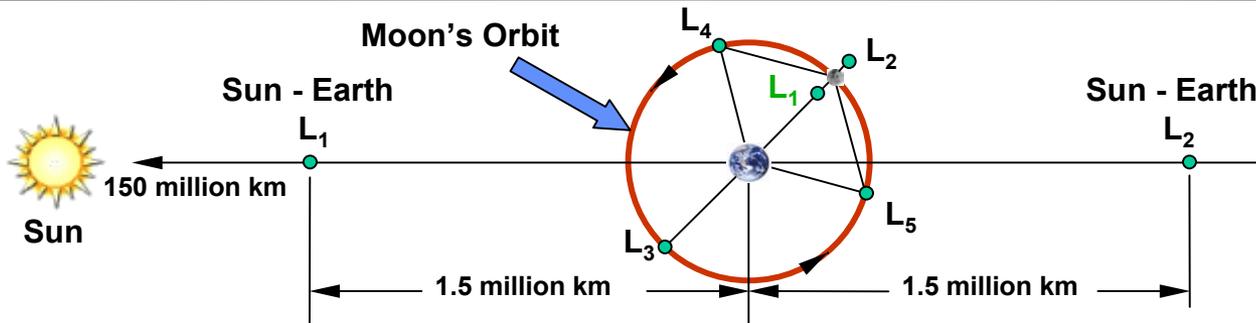
The Value of Technology Investments

Mars Mission Example

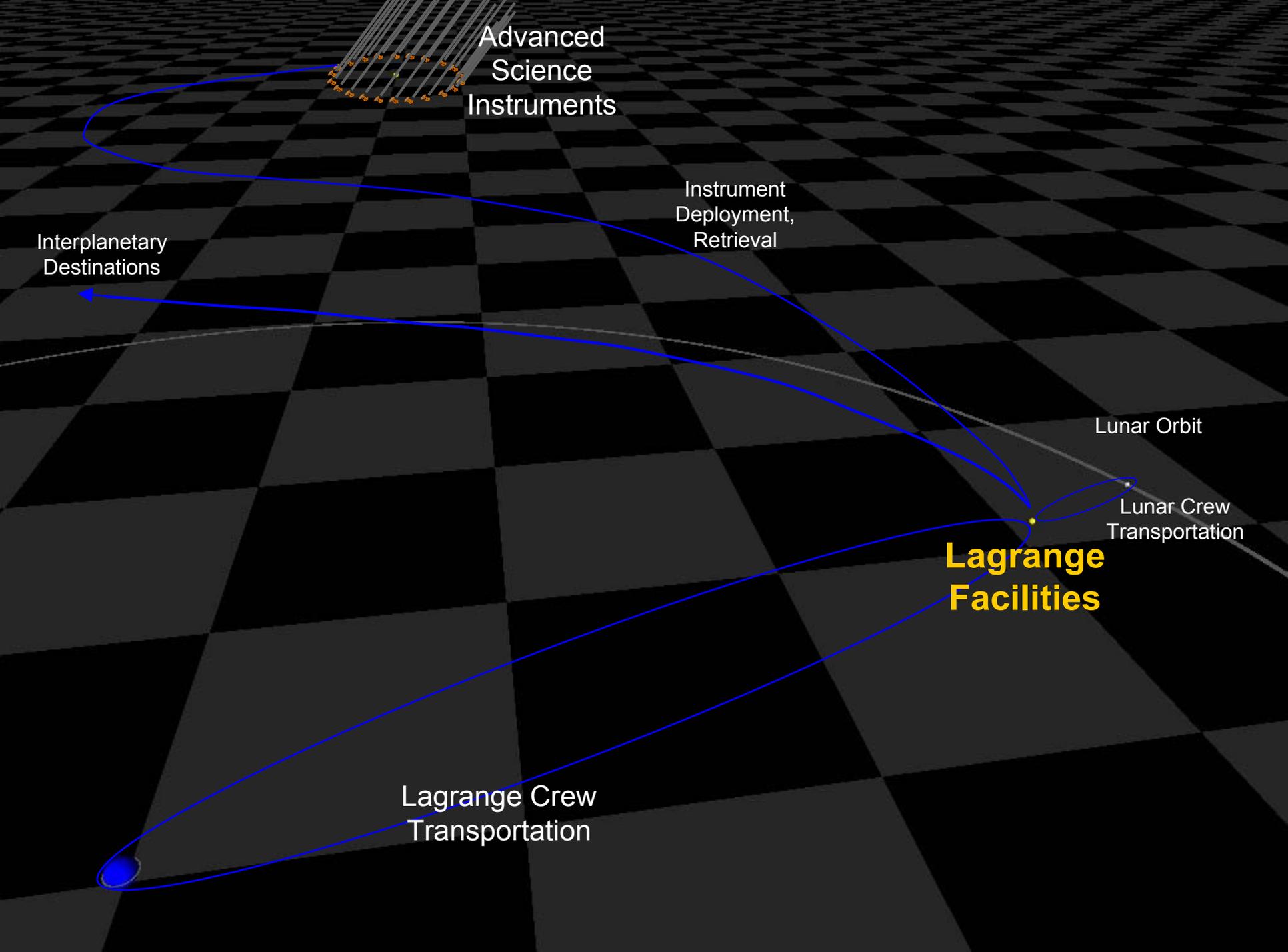


Advanced Development





- Orbital Dynamics in Earth-Moon System Leads to Unique Capabilities
 - Low-Energy Transfer from Earth-Moon L_1 to Solar Libration Points and Return
 - Potential Staging Point for Human Mars Missions
- Allows for Earth-Moon L_1 Deployment and Servicing of Science Assets



Advanced
Science
Instruments

Instrument
Deployment,
Retrieval

Interplanetary
