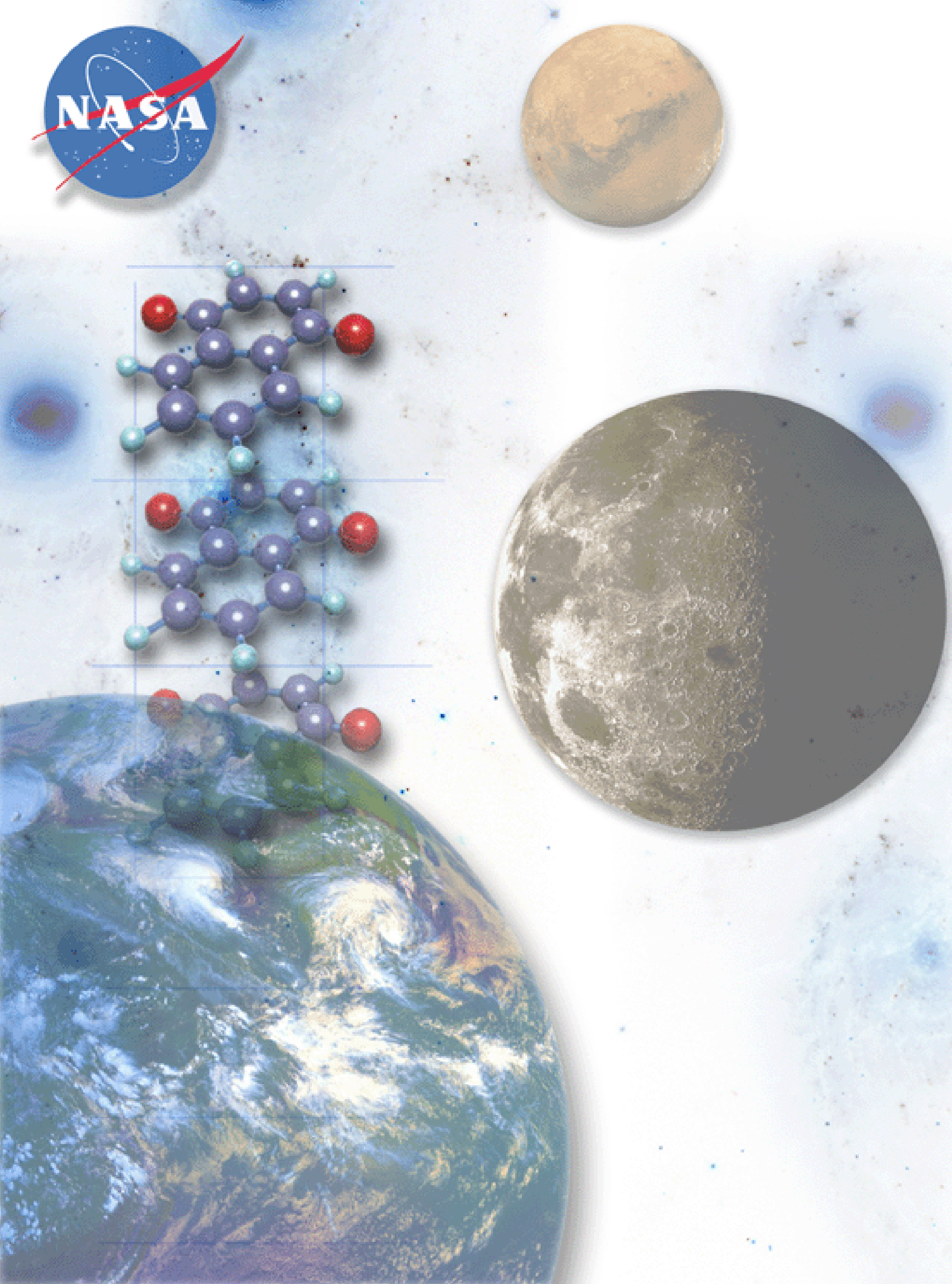


Future Directions:

Strategy for Human and Robotic Exploration

Gary L. Martin
Space Architect

November 2003

Robust Exploration Strategy

Traditional Approach: A Giant Leap (Apollo)

- Cold War competition set goals, National Security justified the investment
- Singular focus on the Moon
- Humans in space an end unto itself
- Robotic exploration secondary to crewed missions
- Rigid timeframe for completion with unlimited resources
- Technologies are destination- and system-specific
- Inspirational outreach and education secondary to programs

High-risk with limited vision beyond demonstrating a technology capability

New Strategy: Stepping Stones and Flexible Building Blocks

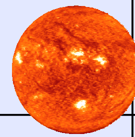
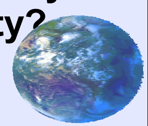
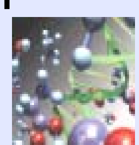
- NASA Vision and Mission drive goals and must justify investment
- Robust and flexible capability to visit several potential destinations
- Human presence is a means to enable scientific discovery
- Integrate/optimize human-robotic mix to maximize discovery
- Timeframe paced by capabilities and affordability
- Key technologies enable multiple, flexible capabilities
- Inspiration and educational outreach integral to programs

Robust and flexible, driven by discovery, and firmly set in the context of national priorities

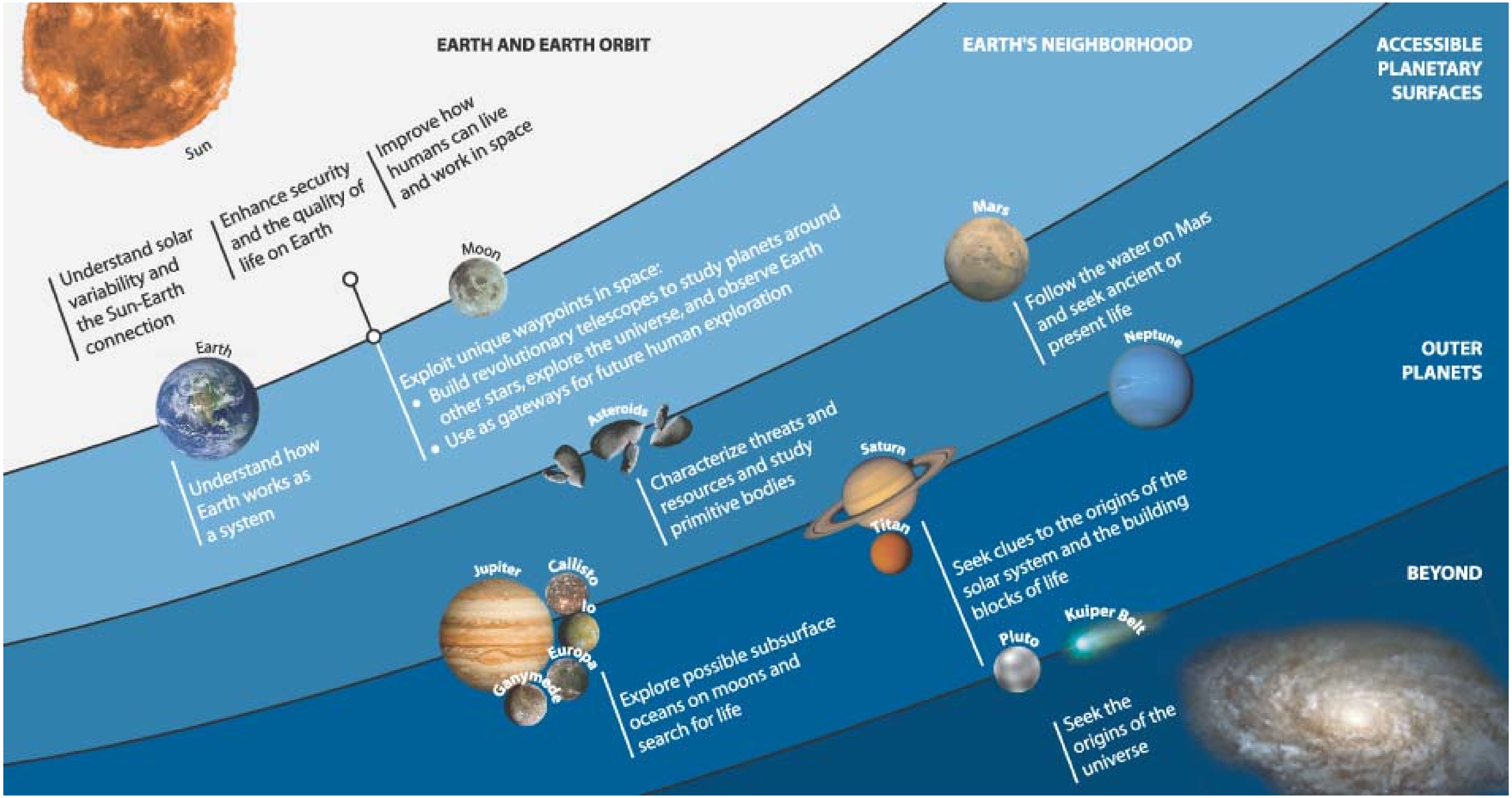

www.nasa.gov
The NASA Vision
To improve life here,
To extend life to there,
To find life beyond.
The NASA Mission
To understand and protect our home planet,
To explore the universe and search for life,
To inspire the next generation of explorers
... as only NASA can.

