The Future of Human Exploration

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Pages from Schiaparelli's observing notebook, 1879
Core Capabilities & Technologies

Common Technology Building Blocks
(Core Technologies)

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"

Common System Building Blocks
(Core Capabilities)

Mission Analyses

Potential Destinations

System Design
Mars Architecture Mass Comparison

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
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<tr>
<td>1988</td>
<td>1988 Mars Expedition (Chem A/B)</td>
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<td>1989</td>
<td>1989 Mars Evolution (Chem A/B)</td>
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<td>1990</td>
<td>1990 90-Day Study (NTR)</td>
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<td>1991</td>
<td>1991 Synthesis Group (NTR)</td>
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<td>1995</td>
<td>1995 DRM 1 Long Stay (NTR)</td>
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<td>1997</td>
<td>1997 DRM 3 Refinement (NTR)</td>
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<tr>
<td>1998</td>
<td>1998 DRM 4 Refinement (NTR or SEP)</td>
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<td>1999</td>
<td>1999 Latest Results (SEP)</td>
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ISS @ Assembly Complete (470 tons)
The Value of Technology Investments
Mars Mission Example

Mass Savings Normalized to ISS Mass

Today

- All Propulsive Chemical
- Aerocapture (50%)
- Advanced Propulsion (EP or Nuclear) (46%)
- Closed Loop Life Support (19%)
- Advanced Materials (14%)
- Maintenance & Spares (21%)
- Advanced Avionics (11%)
High Earth Orbit Staging Mission Scenarios

Space Station Orbit (LEO) -> Mars

Chemical Injection Burn

Moon

Elliptical Parking Orbit (EPO) -> Mars Aerocapture

Near Earth Asteroids

Libration Points
Human Mars Exploration
- Technology Development
- Deep-Space Operational Experience
- Mission Staging (Hybrid Prop Module Fuel Depot)

“Earth’s Neighborhood”
Construct, Deploy, and Service Capabilities
- Detect Biological Activity on Extra-Solar Planets
- Image Surfaces of Extra-Solar Planets

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

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

Orbital Dynamics in Earth-Moon System Leads to Unique Capabilities

- Low-Energy Transfer from Earth-Moon L1 to Solar Libration Points and Return
- Potential Staging Point for Human Mars Missions

- Allows for Earth-Moon L1 Deployment and Servicing of Science Assets
**Architecture Evolution**

- **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

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2/12/01
Earth’s Neighborhood, Libration Points Architecture

Key Attributes

- Crew of 4
- 65 day mission duration
- Deployment, assembly, and servicing of large complex science facilities to achieve revolutionary discoveries
- ISS integral as a staging platform
- Serves as a “stepping stone” by providing an opportunity to test technology and operational concepts, reducing risk of future exploration endeavors
- Architecture can be bought “by the yard” resulting in increasing capabilities and operational experience
- Modest augmentation of commercial launch vehicles
- Common architecture elements for all Earth’s Neighborhood missions
Lunar L₁ "Gateway"

Key Attributes

- Crew of 4
- Global lunar access – 3 day
- Lunar polar outpost – 30 days
- ISS integral as a staging platform
- Lunar missions serve as "stepping stones" by providing an opportunity to test technology and operational concepts, reducing risk of future exploration endeavors
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Solar Electric Propulsion Concept

- Array sized to provide 1700 kW_e throughout first mission
- 14700 m² CuInS₂ array area
- 171 m span (wingtip-wingtip)
- 17 x 100 kW_e Hall Thruster Propulsion
- Articulated boom thruster gimballing

ISS Mass ≈ 470 MT
SEP-TV dry mass ≈ 36 MT

Central Hub Detail
Mars Mission Vehicle Concepts

**Mars Transit Vehicle**
- Supports mission crew of six for up to 200-day transits to and from Mars
- Return propulsion stage integrated with transit system
- Provides return-to Earth abort capability for up to 30 hours post-TMI
- Total Vehicle Mass in High-Earth Orbit = 188 mt

**Mars Surface Habitat**
- Vehicle supports mission crew of six for up to 18 months on the surface of Mars
- Provides robust exploration and science capabilities
- Descent vehicle capable of landing 36,000 kg
- Total Vehicle Mass in High-Earth Orbit = 99 mt

**Descent/Ascent Vehicle**
- Transports six crew from Mars orbit to the surface and back to orbit
- Provides contingency abort-to-orbit capability
- Supports six crew for 30-days
- Vehicle capable of utilizing locally produced propellants
- Total Vehicle Mass in High-Earth Orbit = 103 mt
Mars Mission Overview

Habitat Lander and Ascent/Descent Vehicles delivered to Low Earth Orbit with Magnum. Solar Electric Propulsion stage spirals cargo to High Earth Orbit. Chemical injection used at perigee. SEP spirals back to LEO for reuse.

Crew travels to Mars in “fast transit” 180-day transfer. Aerobrakes into Mars orbit.

Transit Habitat vehicle delivered to LEO with Magnum. SEP spirals Transit Habitat to High Earth Orbit. Crew delivered to vehicle via crew taxi. SEP spirals back to LEO for reuse.

Surface Habitat and exploration gear aerocaptures into Mars orbit.

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

Crew rendezvous with Descent/Ascent Vehicle in Mars orbit then lands in vicinity of Habitat Lander.

30 days provided to satisfy “long-stay” criteria.

Habitat remains in Mars orbit.

Crew returns to Earth on “fast transit” 180-day transfer. Direct entry at Earth.

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

Crew ascends and rendezvous with waiting Transit Habitat.

Earth Orbit

Mars Surface