Destinations

Lunar Orbit

Lunar Crew
Transportation

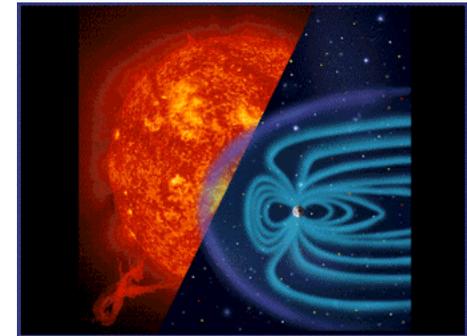
**Lagrange
Facilities**

Lagrange Crew
Transportation



Human Mars Exploration

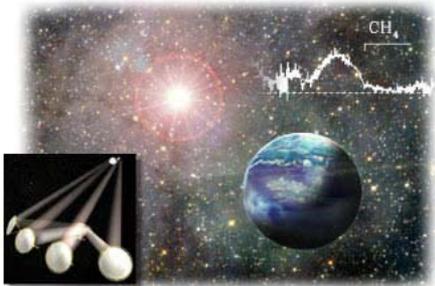
- Technology Development
- Deep-Space Operational Experience
- Mission Staging (Hybrid Prop Module Fuel Depot)



Construct and Deploy Solar Sentinels

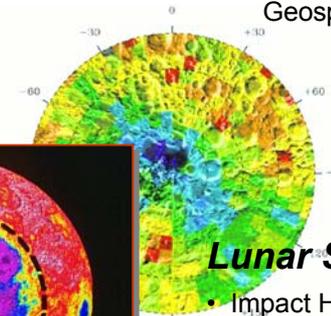
- Search for Location and Mechanism of Solar Flares
- Increase Lead Time and Accuracy for Geospace Forecasts