Science Drivers Determine Destinations

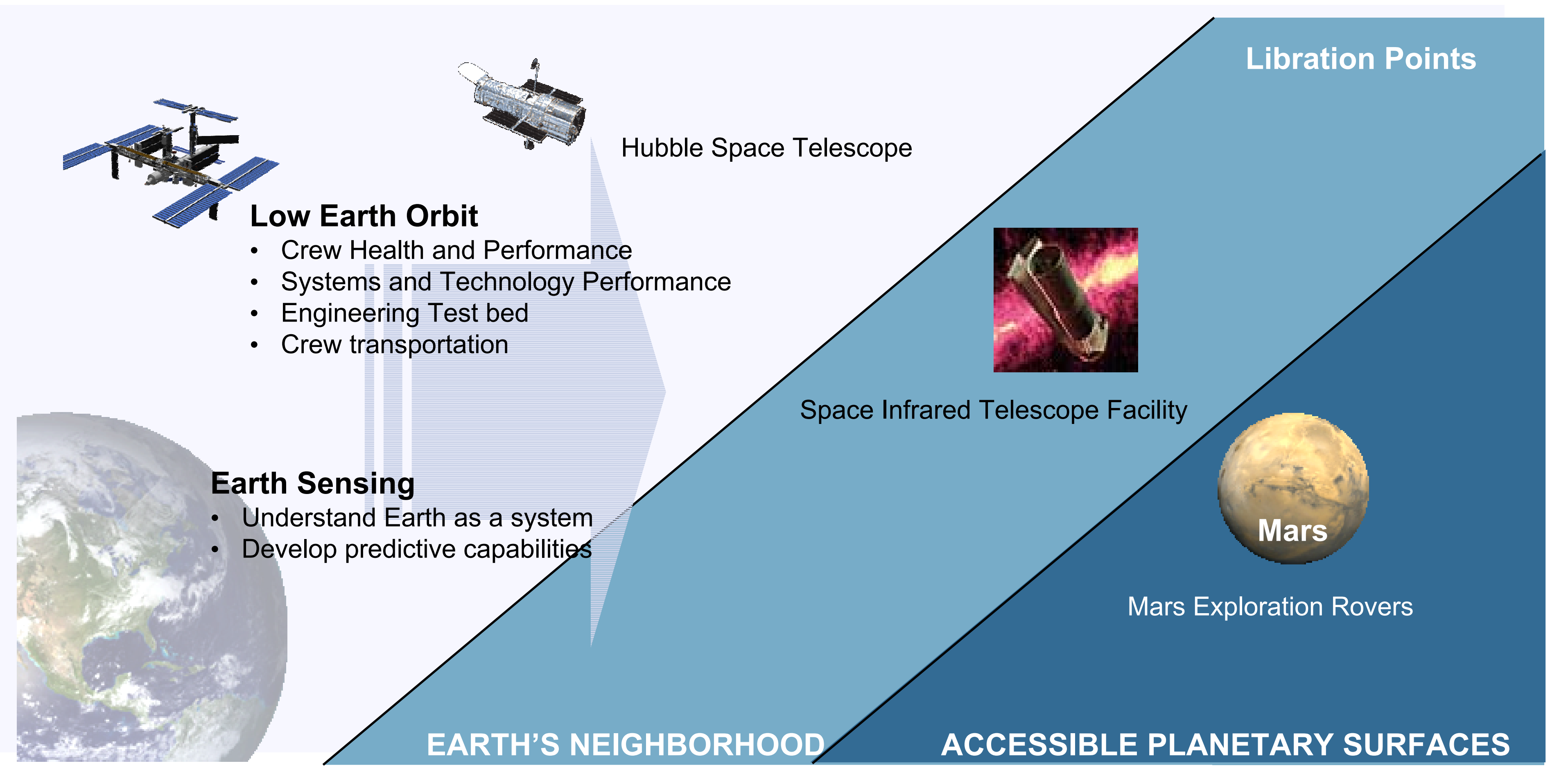
(Selected Examples)

	Science Questions	Pursuits	Activities	Destinations
How did we get here?	• How did the Solar System evolve? 	• History of major Solar System events	• Planetary sample analysis: absolute age determination "calibrating the clocks"	• Asteroids • Moon • Mars • Venus
Where are we going?	• How do humans adapt to space? 	• Effects of deep space on cells	• Measurement of genomic responses to radiation	• Beyond Van Allen belts
	• What is Earth's sustainability and habitability? 	• Impact of human and natural events upon Earth	• Measurement of Earth's vital signs "taking the pulse"	• Earth orbits • Libration points
Are we alone?	• Is there Life beyond the planet of origin? 	• Origin of life in the Solar System • Origin of life in the Universe	• Detection of bio-markers and hospitable environments	• Cometary nuclei • Europa • Libration points • Mars • Titan

Stepping Stone Strategy

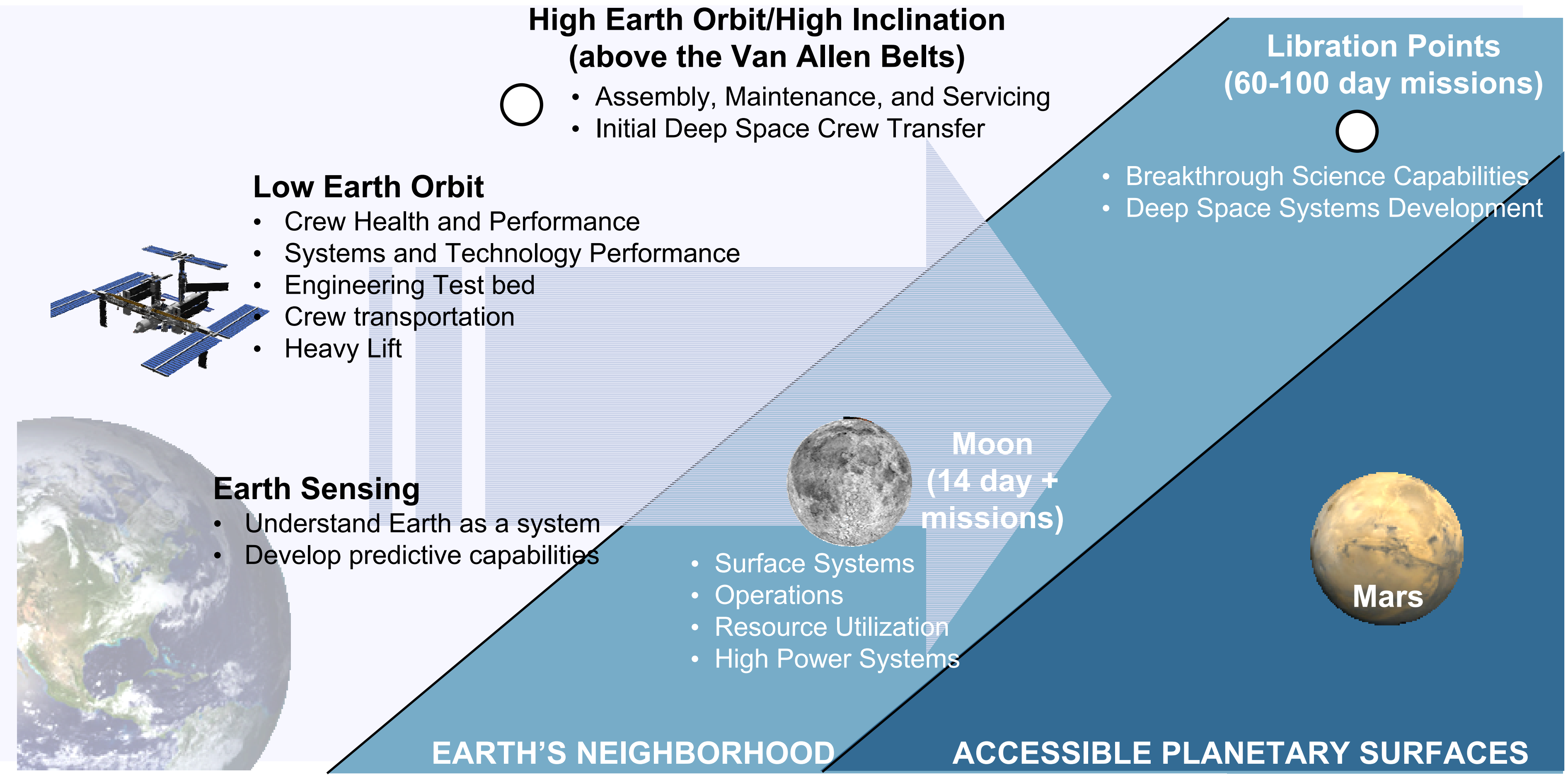


Stepping Stone Approach
Current Capabilities



Stepping Stone Approach

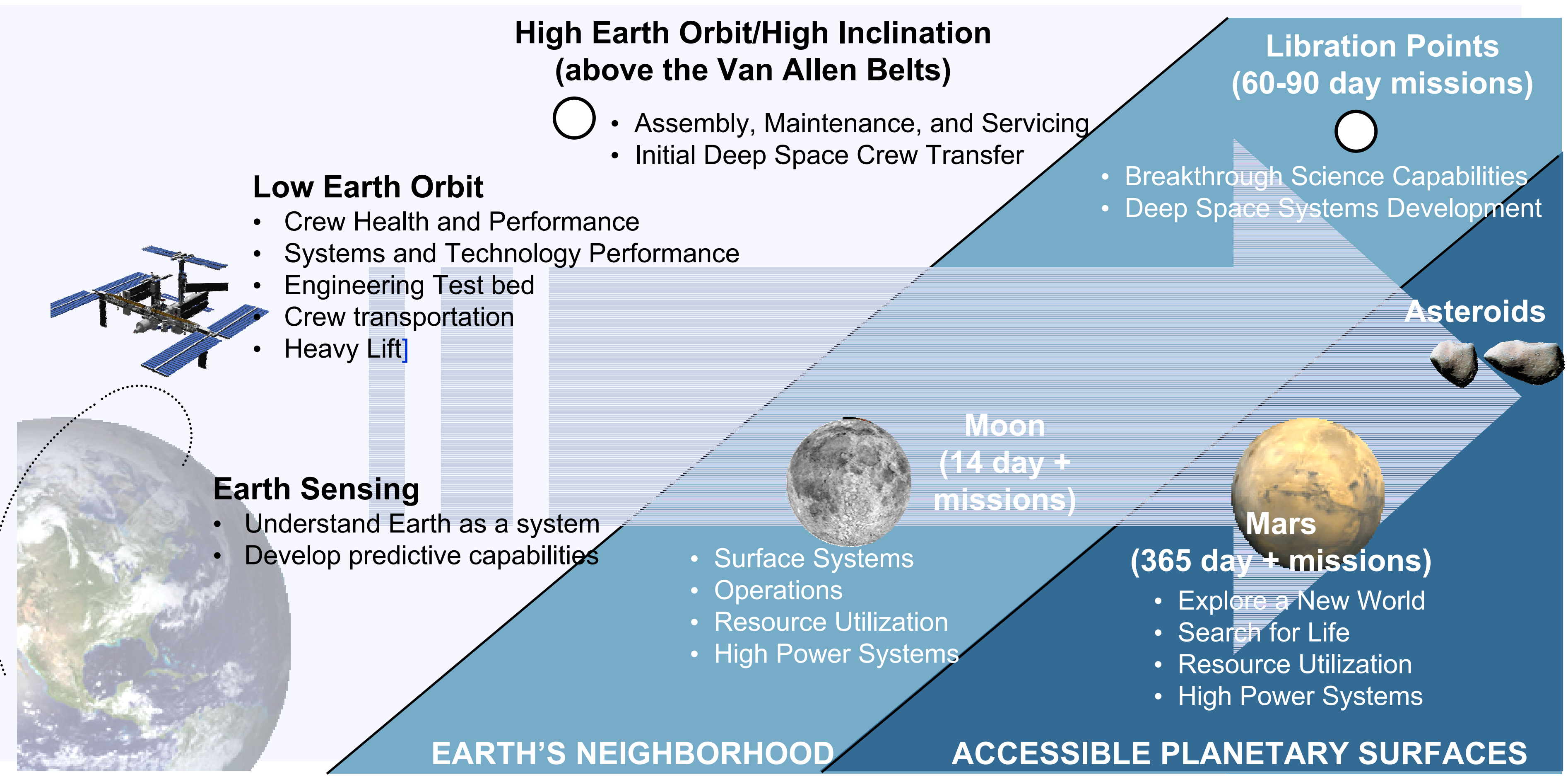
Near-term Next Steps for Human and Robotic Exploration