“Earth’s Neighborhood” Capabilities



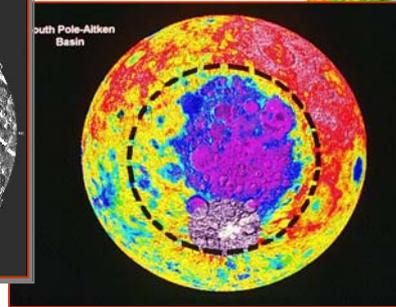
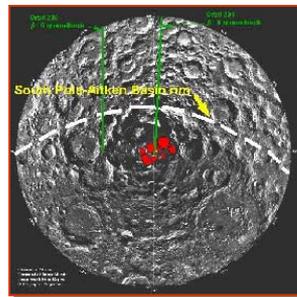
Construct, Deploy, and Service Advanced Astronomical Instruments

- Detect Biological Activity on Extra-Solar Planets
- Image Surfaces of Extra-Solar Planets



Lunar Science

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

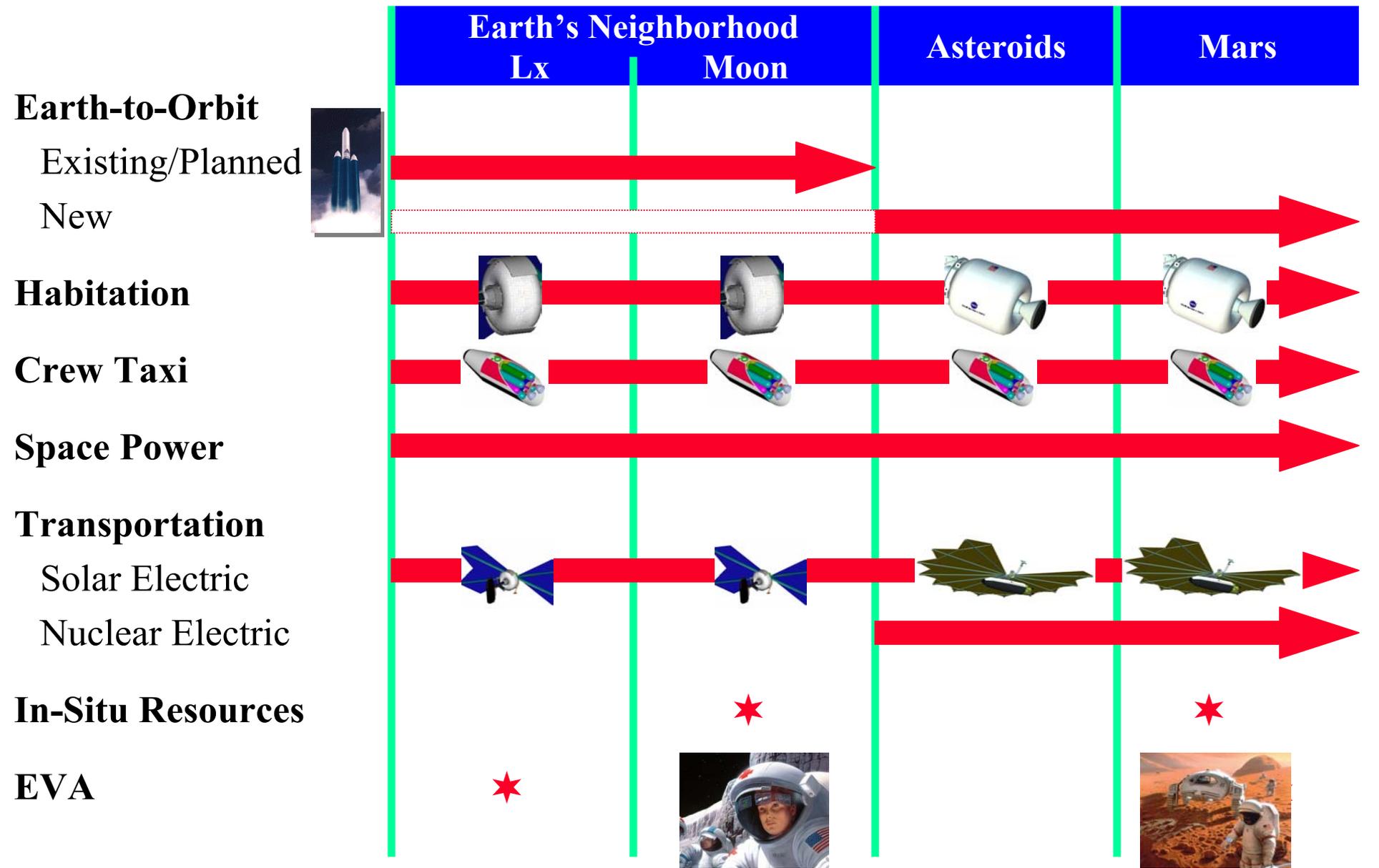




Evolutionary Elements



Advanced Development

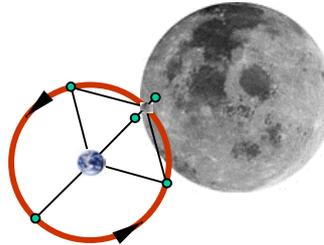


POTENTIAL DESTINATIONS

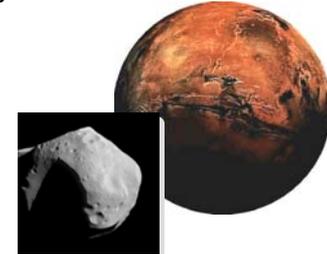
- MEDIUM EARTH ORBIT