Potential Sites for Operations Above Low Earth Orbit

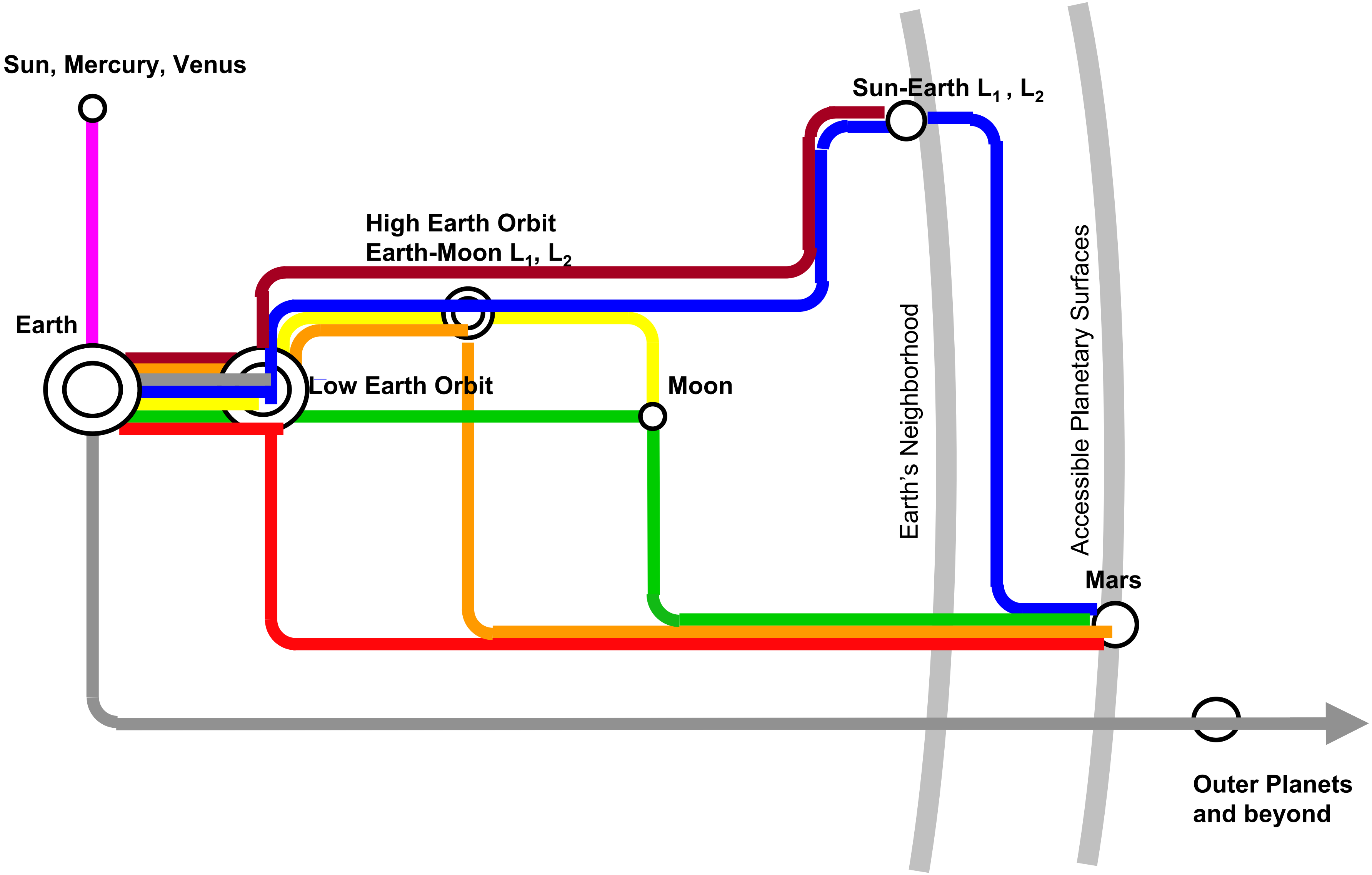
Stepping Stone Approach

Far-Term Next Steps for Human and Robotic Exploration

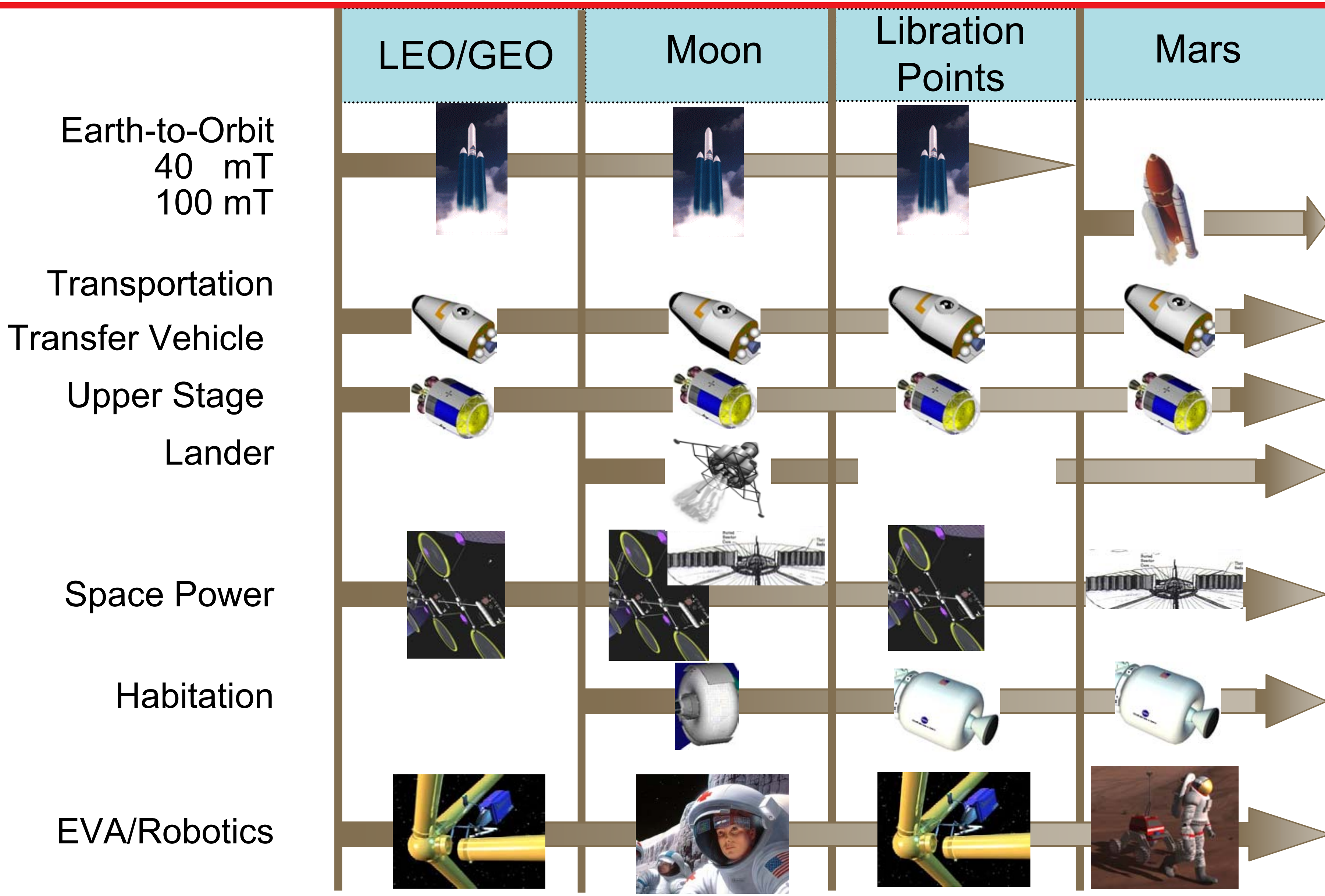


Potential Sites for Operations Above Low Earth Orbit

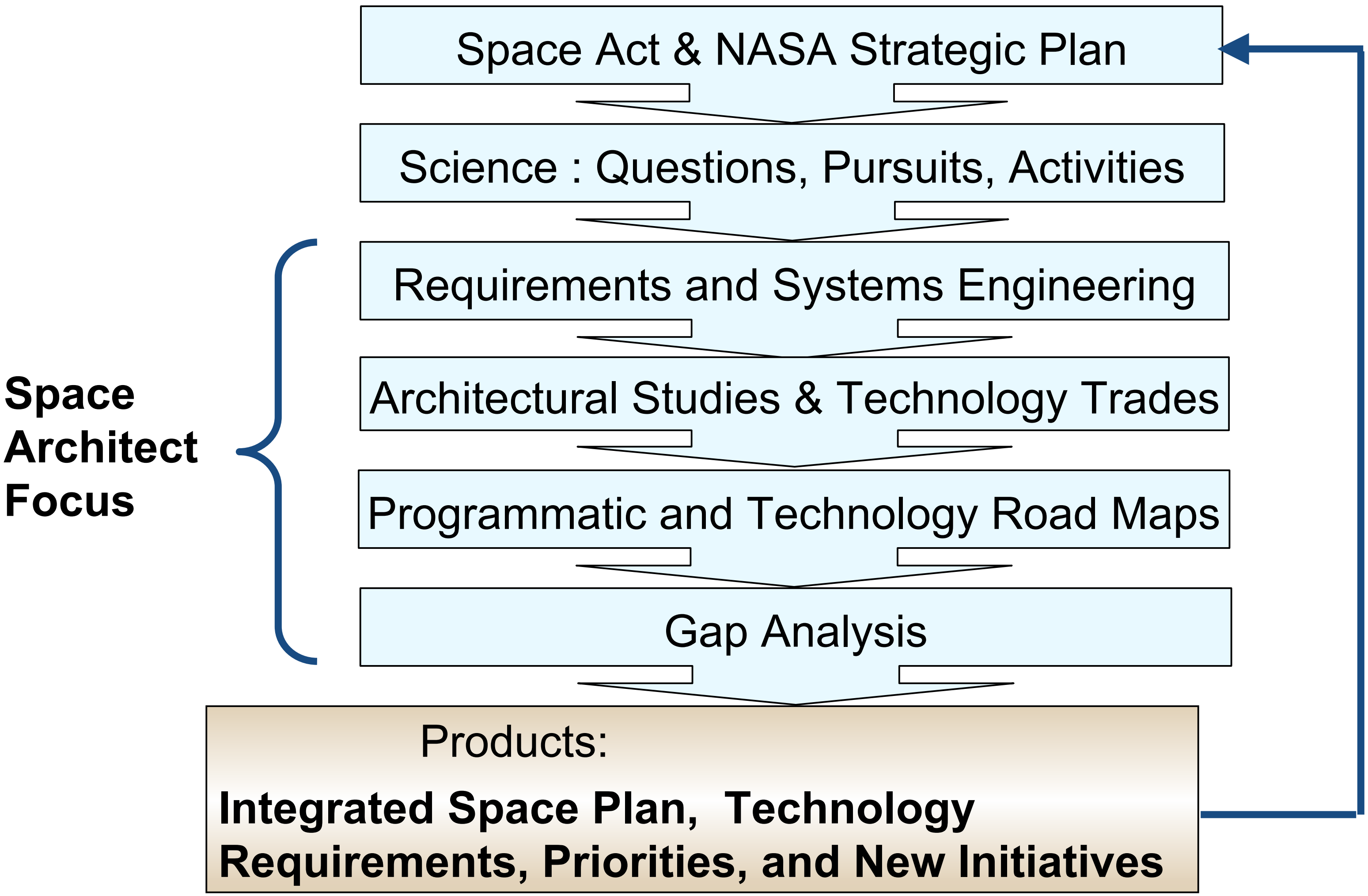
Progression in Capability Development
Exploration Metro Map