- HIGH EARTH ORBIT
- GEOSYNCHRONOUS ORBIT
- EARTH-MOON L_1
- LUNAR VICINITY
- EARTH-SUN L_2

- LUNAR VICINITY
- EARTH-SUN L_2



- Near-Earth Asteroids
- Mars



CAPABILITIES

- MEO SORTIES
- LOW-SPEED AEROCAPTURE

- HEO SORTIES
- HIGH-SPEED AEROCAPTURE

- EXTENDED-DURATION OPERATIONS BEYOND LEO
- CONSTRUCTION, MAINTENANCE AT LIBRATION POINTS

- EXTENDED-DURATION OPERATIONS IN DEEP SPACE
- HUMAN MISSIONS TO MARS

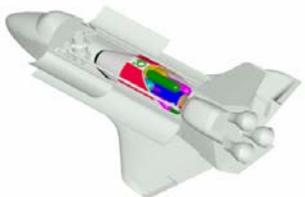
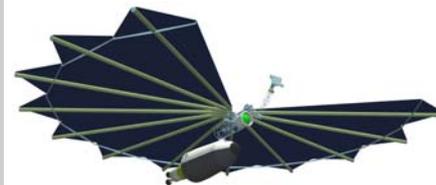
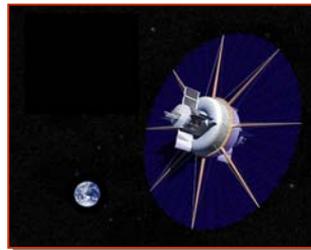
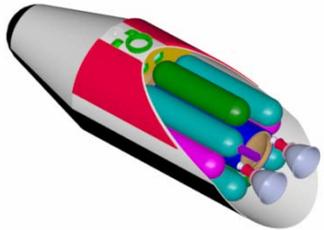
ELEMENTS