Human and Robotic Concepts



Systematic Investment Strategy

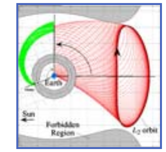


Key Technology Challenges

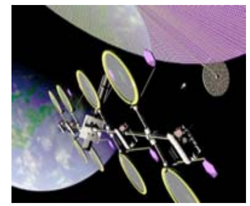
- **Space Transportation**
  - Safe, fast, and efficient
- **Affordable, Abundant Power**
  - Solar and nuclear
- **Crew Health and Safety**
  - Counter measures and medical autonomy
- **Optimized Robotic and Human Operations**
  - Dramatically higher productivity; on-site intelligence
- **Space Systems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


RLV

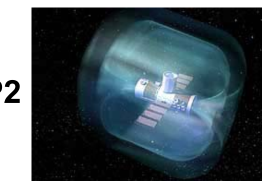

NEP

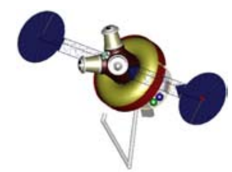

Invariant Manifolds

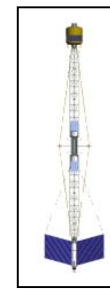

Aerobraking


Space Solar Power

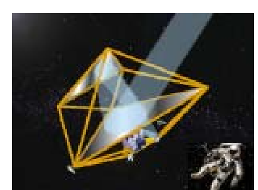
M2P2

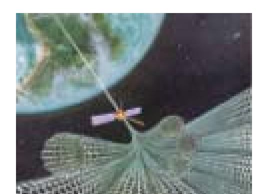



L_1 Outpost


Artificial Gravity


Robonaut


Gossamer Telescopes


Nanotube Space Elevator

Strategic Building Block Investments

Technological Barriers

Power:
Providing ample power for propulsion and science

Transportation:
Providing safe, reliable and economical transportation to and from space and throughout the solar system

Human Capabilities:
Understanding and overcoming human limitations in space

Communications:
Providing efficient data transfer across the solar system

FY 2003

Nuclear Systems Initiative
- Greatly increased power for space science and exploration

Integrated Space Transportation Plan
- Orbital Space Plane
- Extended Shuttle Operations
- Next Generation Launch Systems

In-Space Propulsion Program
- Efficient Solar System Transportation

Space Station Restructuring
- Research Priority Focused
- Management Reforms
- Sound Financial Base

Bioastronautics Program
- Roadmap to address human limitations

FY 2004

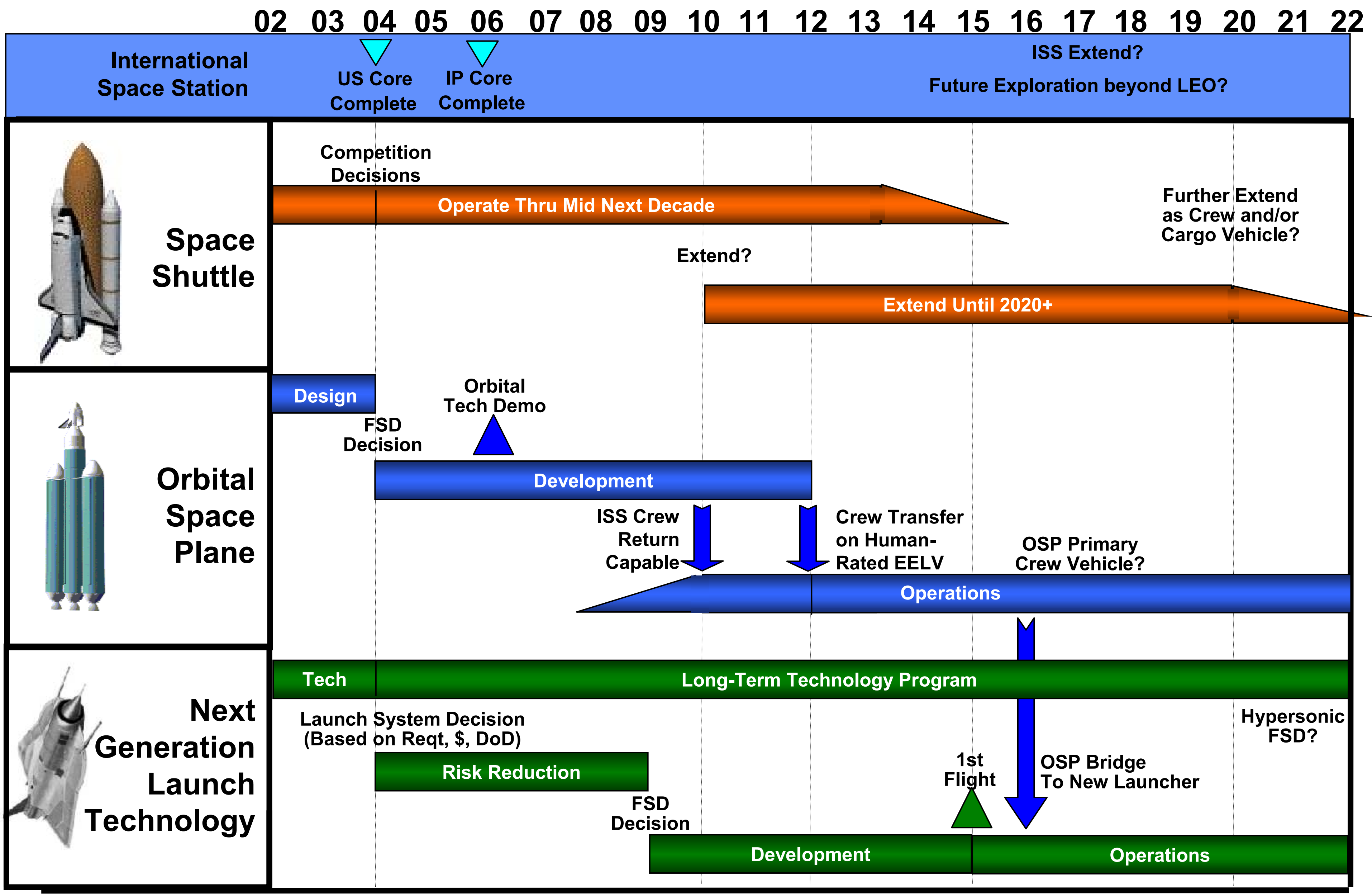
Project Prometheus
- Nuclear power and propulsion for revolutionary science and orbital capabilities
- First mission to Jupiter's Moons

Human Research Initiative
- Accelerate research to expand capabilities
- Enable 100-plus day missions beyond low-Earth orbit

Optical Communications
- Vastly improve communication to transform science capability
- First demonstration from Mars

Update: 10/24/02

Integrated Space Transportation Plan

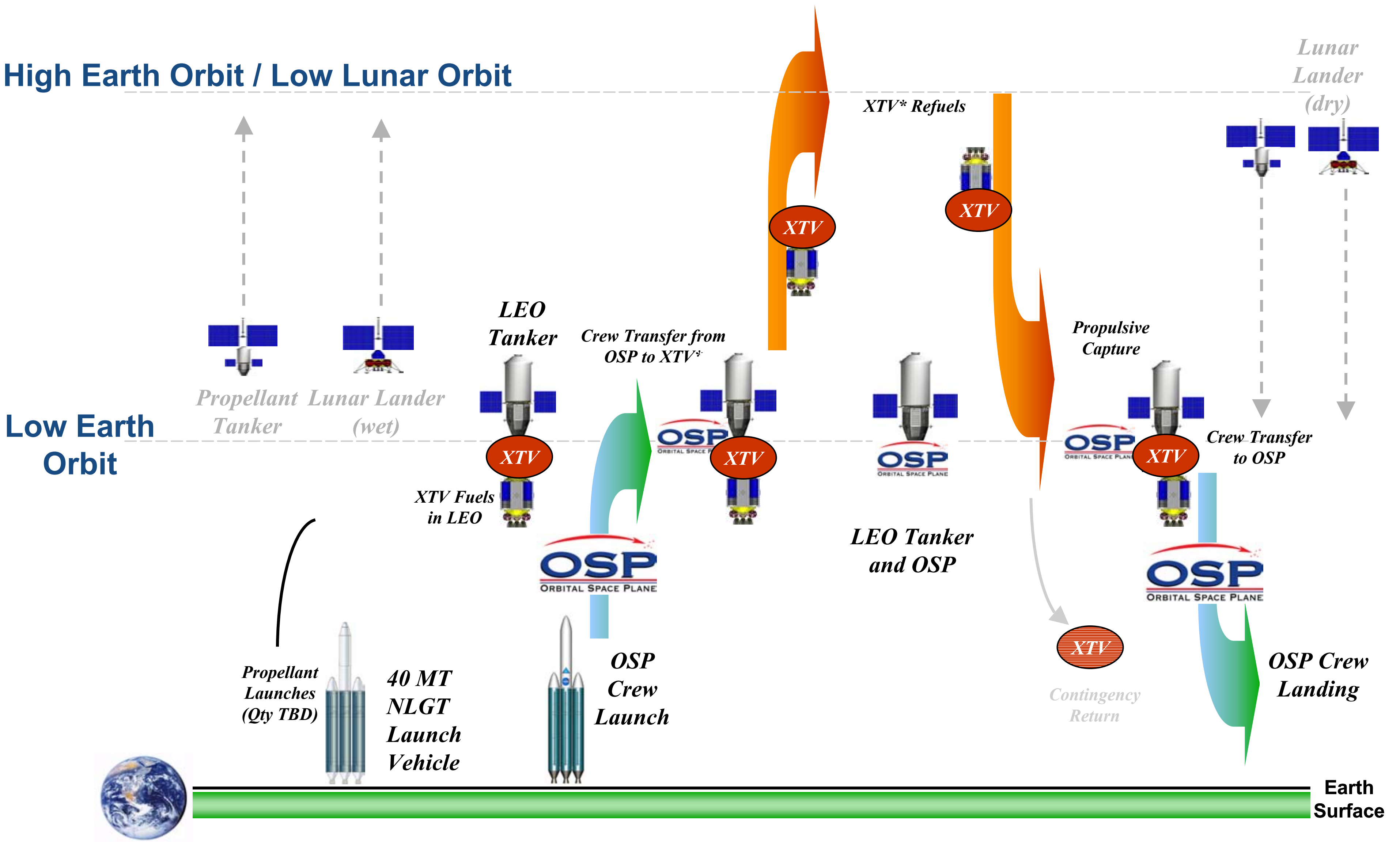


Orbital Space Plane

The Orbital Space Plane (OSP) will:

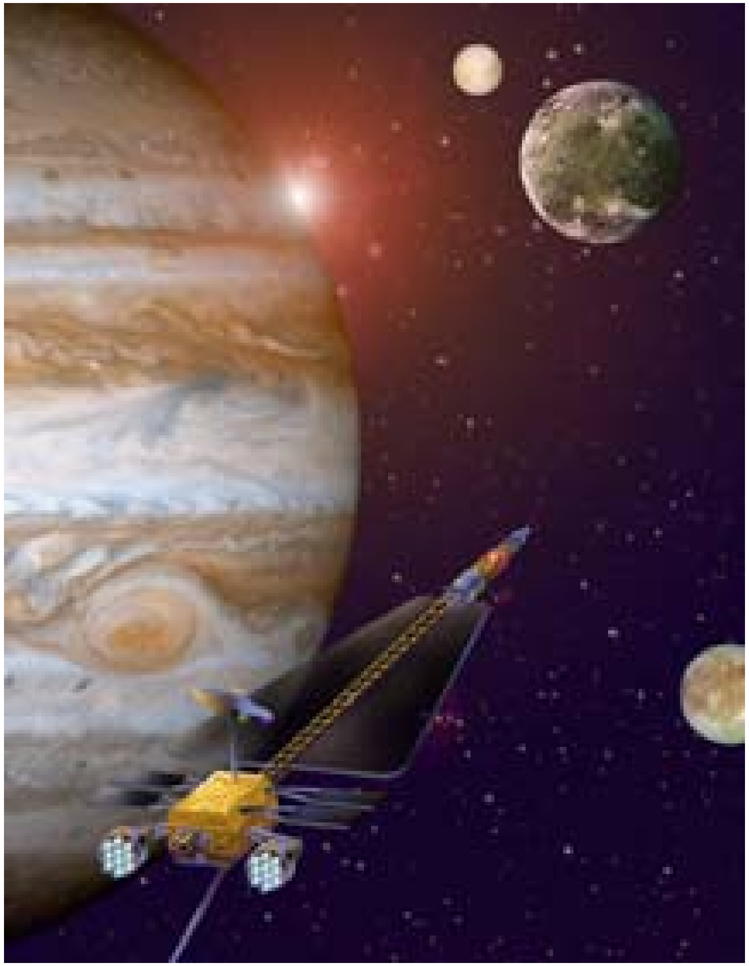
- Support NASA's strategic goals and science objectives by achieving assured access to the International Space Station (ISS) and Low Earth Orbit (LEO)
  - Crew return capability from the International Space Station as soon as practical but no later than 2010 (Goal is now 2008)
  - Crew transfer to and from the ISS as soon as practical but no later than 2012 (Goal is now 2010)
- Provide the basis for future exploration beyond Low Earth Orbit

OSP Primary Earth-to-LEO Transportation



Project Prometheus

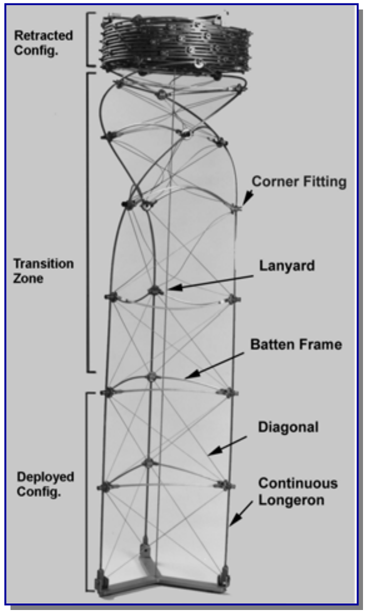
- **Revolutionary capabilities for nuclear propulsion and power**
  - Much greater ability to power instruments, change speed, and transmit science data
  - No launch constraint to use gravity assists
  - Can orbit multiple objects or moons with vastly greater, persistent observation time
  - Can change target mid-mission (to support change in priorities)