- CREW TRANSFER VEHICLE

- EELV HEAVY and DERIVATIVES
- HIGH ENERGY INJECTION STAGE

- DEEP-SPACE HABITATION ("GATEWAYS")
- ELECTRIC PROPULSION
- ADVANCED IN-SPACE EVA

- ADVANCED ELECTRIC PROPULSION
- PLANETARY SURFACE ACCESS

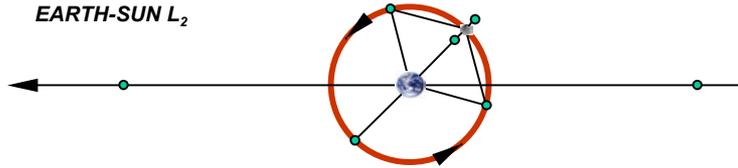


POTENTIAL DESTINATIONS

- **LOW EARTH ORBIT**

- **MEDIUM EARTH ORBIT**

- **HIGH EARTH ORBIT**
- **GEOSYNCHRONOUS ORBIT**
- **EARTH-MOON L_1**
- **LUNAR VICINITY**
- **EARTH-SUN L_2**



- **LUNAR SURFACE**



CAPABILITIES

- **EXTENDED-DURATION LOW EARTH ORBIT OPERATIONS**

- **MEO SORTIES**
- **LOW-SPEED AEROCAPTURE**

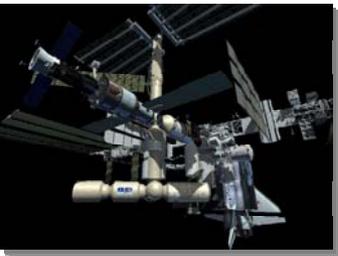
- **HEO SORTIES**
- **HIGH-SPEED AEROCAPTURE**

- **EXTENDED-DURATION OPERATIONS BEYOND LEO**
- **CONSTRUCTION, MAINTENANCE AT LIBRATION POINTS**

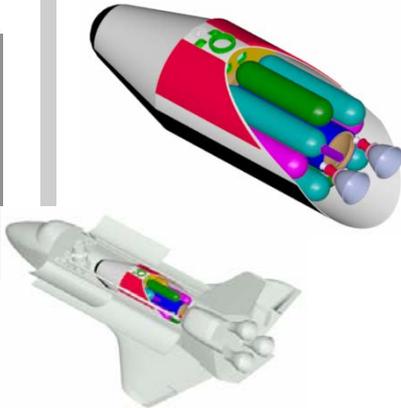
- **GLOBAL LUNAR SURFACE ACCESS**

ELEMENTS

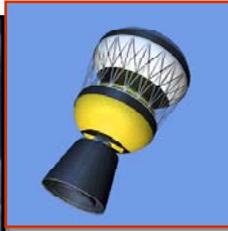
- **SPACE SHUTTLE**
- **ISS**



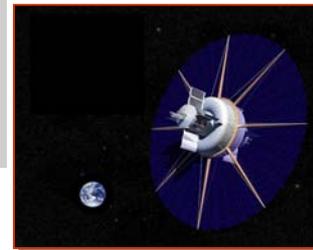
- **CREW TRANSFER VEHICLE**



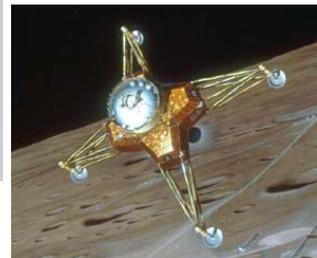
- **EELV HEAVY and DERIVATIVES**
- **HIGH ENERGY INJECTION STAGE**



- **DEEP-SPACE HABITATION ("GATEWAYS")**
- **ELECTRIC PROPULSION**
- **ADVANCED IN-SPACE EVA**



- **LUNAR LANDER**
- **SURFACE SUPPORT SYSTEMS**
- **ADVANCED SURFACE EVA**





Core Capabilities & Technologies



**Common Technology Building Blocks
(Core Technologies)**

**Common System Building Blocks
(Core Capabilities)**

**Potential
Destinations**

Examples

Efficient In-Space Prop..

Aeroassist

Low-cost Engines

Cryo Fluid Management

Robust/Efficient Power

Lightweight structures

Radiation Research

Zero/Low-g Research

Regenerable Life Support

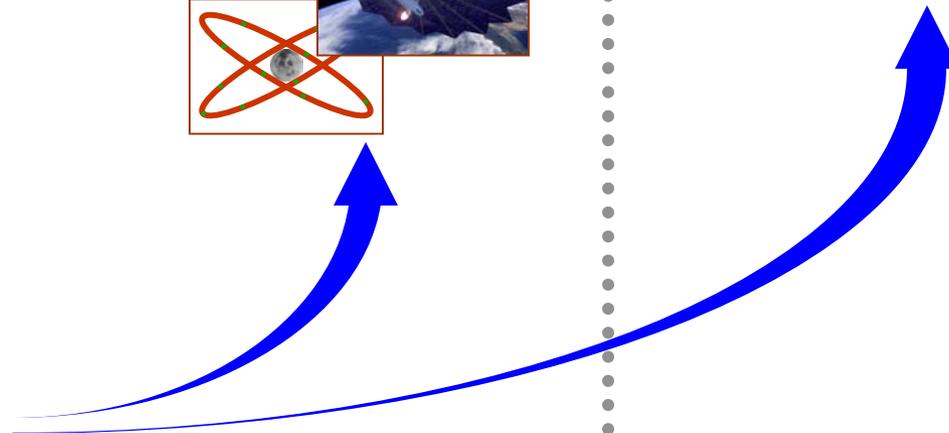
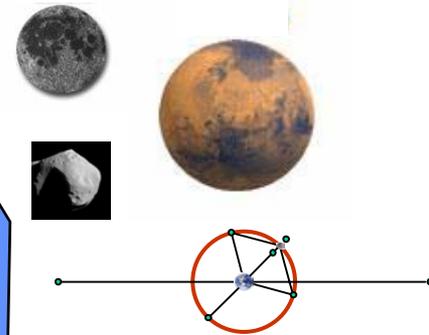
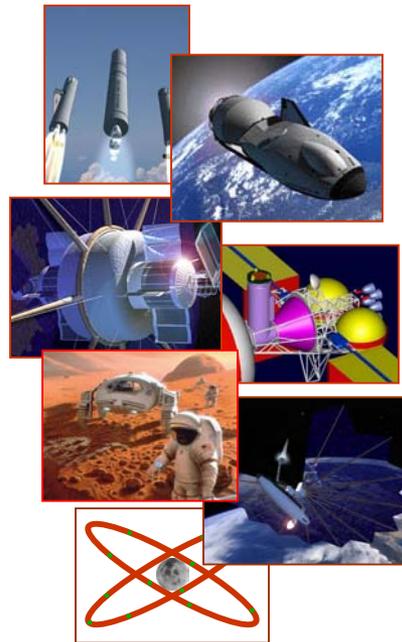
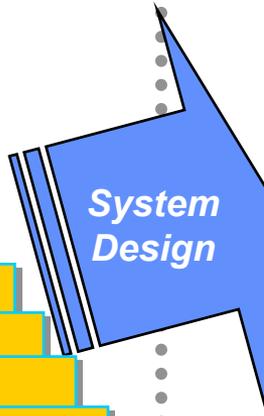
Advanced Lightweight
EVA