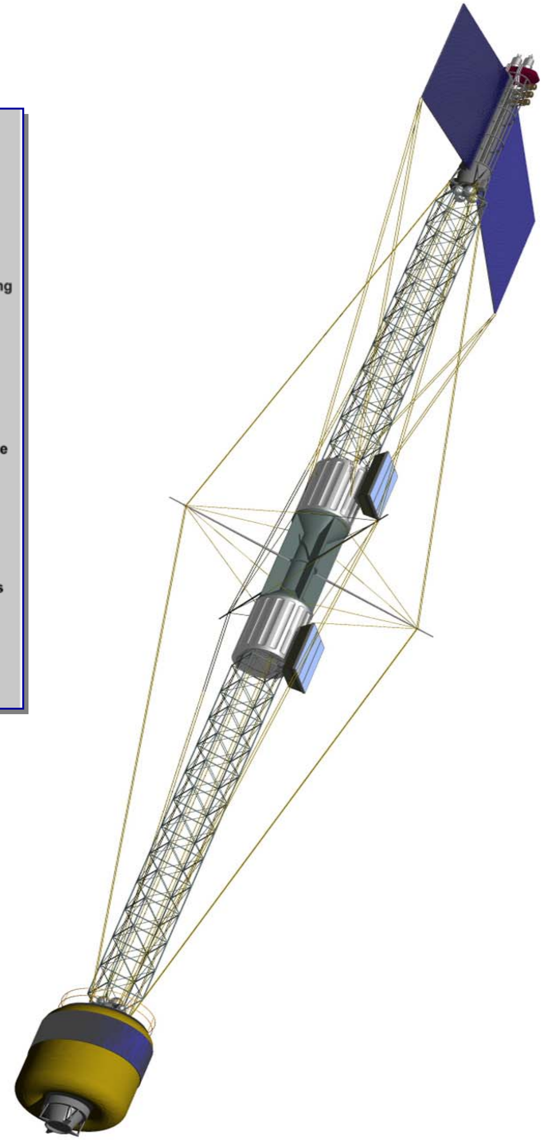


- **First use: Jupiter Icy Moon Orbiter**
  - Search for evidence of global subsurface oceans on Jupiter's three icy Galilean moons: Europa, Ganymede, and Callisto. These oceans may harbor organic material.
  - Nuclear technology will enable unprecedented science data return through high power science instruments and advanced communications tech

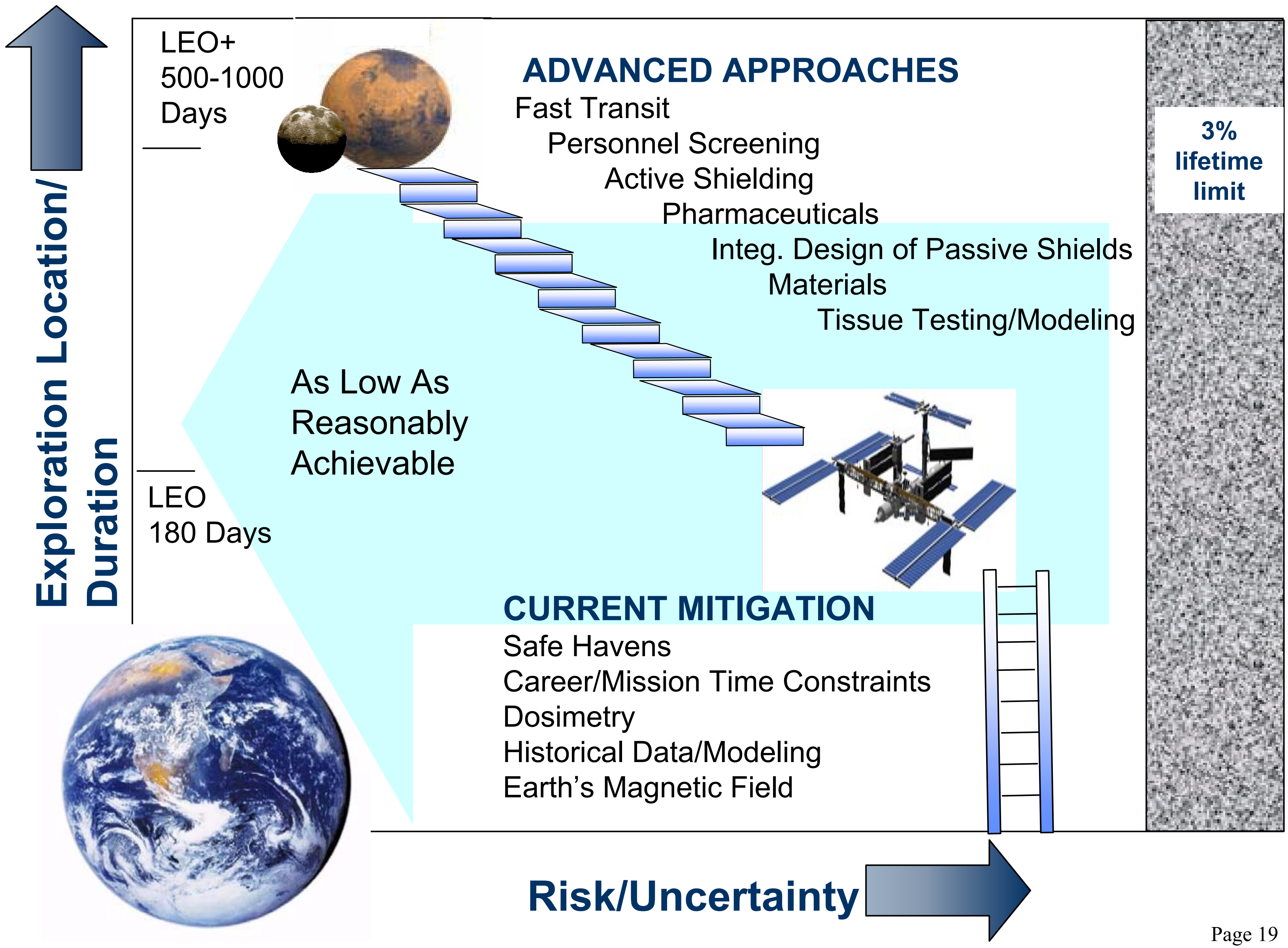
Artificial Gravity NEP Vehicle System Concepts

- **Mission Needs**
  - 1-g, 4 rpm system – consistent with human centrifugation tests
  - Minimize AG vehicle mass "penalties" & complexity
  - 18-month Mars roundtrip, nuclear electric propulsion
- **Assessments**
  - AG crew hab module design assessment
  - Power/propulsion/trajectory trades
  - Angular momentum management/vehicle steering strategies
  - Preliminary assessment of structural, power system designs
- **Results**
  - Only small dry mass AG penalties identified (<5%)
  - Good synergy among power system and propulsive performance
  - Propellant-efficient steering strategies identified





Attacking the Radiation Challenge



Optimizing the Human/Robotic Equation

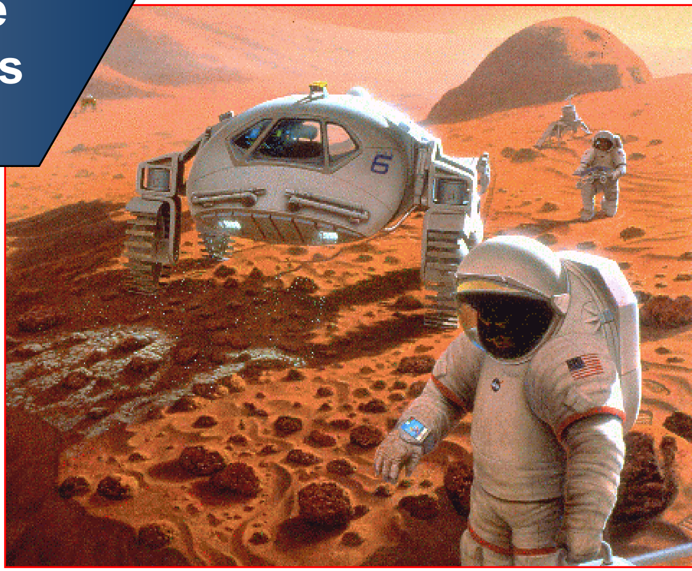
- Technology Projections
- Experience and Lessons Learned
- Misson Performance Assessments

Optimal Human and Robotic Combinations

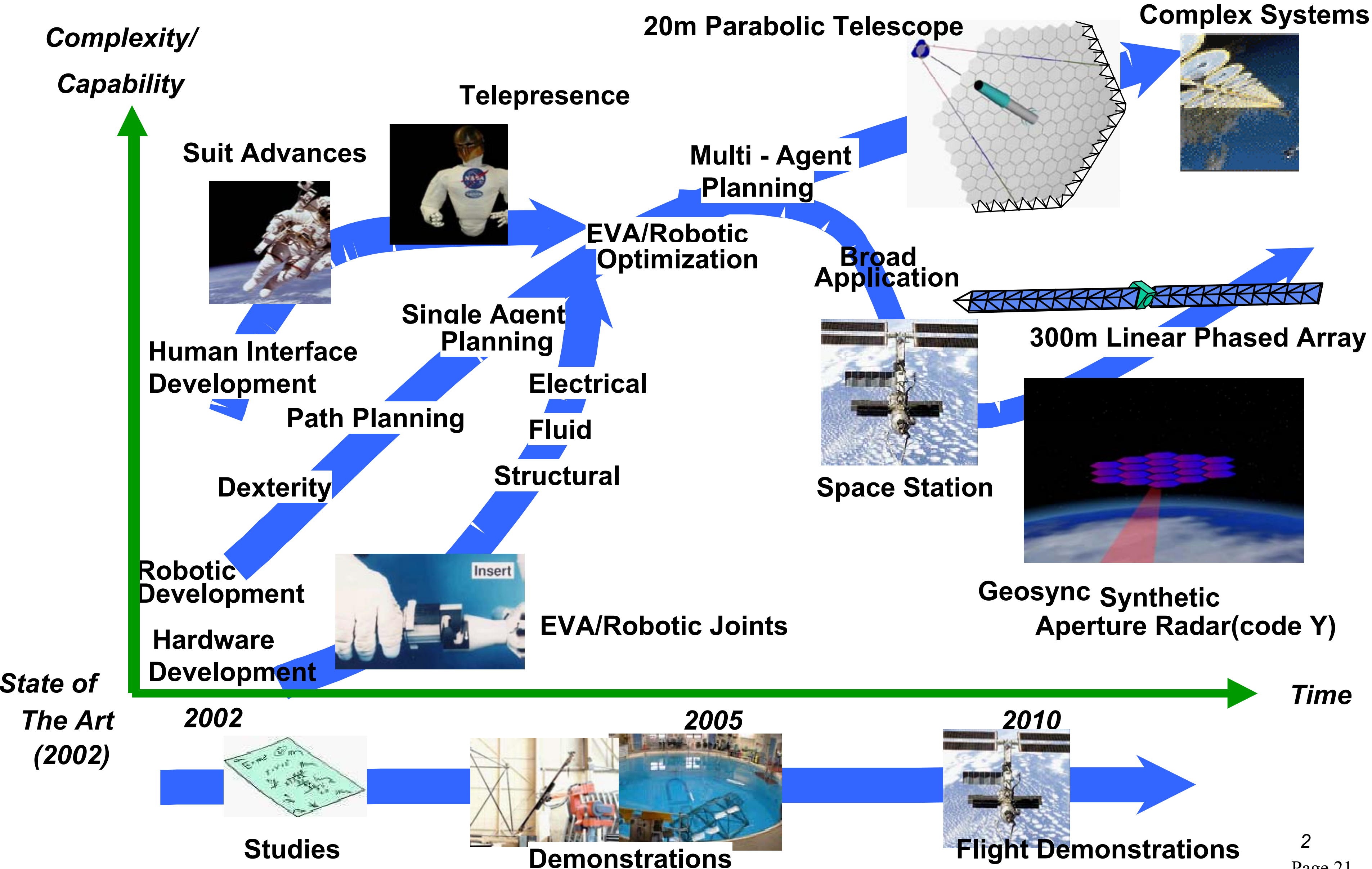
Example Science Activities

Creating science instruments and observing platforms to search for life sustaining planets

Search for evidence of life on planetary surfaces

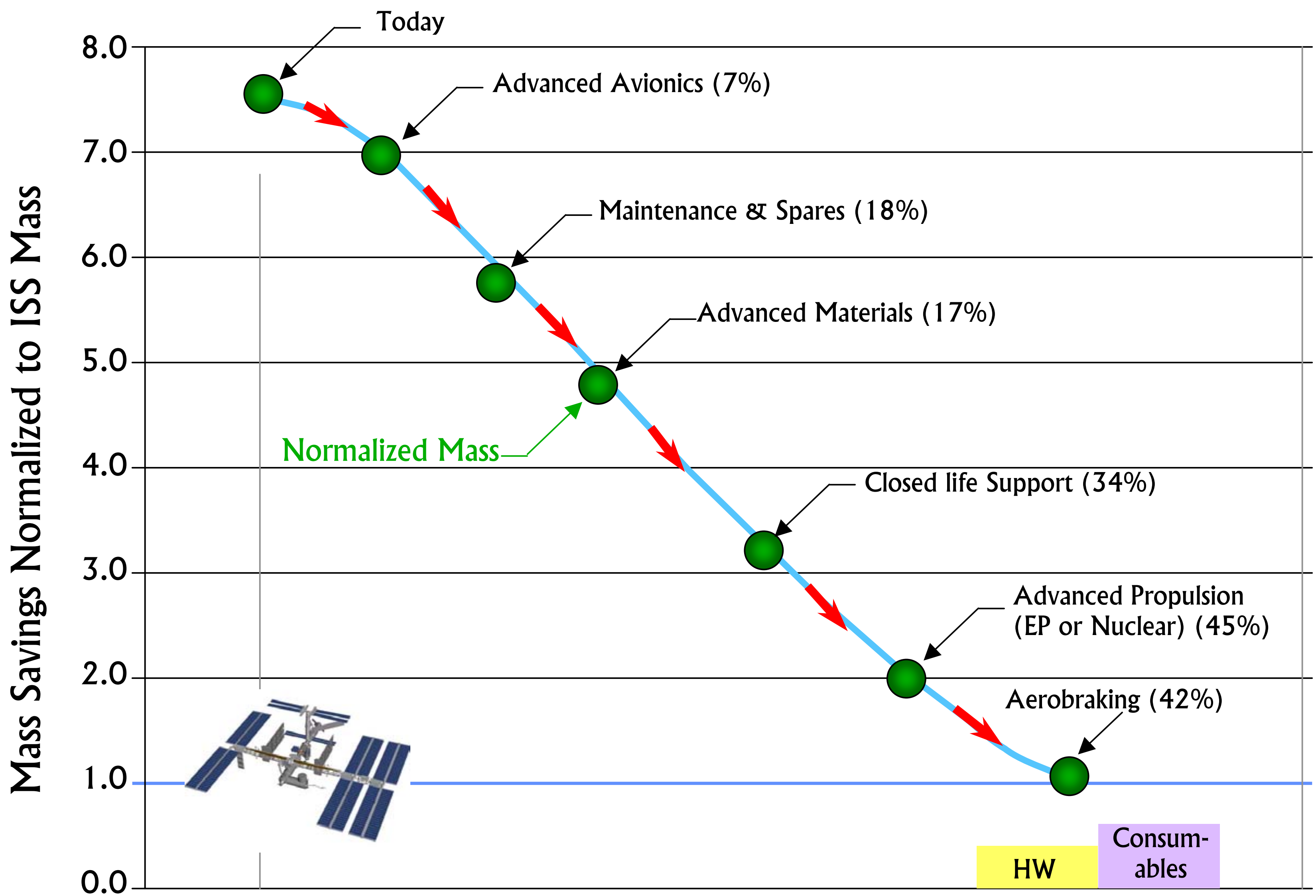


Large Space Telescope Construction and Maintenance



Space Systems

Example: Mars Human Mission



“As for the future, your task is not to foresee it, but to enable it.“

Antoine de-Saint-Exupery