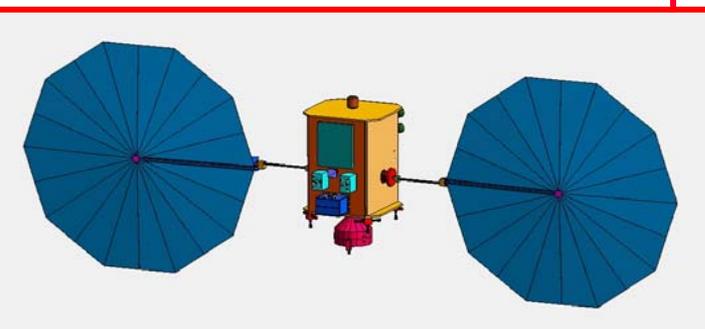
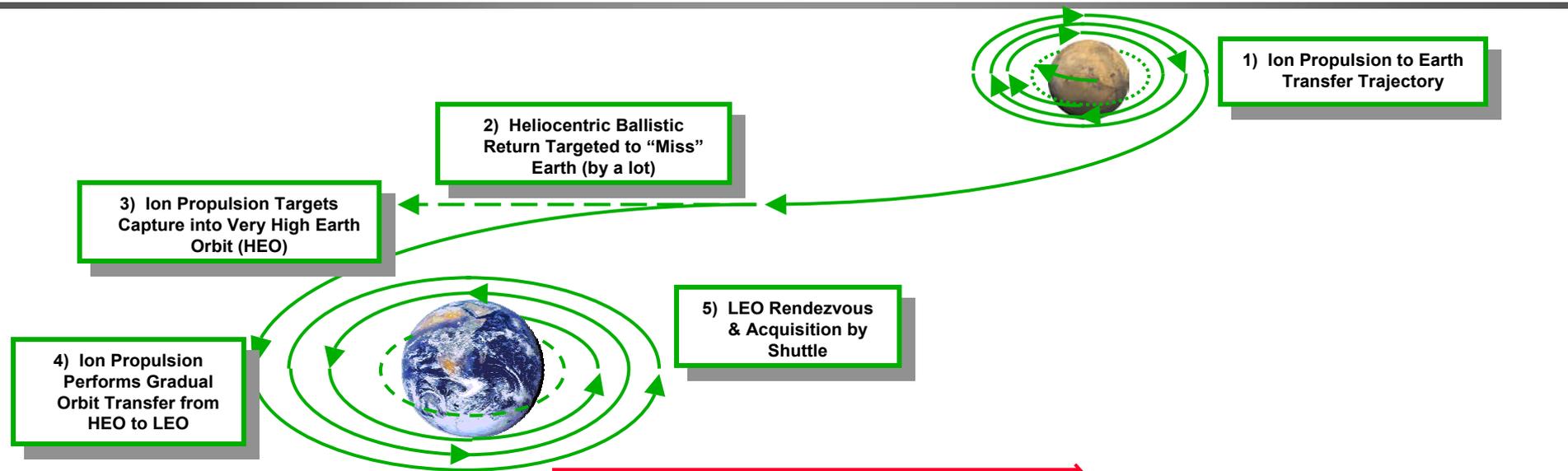
"Breakthrough"

"Breakthrough"

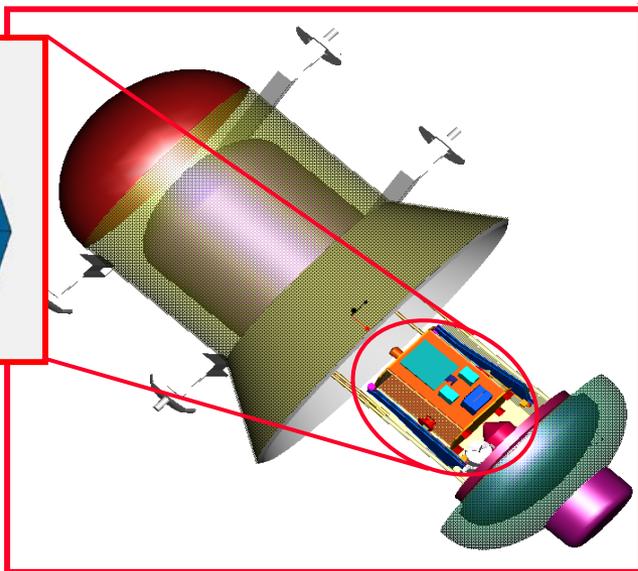
"Breakthrough"

"Breakthrough"
Technologies

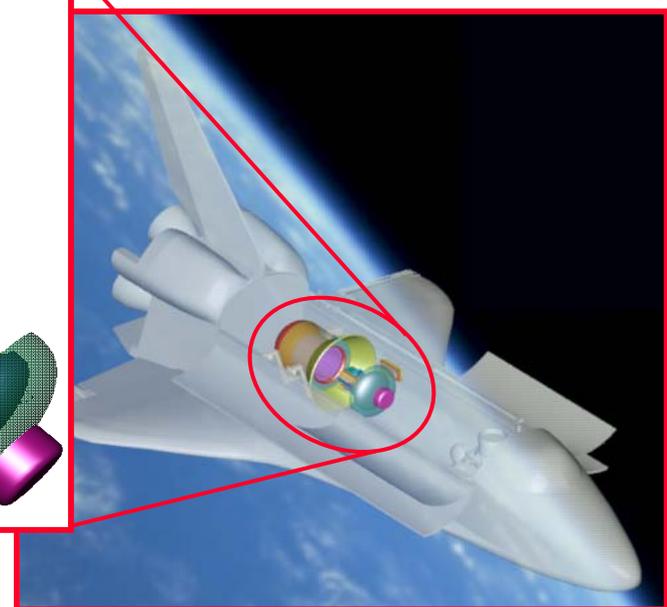




Solar Electric Propulsion
Mars Sample Return Spacecraft

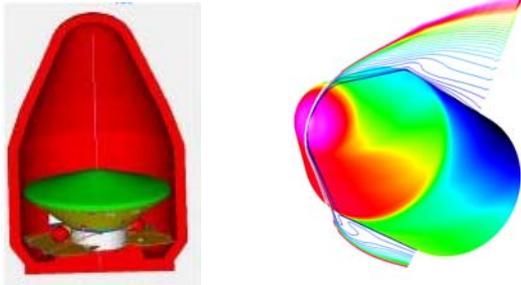


Sample Containment Vault

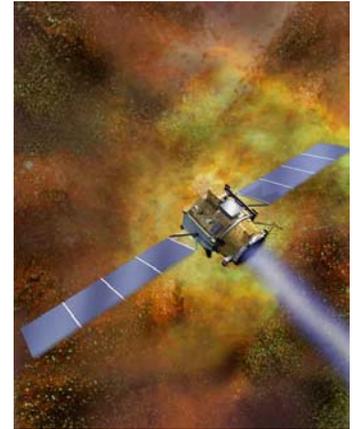


Shuttle Retrieval

- Higher Efficiency Aero-Entry
 - SOA is 70's Viking shape
 - Poor launch vehicle packaging efficiency, limited maneuvering capability
 - Bi-Conic or "Ellipsled" shapes offer superior performance



- Solar Electric Propulsion
 - Mass reduction over chemical
 - Opens new mission options (MSR to earth orbit)



Precision Landing

- Three-sigma footprint reduction from 200x100 km to less than 10x10 km predicted

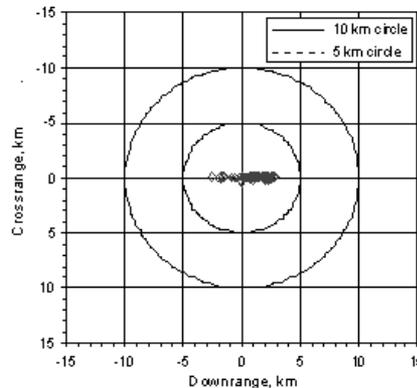
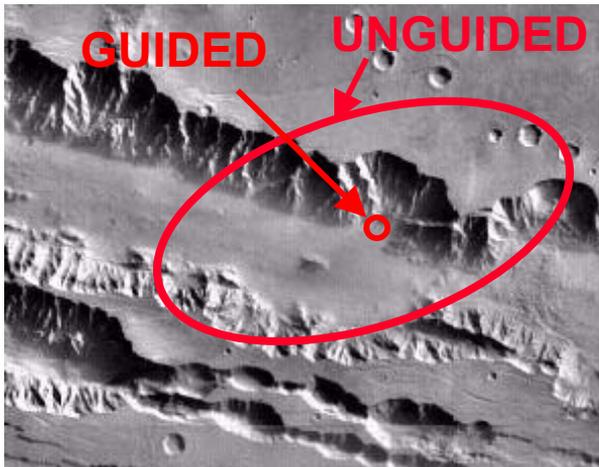


Figure 4.1. Target miss distance (Nav minus target at chute deploy)

Hazard Avoidance

- JSC participating with ARC, JPL, LaRC to develop autonomous system
- Apollo-LEM-based algorithms combined with LIDAR system show significant potential





The Value of Technology Investments

Mars Mission Example



Advanced Development

